LATVIA
UNIVERSITY OF
AGRICULTURE

RESEARCH
FOR
RURAL
DEVELOPMENT

2007

INTERNATIONAL
SCIENTIFIC
CONFERENCE
PROCEEDINGS

Jelgava 2007

LATVIA
UNIVERSITY OF
AGRICULTURE

RESEARCH FOR RURAL DEVELOPMENT

2007

INTERNATIONAL SCIENTIFIC CONFERENCE PROCEEDINGS

Jelgava 2007

EDITORIAL

With this issue of 2007, we bring 48 proceedings of the 91, which started life as presentations at the 13 International Scientific Conference "Research for Rural Development 2007" held at the Latvia University of Agriculture, in Jelgava, on 16th to 18th May 2007.

In the retrospect of four months later, we can count the Conference as a great success. The theme – Research for Rural Development - attracted participation of 410 researchers with very different backgrounds. There were 2 presentations from Czech Republic, 2 from Azerbaijan, 2 from Norway, 1 from Nigeria, 1 from Belgium, 20 from Lithuania and 63 from Latvia.

Four independent reviewers estimated each report.

The proceedings of the 13 International Scientific Conference "Research for Rural Development 2007" is intended for academics, students and professionals researching in the area of crop production, animal breeding, agricultural engineering, agrarian and regional economics, food sciences, veterinary medicine, forestry, wood processing, water management, landscape architecture, information and communication technologies and educational sciences.

The proceedings will also be useful for researchers in educational sciences.

CONTENTS

AGRICULTURAL SCIENCES (CROP SCIENCES, ANIMAL SCIENCES)

SYSTEMS OF FARMING AND RURAL LANDSCAPE IN THE CZECH REPUBLIC

Jan Moudrý, Petr Konvalina
University of South Bohemia, Czech Republic
E-mail: JMoudry@zf.jcu.cz

Abstract

Agriculture of the Czech Republic has features of submonate and montane agriculture. More than half of the surface of the Czech Republic are less favourable areas (LFA). Organic farming is carried out on the area of 6% of the surface of arable land. The contemporary state of farming has been evaluated and organic and conventional farming systems have been compared in the framework of the analysis of structure of farming in the Czech Republic. The selective group of 437 associations, consisting of 3 subgroups, is divided into several categories according to the farming method and altitude. Parametres of plant and animal production and use of the agroenvironmental programmes and measures are evaluated. The evaluation of the structure of farming permits to find optimal possibilities for future development of conventional and organic farming in the Czech Republic and for arrangements of the settings of grants and subsidies.

Keywords: Organic farming, structure of farming, plant production, agroenvironmental programmes.

Introduction

Agricultural policy in the Czech Republic has undergone several stages of its development from the beginning of 1990 s till nowdays. At first, the transformation process was taking place at the beginning of the 1990 s, causing reformation of proprietary relationships to agricultural properties and stabilization of the business structure. After that, it was necessary to solve the problem of the insufficient protection and maintenance of the nature and countryside, which happened especially in less favourable areas where agriculture has been declining without any subsidies and support. It was necessary to support the breeding of cattle and sheep, maintain perennial grass crop stands, and plant the countryside with trees for the purpose of restructuring the production in certain areas and maintain cultural nature of the countryside. The law No. 252/1997 Sb. on the agriculture ('Agricultural law'), which codified the support of less favourable areas and non-production functions of farming, has brought the crucial changes (Tuček, 1997). At first, the programme of maintenance of farming associations, grass crop stands and arable land was the crucial one. The programme was based on the principle of a compensation of less favourable areas. The support for organic farming, which involved compensation for economic detriment caused by the implementation of such type of farming, was very important sort of programme.

Agriculture of the Czech Republic has features of submonate and montane agriculture. More than half of the surface of the Czech Republic are less favourable areas (LFA) (Kvapilík et al., 2002). An active state support for farming, focused on the extensive production and maintenance of the countryside and other environmental services, is the crucial point of a successful development of a competitive and economical (from the point of view of the environment) production in LFA (Střeleček et al., 2003). Besides the classic conventional production, the possibilities of the Czech farming are based on the development of the production of favourable commodities for internal needs or export, diversification of the production of untraditional commodities (e.g. renewable raw materials and energy ressources), maintenance of the countryside, protection of water sources, and other environmental services (Šroller et al., 2001). The economical farming and working of land are crucial for a low-yield locations (Hampicke et al., 2005). These intentions keep track with crucial principles of the European farming system which prefers economical production methods to the environment, maintenance of the countryside, and

development of rural activities (maintenance of work opportunitites) (Šoller et al., 2001).

Perennial and temporary grass crop stands with connection on animal husbandry of cattle with milk production will be also important in lower areas in the future. Extensive meadows (specific methods of management, agroenvironmental programmes) and pastures (graze of cattle without and connection with market milk production) become more common in higher altitude grass crop stands without any graze of cattle, fallow and succession areas, and pointed forests may be found in environmentally sensitive localitites. The diversification of income resources becomes more important in unfavourable location conditions.

Presented analysis was made for comparsion of conventional and organic systems of farming in Czech Republic and examination of progress of organic farming and influence of conversion to organic farming for rural landscape.

Materials and Methods

The analysis of the farming structure of agricultural enterprises in the LFA regions and their comparison to enterprises in production regions is divided into three parts, each of which independently analyses one specific file of selected farming subjects.

1. Selection file of 278 organical or conventional farming enterprises from all the Czech Republic,
2. Selection file of 57 organical or conventional farming enterprises from the Bohemian submontane region,
3. Complete file of 102 organic farms from south and west regions of Czech Republic (NUTS2).

The actual solution is based on following research methods:

- the analytical method used for farming subject in the area of interest;
- the questionnaire selection analysis;
- targeted interviews with users;
- self-observations;
- statistic assessment defining the demonstrativity and dependence of tested parameters.

The subjects included in the selection sample file make relatively a representative selection. Based on the findings referring to the selection sample file the basic files, of farming enterprises in submontane regions were analyzed.

Within the first and second selection file, the structure of farms in respect to the farming method (organic or conventional) is compared in relation to elevation. The third selection file is examined in detail for organic farming enterprises' structure in relation to elevation. The monitoring within all the selection files focuses on 38 basic parameters (Tab. 1). Additional parameters are a derivative combination of above-mentioned basic aspects. The defined basic parameters were compared. As the key indicators of sustainability were used: percentual share of permanent grasslands within the whole farming area, stocking rate of the land, percentual share of cereal crops on arable land, and other possible parameters (agroenvironmental measures applied, etc.).

Results and Discussion

Allocation of associations in relation to farming system and altitude

Organic farming is carried out on the area of 6% of the surface of arable land. Most of arable land is worked with conventional methods of farming. The amount of organic associations and the surface of the land, which is worked with organic methods of farming, increase in dependence on the altitude. The range of organic farming is negligible in the production areas of the Czech Republic. There are about 4% of organic associations in the areas of altitude of 400 metres, and about 30% of organic associations in the areas of altitude of 700 metres. Such a huge difference of the surface of organic areas in altitude of 650 metres is caused by the border of marginality and economic efficiency of conventional method of the production of traditional commodities. The environmental non-production function is well-developped in montane LFA. The production function of organic farming is reduced - it provides a narrow range of organic products on the market.

Size of an association in relation to altitude

Size and structure of the Czech farming associations have a dual character. There are a lot of small associations, but the surface of agricultural land is small – 70% of all the associations work just 2.3% of a certain surface of agricultural land. The situation is contrary to big associations – 2.1% of them work 60% of agricultural land. The average surface of all the associations, which is expressed by elementary arithmetic average, is 71 ha of agricultural land. When taking into account the different size of the associations and their different importance for the total surface of worked agricultural land,

Table 1

Selected monitored parameters in selected files of enterprises

Parameter	Units	File I (ČR)	File II (Bohemian F.)	File III (NUTS2)
Elevation	m a. s. l.	*	*	*
Farming method	Organic f./ conventional f.	*	*	*
Agriculture land area	ha	*	*	*
Arable land area	ha	*	*	*
Permanent grasslands area	ha	*	*	*
Cereal crops area	ha	*	*	*
Area under wheat	ha	-	*	*
Area under spelt	ha	-	-	*
Area under rye	ha	-	*	*
Area under tritikale	ha	-	*	*
Area under barley	ha	-	*	*
Area under oat	ha	-	*	*
Area under legumes	ha	*	*	*
Area under oil plants	ha	*	*	*
Area under root crops	ha	*	*	*
Area under maize	ha	*	*	*
Area under forage crops on arable land	ha	*	*	*
Numbers of livestock	pcs. (livestock units)	*	*	*
Dairy heard	pcs.	*	*	-
Numbers of cattle with non-milk products	pcs.	*	*	-
AEP participation	n.	*	-	-

* parameter was monitored in this file
- parameter wasn't monitored in this file

a much higher weighted arithmetic average is obtained: 1507 ha. It is 291.9/181.3 ha (conventional/organic farms) in the production areas (altitude not higher than 450 metres), 302.7/191.8 ha in the border areas (altitude of 450-600 metres), and 173.9/338.5 ha in the areas of higher altitude (more than 600 metres).

Proportion of grass crop stands in relation to altitude and farming method

The average proportion of grass crop stands is 22% in the Czech Republic. The target proportion of grass crop stands should be higher by 15% - to 37% like average proportion of grass crop stands in the countries of the EU. The surface of grass crop stands and their proportion on the total agricultural genofond increase depending on the increase of altitude (the method of farming is not taken into account). The proportion of grass crop stands varies from 0 to 100% in organic and conventional associations and reaches 80%

of the total surface of agricultural land in most of organic associations (82.05%). Just 5.77% of them have the proportion of grass crop stands lower than 30% of the total surface of agricultural land. Concerning conventional associations, the proportion of grass crop stands is lower than 30% in more than half of the assocations (52.34%). On the other hand, proportion of 80% can be found in 27% of the associations. High percentage of grass crop stands is usual in very small conventional associations (the total surface of agricultural land - 10 ha).

The difference between conventional and organic associations is obvious. The average proportion of grass crop stands is 93.56% in organic associations (the Czech Republic – 87.74%, the Šumava mountains – 89.70%, NUTS 2 – 95.42%) and 25.95% in conventional ones (the Czech Republic – 16.20%, the region of Klatovy – 40.38 %).
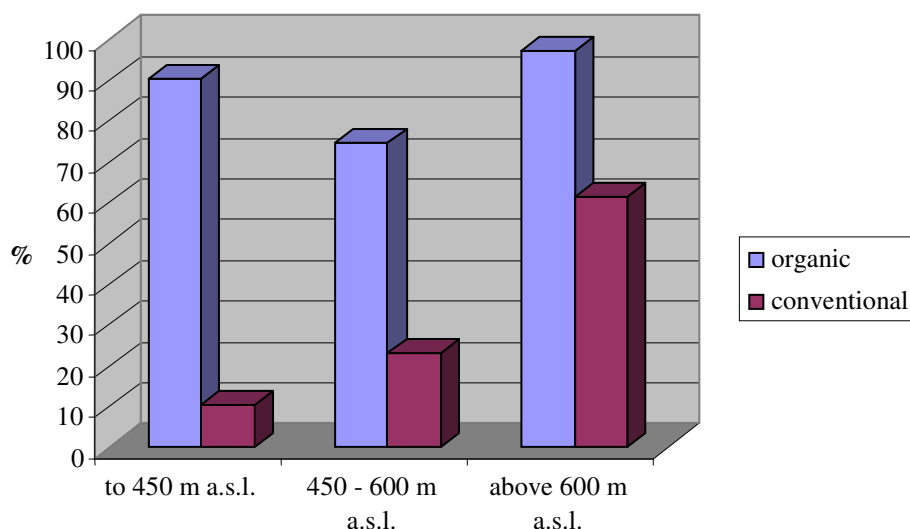
Figure 1. Proportion of grass crop stands on the total surface of conventional and organic associations in relation to altitude in the selected group of the Czech associations.

Stocking rate

Stocking rates (livestock unit (LU) ha^{-1}) increase with elevation. The average stocking rate reaches 0.44 LU ha^{-1} in all the subjects monitored.

Above all the conventional enterprises often generate local loads, which does not conform to the agroenvironmental aspects. While the areas surrounding the high-capacity animal objects are overloaded, the distant grasslands are not markedly exposed.

Conventionally farming enterprises play the main role in milk production (MMP), which produce 10% of organic farms only. On the contrary animal husbandary of the cattle without milk production is typical for organic farming, which is also connected to high rates of permanent grasslands. In the submontane regions the agroenvironmental measure Grasslands maintenance - is often applied (titles, 'Pastures' and 'Extensive pastures').

Structure of the plant production

In the production regions the share of arable land reaches almost 90%. Also in the areas of middle elevation (450-600 m a.s.l.) the share of arable land is high – 76.90%. This changes only in regions over 600 m a.s.l., where the rate drops to
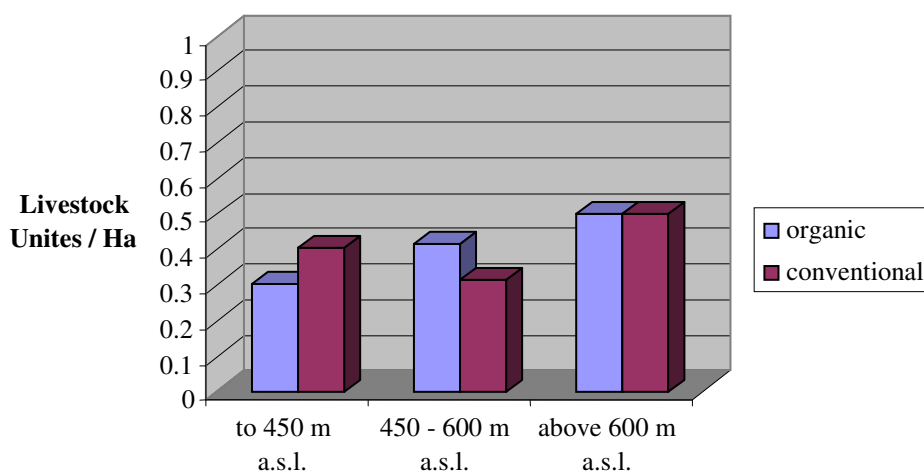
Figure 2. Stocking rates, LU ha^{-1}, related to elevation within the selection file I for both farming systems.
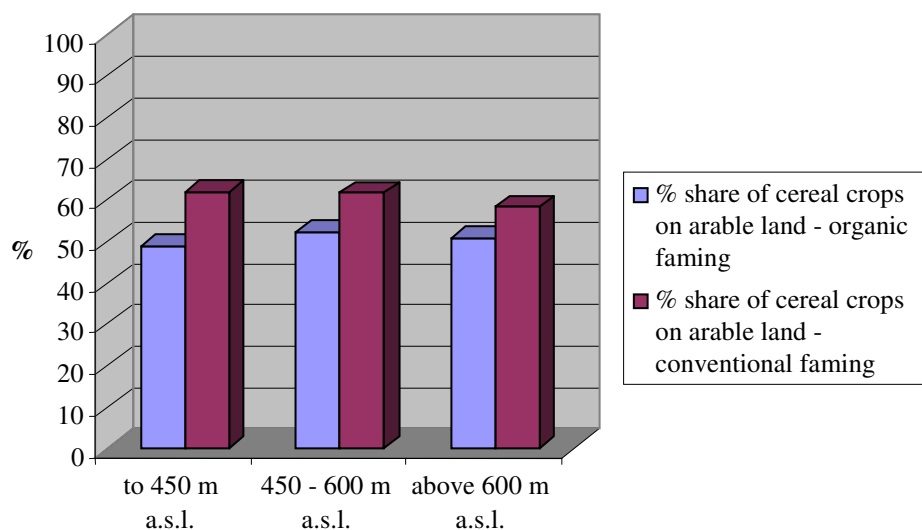
Figure 3. Share of cereal crops on arable land by the conventional and organic enterprises within the
Selection file I (ČR).

38.27%. The LPIS register stated 74.7% of arable land on date 7. April, 2005. The organic farms exploit permanent grasslands with non-milk cattle production (BRPM) predominantly, percentual share of the organic farms focused on arable land farming reaches nearly one third (27%), the rate of arable land is 6.44%. Almost complete grassing (up to 100%) in regions above 700 m a.s.l. is logical for environmental and even for economic reasons. Most of associations farming on arable land converting to the organic farming method do not proceed gradually but there is applied a complete grassing combined with cattle non-milk production.

The grant-in-aid landscape tending is not sufficient as the only financial source for associations farming in the mountain and submontane regions. Such maintenance is either too expensive or low-quality. However, the landscape tending is cheaper and more cost-effective when externally included into other production or non-production activities. Such combination of these activities taking advantage of comparative advantages of region is the fundamental principle of the multifunctional agriculture and farming in the landscape respectively.

Cropping structure

The cropping structure by the monitored enterprises farming on arable land does not match the environmental requirements. Predominantly there are only 2-3 crops in the crop rotations.

The rates of cereal crops used by both

organic and conventional farms reach 62.0% in the production regions, 61.1% in the transition areas (450-600 m a.s.l.), and 58.2% in areas with elevation over 600 m a.s.l. The high percentage of cereal crops results from reducing the forage crops on arable land due to fall in cattle numbers before entering EU.

Wheat is the most widely distributed cereal crop within the selection file, reaching 26.42% area rate, then follow oats (23.04%), barley (21.17%), and rye (19.54%). Percentual share of tritikale is 5.73% and share of spelt is 4.11%.

The area under oil plants (rape most of all) decrease in dependence on the increase ofelevation. There is a distinctive transfer of rape cultivation into lower elevation. The rate of oil plants in the crop rotation reaches 16.5% in elevation around 600 m a.s.l., and 15% percentage of oil plants in crop rotation can be considered as improper.

The arable land area under potatoes 1.23%) absolutely does not correspond to the optimal root plants rate of 5%, which positively affects the soil fertility (manuring), weed control (row cultivation), etc.

Similar situation applies to legumes usage on arable land (1.52%). Share of legumes (leguminous and clover plants) on arable land is not high enough.

Use of fodder crops on arable land is fixed on cattle milk-production. However, the fodder crop production also covers the winter fodder base for other non-milk cattle and animal categories. The average rate of forage crops on arable land

reaches 11.8%.

Farms participation in the Agroenvironmental programmes

Within the monitored Selection file of farming subjects, 77% of the whole agricultural area was included into the Agroenvironmental programme (AEP) under the title 'Permanent grasslands maintenance'. For comparison, within the whole Czech Republic this title was applied to 62% of the area involved in the Agroenvironmental programme. Besides the support for organic farming, 91% of all organic farms draw the support from title "Permanent grasslands maintenance" in each region. There are several farms excluded only in the lower altitude region (up to 450 m a.s.l.).

The subvention on organic farming and grasslands maintenance cumulate and basically provide economic stability for organic farms over all altitudes.

Remaining AEP measures are not distinctly applied by the organic farms. The reason is the low representation of arable land that the programmes are mostly focused on and insufficient knowledge of other AEP programmes. The same as the organic farms, the conventional enterprises derive benefit from AEP Permanent grasslands maintenance, i.e. 87.96%. The subsidy title 'AEO Intercropping' is applied by 18.52% and the title 'AEO Biozones' by 6.48% of farms. AEP programmes are supposed to be generally spread to prevent rising polarization due to insufficiently performed environmental activities by conventional farming on one hand and low production by the organic farming on the other hand. If there is an expectation that in the year 2010 the organic farming should take 10% of agricultural land, then it has to be spread into the submontane LFA regions, into environmentally sensitive locations, and into the production regions on arable land before all. Besides, the conventional farming enterprises have to be motivated to participate more intensively in AEP programmes and to respect the principles of sustainable farming. This will contribute to production and non-production functions optimisation for both farming methods and should lead to more cost-effective subvention of ecological, economical and social sustainable farming on arable land.

Conclusions

According to the analysis of the initial structure of farming of the agricultural associations belonging to groups I-III, the restructuring of agriculture is not sufficient and is limited especially in border areas. High proportion of arable is usual in most of them, but the range of crops is narrow (especially cereals). Though the total proportion of grass crop stands should increase, it is quite high in organic farming associations, therefore the proportion of arable land should increase there. The arrangement and adjustment of subsidies and grants of agroenvironmental programmes is necessary. The proportion of perennial grass crop stands should increase in conventional associations, but should decrease in organic associations. Another important change: is the change in the structure of plant production (the range of plants and the composition of the croppings should be wider, they should be in more narrow connection with land and climatic conditions, and alternative crops should be grown more).

Acknowledgements

References

1. Hampicke U., Liptersky B., Wichtmann W. (2005) Ackerlandschaften – Nachhaltigkeit und Naturschutz auf ertragsschwachen Standorten (Sustainability and nature protection in marginal areas), Springer-Verlag, Berlin Heidelberg, 311 p. (in German).
2. Kvapilík J., Vaněk D., Nová V. (2002) Trvalé travní porosty a chov přežvýkavců v ČR v kandidátských zemích a v EU (Permanent grasslands and cud breeding in Czech republic, candidate countries and EU). In: chov polygastrů v méně příznivých oblastech a možnosti naplňování zásad evropského modelu multifunkčního zemědělství. Rapotín 2002, pp. 48 – 61 (in Czech).
3. Střeleček F., Kollár P., Lososová J. (2003) Vliv dotací na hospodářský výsledek zemědělských podniků v produkčních a marginálních oblastech (Influence of subvencion titles for economic effects in produce and marginal areas). In: Agricultural economics : zemědělská ekonomika. 1(6), 10. pp. 251-260, CZ, 0139-570X (in Czech).

4. Šroller J., et al. (2001) Pěstitelské soustavy v marginálních oblastech (Grower systems in marginal areas), zemědělské informace ÚZPI Praha, 6, 45 p. (in Czech).

5. Tuček P. (1997) Aktuální perspektivy mezinárodního agrárního trhu (Actual perspectives of international agrarian market). In: Sbor. ref. 7. mezinárodní konference Zamyšlení nad rostlinnou výrobou, ČZU v Praze, pp. 6 – 19 (in Czech).

FUNGICIDE APPLICATION EFFECT ON YIELD AND QUALITY FORMATION OF WINTER OIL-SEED RAPE (BRASSICA NAPUS L.)

Oskars Balodis, Zinta Gaile, Biruta Bankina, Rita Vītola
Latvia University of Agriculture
E-mail: balodis.oskars@inbox.lv

Abstract

Sowing area under oil-seed rape (*Brassica napus* L.) has grown dramatically only during the last 10 years in Latvia. Lack of knowledge and research on different issues is observed. The aim of our research, started on season 2005/2006 in Research and Study farm 'Vecauce', was to investigate the influence of split fungicide (1st dose of fungicide juventus 90 s.c. (metconasol 90 g L^{-1}) used as growth regulator in autumn at the 4-6 leaf stage and the 2nd dose – at the growth stage 63-64) application. Winter rape development in autumn, winterhardiness, disease incidence, and yield and its structure elements were estimated. Totally 13 cultivars were used in the trial, but several assessments were done for 5 cultivars. Additional objective was to evaluate economic effect of fungicide use. Winter rape biometrical indices were influenced by the fungicide application in autumn period and by used cultivar. Fungicide treatment in autumn increased also the rape winterhardiness. Our research for the first time indicated that *Phoma* stem canker could become a problem for rape growers in Latvia. Fungicide use (in growth stage 63-64) decreased incidence of this disease a little (on average by 5%). Fungicide treatment according to applied scheme increased the average seed yield (check – 5.37 t ha^{-1}, with fungicide – 5.80 t ha^{-1}; $LSD_{0.05}$ = 0.18 t ha^{-1}), but impact on yield structure elements was mainly non-essential. Despite agronomic improvements, economic calculation showed that on average fungicide use in 2006 was not profitable. Research should be continued for specification of conclusions.

Keywords: winter rape, growth regulation, winterhardiness, diseases, fungicide, yield.

Introduction

Sowing area under oil-seed rape (*Brassica napus* ssp. oleifera) has grown dramatically during the last 10 years in Latvia: from 400 ha in 1997 up to 77 000 ha in 2006. Winter form of crop is preferred due to possibility to obtain higher seed yield. Winterhardiness of winter oil-seed rape is one of the key factors for successful growing of this crop. Wintering of rape depends on the plant development stage in the autumn, which could be affected by the growing manner including used cultivar and agro-climatic factors. Before the winter period, rapeseed plant should create a sufficient aboveground and root mass, but on the other hand it should not be overgrown. Important characteristics are: root-neck diameter (should reach 8 to 10 mm), height of growth-point above the soil (should be less than 30 mm), and number of leaves (at least 6 to 8 leaves). Becka et al. (2004) reported that more leaves, less height of growth-point and greater diameter of root-neck are the result of lower crop density, when plants have enough space and there does not exist a strong intra-specific competition. Optimum crop density for successful wintering is reported 30 to 70 plants m^{-2} (Velicka, 2003; Leach et al., 1999). Some researchers from other countries and in different conditions reported (Gaveliene

et al., 2002; Becka et al., 2004; Miliuviene et al., 2004) that application of growth regulator increases number of leaves per plant and root-neck diameter, and decreases height of growth-point of winter rape, thus favouring winterhardiness of the crop. In agro-ecological conditions of Latvia, winter rape growth in autumn period and any possibility to affect important plant characteristics for good wintering have not been documented. Similarly only few data exist on rape disease incidence and caused damage (Treikale et al., 2006). Our preliminary experience suggested that with increase of rape proportion in crop structure, growers in Latvia have to pay attention to *Sclerotinia* stem rot. Researchers in other parts of world widely draw attention to another disease: *Phoma* stem canker or *Phoma* leaf spot (West et al., 2002; Huang et al., 2005). In previous years nobody in Latvia has paid attention to this disease and its development cycle. Contradictory is the opinion about the necessity to apply fungicide for oil-seed rape, about which only very few papers have reported and analysed its economic substantiation in Latvia (Treikale et al., 2006). The possible fungicide effect on yield structure elements has not been documented in Latvia at all.

The aim of currently described section of our research was to investigate the influence

Oskars Balodis, Zinta Gaile, Biruta
Bankina, Rita Vītola

FUNGICIDE APPLICATION EFFECT ON YIELD AND QUALITY
FORMATION OF WINTER OIL-SEED RAPE (BRASSICA NAPUS L.)

of split fungicide (in autumn used as growth regulator) application on winter rape development in autumn, winterhardiness, disease incidence, and yield and its structure elements in agro-ecological conditions of Latvia. The economic effect of fungicide use has to be evaluated in addition.

Materials and Methods

Two-factor field trials were carried out in the Research and Study farm 'Vecauce' of the Latvia University of Agriculture starting with 2005. Autumn development of oil-seed rape is described from two-year field trials, but disease incidence in summer, seed yield and its quality, and economic aspects of fungicide use – only as results of 2006. Thirteen different winter rape cultivars (factor A) were included in the trial (see the names in Table 2). Fungicide application was factor B (B1 – control, without fungicide; B2 – split fungicide application). Fungicide application scheme: 1st dose (0.5 L ha^{-1}) of fungicide juventus 90 s.c. (metconasol 90 g L^{-1}; September 22 in both years) was applied at the 4-6 leaf stage, and the 2nd dose (0.5 L ha^{-1})– at the growth stage 63-64 (date in 2006 depends on the cultivar). Treatments were arranged in four times replicated randomised blocks, plot size was 7 m^2.

Soil in the trials' site was strongly-altered-by-cultivation loam with pH$_{KCl}$ = 6.7 to 7.0; content of available for plants K = 98 to 122 mg kg^{-1} and P = 103 to 147 mg kg^{-1}; humus content 19 to 21 g kg^{-1}. Traditional soil tillage with mould-board ploughing was used. Crop was fertilized with special mineral fertilizer for rape containing also sulphur and microelements at the following rate: N 21 to 33 kg ha^{-1}, P 22 to 27 kg ha^{-1}, and K 52 to 57 kg ha^{-1} before sowing depending on a year. Top-dressing with nitrogen fertilizer at the rate of 70 kg ha^{-1} N (at the start of vegetation, 13 April 2006) plus 70 kg ha^{-1} N (at the stage of well developed rosette, 8 May 2006) was used. Sowing was done in optimal time (up to 20 August) for Latvia's conditions, and used seed rate was 5.0 kg ha^{-1} in 2005 and 4.0 kg ha^{-1} in 2006. Weeds were controlled using herbicide butisan star s.c. (metasachlor, 333 g L^{-1} + kvinmerac 83 g L^{-1}) 2.5 L ha^{-1} on 19 August 2005 and 29 August 2006; monocotyledons were controlled using azhil e.c. (propakvizaphop 100 g L^{-1}) 1.0 L ha^{-1} in 29 September 2005 and 0.7 L ha^{-1} in 11 September 2006. Insects were controlled by fastac e.c. (alfa cipermetrin, 100 g L^{-1}) 0.15 L ha^{-1} (5 May 2006). The yield was harvested by direct combining (plot combine HEGE-140, 3-4 August 2006) and was calculated to 100% purity and 8% moisture.

At the end of autumn vegetation (2005 and 2006), 10-plant samples were taken randomly for five randomly selected cultivars (see names in Table 1) from each plot for biometrical analysis (24 October 2005 and 30 October 2006). Number of leaves per plant, plant, root, and shoot weight, g, root length, cm, diameter of root neck, mm, and height of growth-point, mm, were measured in a laboratory. Disease incidence and severity in the autumn was evaluated for 50 plants per plot and expressed in percent (7 October 2005 and 23-24 October 2006). Disease incidence (expressed in percent) in summer 2006 was evaluated: for *Alternaria* pod spot 10 pods in 10 places per plot (17 July 2006), for *Sclerotinia* stem rot and *Phoma* stem canker 50 randomly selected stems per plot directly after harvest. Other observations described in current paper were as follows: plant density in autumn, in spring and after harvesting (plants per 1 m^2) and winterhardiness in points from 9 (very good) to 1 (all plants dead). Yield structure elements (plant productivity, g, number of silique per plant, number of seeds per silique) were detected in growth stage 87 from sample sheets (two sheets per plot from 0.1 m^2) for five varieties (see names in Table 3). Methodology described by D.Malinauskas (2005) was used.

After harvesting, 200-g samples per each variety were taken for analyses of seed oil content (analysed by LVS EN ISO 734-1 method, g kg^{-1} of dry matter) and crude protein (analysed by ISO 5983-2 method, g kg^{-1} of dry matter). Analyses were done in the Analytical Laboratory for Agronomy Research of thee Latvia University of Agriculture. Volume weight was analysed using standard method LVS 273, and 1000 seed weight – according to ISTA methodology.

ANOVA procedures and correlation analyses were used for processing the experimental data. Economical evaluation of obtained results was done using constructive and comparative methods.

Meteorological conditions of the research year 2005/2006 can be characterized by severe winter, late spring and an extremely hot and dry summer. Although summer of 2006 was extremely dry and air temperature was high, winter oil-seed rape used the moisture reserves suspended during winter and growth and development of crop occurred without irregularities. The fall of 2006 was warm with enough moist, and long.

Table 1

Effect of fungicide juventus 90 on the height of growth-point, number of leaves per plant, and root mass of winter rape in autumn, 2005 and 2006

Cultivars	Height of growth-point, mm				Number of leaves per plant				Root mass, g			
	2005		2006		2005		2006		2005		2006	
	C†	F‡	C†	F‡	C†	F‡	C†	F‡	C†	F‡	C†	F‡
Excalibur	38.7	22.6	24.4	18.0	8.7	13.2	7.0	7.2	7.5	8.9	7.8	7.0
Californium	24.8	17.8	15.5	16.4	9.2	10.8	5.9	6.4	4.1	5.5	2.9	4.0
Elixir	48.1	27.5	26.3	17.8	8.3	9.7	6.6	7.3	6.6	6.4	5.9	6.8
Orkan	38.2	20.8	24.8	17.5	8.5	11.1	7.6	8.2	5.8	7.5	6.5	7.6
Falstaf	29.4	22.2	18.3	15.8	9.8	10.0	7.4	7.3	6.4	7.5	5.3	3.9
Average	35.9	22.2	21.9	17.1	8.9	10.9	6.9	7.3	6.1	7.2	5.7	5.9
LSD$_{0.05}$	3.9		2.2		1.1		0.4		0.9		1.1	

C† – check without fungicide treatment; F‡ – fungicide treatment juventus 90 in autumn

Results and Discussion

Oil-seed rape development during autumn and its winterhardiness

Since conditions for germination were adequate, optimal average per trial crop density was noted in both trial years (on average 69 seedlings m^{-2} in 2005, and 57 seedlings m^{-2} in 2006). From the two-year results (2005-2006) it is evident that winter rape biometrical indices were influenced by the fungicide application in autumn period as well as by used cultivar (Table 1). A significant impact ($p < 0.05$) of fungicide application in autumn was noted on the height of growth-point in both trial years (by 42% in 2005, and by 24% in 2006). Two-year experiments showed that cultivar with the highest growth-point was 'Elixir'. Average height of growth point in 2005 (check – 35.9 mm; with fungicide – 22.2 mm) was higher than that in 2006 (check – 21.9 mm; with fungicide – 17.1 mm) that probably could be explained by slightly different crop density. A significant impact ($p < 0.05$) of fungicide application in autumn was noted as well for number of leaves per plant in both trial years (by 25% in 2005, and only by 6% in 2006). This is in accordance with results of other studies (Gaveliene et al., 2002; Miliuviene et al., 2004) where more leaves were obtained using specific growth regulators. Cultivar influence on this parameter was not significant ($p > 0.05$) in 2005, but significant ($p < 0.01$) impact was noted in 2006 (by 48%). The number of leaves per plant in trial years also was optimal for good wintering of winter rape.

Researchers in Lithuania (Gaveliene et al., 1998; Miliuviene et al., 2004) found that use of growth regulators significantly increases the main root diameter and root mass in autumn. Our results showed significant impact ($p < 0.05$) of fungicide application in autumn on the fresh root mass only in trial year 2005 (by 8%), but cultivar influence on this parameter was significant ($p < 0.05$) in both trial years (by 33% in 2005 and by 59% in 2006). Significant correlation ($r = 0.761 > r_{0.05} = 0.632$; $n = 10$) was found between root mass in autumn and seed yield.

Use of growth regulators in autumn can increase the root-neck diameter (Miliuviene et al., 2004), but use of fungicide juventus 90 as growth regulator in our experiment did not affect the root-neck diameter significantly ($p = 0.46$ in 2005; $p = 0.55$ in 2006). This parameter was affected by the cultivar ($p < 0.01$) only in 2006. Despite this, average root-neck diameter also was optimal in both years (2005: 9.3 mm without fungicide, 9.6 mm – when fungicide was used; 2006: 8.5 and 8.3 mm respectively) for good winter rape wintering. Probably root-neck diameter is mostly affected by other uninvestigated factors. The plant and shoot weight and root length were not influenced significantly ($p > 0.05$) by fungicide treatment, but influence of used cultivar was mainly significant ($p < 0.05$).

Winter oil-seed rape winterhardiness is almost the most important characteristic for the cultivar used in conditions such as in Latvia where winters with sharp temperature fluctuations, black frost and other adverse factors may occur. Possibility to improve rape winterhardiness using any growth regulation in autumn is not documented in Latvia and is poorly recorded also in neighbouring countries. Some references in literature show (Gaveliene et al., 2005) that use of

Oskars Balodis, Zinta Gaile, Biruta
Bankina, Rita Vītola

FUNGICIDE APPLICATION EFFECT ON YIELD AND QUALITY
FORMATION OF WINTER OIL-SEED RAPE (BRASSICA NAPUS L.)

growth regulators (auxin analogues) can improve winterhardiness of winter oil-seed rape. Our results from the first research winter showed that also fungicide treatment in autumn can improve this characteristic: plant decrease during autumn and winter in the treated part (on average 27 plants per 1 m^2) of the trial was lower ($p < 0.05$) if compared with untreated part (on average 37 plants per 1 m^2), but winterhardiness evaluated in points – higher ($p < 0.05$; Table 2). Significant positive correlation ($r = 0.396 > r_{0.05} = 0.388$; $n = 26$) was found between rape winterhardiness and seed yield.

Up to now we have analysed the plant fitometric indices and the growth regulation effect on them. Other important indicators of rape wintering are chemical composition of root column and crown bud (Gaveliene et al., 1998; Velicka et al., 2005); evaluation of it should be the next step in our invetigation for better comprehension of rape winterhardiness.

Disease incidence and fungicide effect on it

Fungal diseases such as *Alternaria* blight (*Alternaria* spp.) and *Phoma* leaf spot (*Phoma lingam*, teleomorf *Leptosphaeria* spp.) were noted in the autumn of both trial years. Incidence of *Phoma* leaf spot on leaves of up to 1%

was observed in 2005, but in 2006 incidence of this disease was noted to be up to 8% without fungicide treatment and also up to 1% in the treated with fungicide part of the trial. The incidence of *Alternaria* blight on leaves was similar in both years in the untreated part of the trial (89% in 2005, 81% in 2006), but diverse in the treated with fungicide part: on average 63% in 2005 and 41% in 2006. The severity of *Phoma* leaf spot and *Alternaria* blight did not exceed 2% in both years, which is a typical situation in Latvian agro-climatic conditions. O.Treikale (2006) reported similar results of poor severity of both diseases in autumn in Latvia. In such conditions, fungicide use only for control of disease is disputable. Research results from countries with more mild climatic conditions, such as England, show that fungicide treatment in autumn is effective not only for *Phoma* leaf spot control, but also for prevention of *Phoma* stem canker incidence in the next spring; consequently follows also seed yield increase (West et al., 2002). On the other hand, research in Poland shows that development of *Phoma* stem canker in colder climatic conditions can be completely different (Huang et al., 2005), and thus another pattern for disease control is needed.

Table 2

Effect of fungicide juventus 90 application in autumn on plant density in spring and winterhardiness of rape, season 2005/2006

Cultivars	Plant density in spring, units m^{-2}		Winterhardiness, evaluated visually in points 9 - 1: 9 – very good, plants look vigorous; 1 – all plants dead	
	C†	F‡	C†	F‡
Olphi	38	45	8.3	8.3
Ella	27	47	7.0	8.5
Astrid	42	51	8.3	8.8
Caracas	49	56	9.0	9.0
Catalina	50	46	8.3	8.5
Excalibur	38	44	8.3	9.0
Californium	34	38	7.5	8.8
Elixir	34	37	5.0	8.0
Express	34	37	9.0	9.0
Orkan	29	42	6.5	8.8
Celsius	27	35	8.8	9.0
Falstaf	46	39	8.0	8.5
Banjo	39	33	8.8	8.5
Average	37	42	7.88	8.65
LSD$_{0.05}$	4.0		0.3	

C† – check without fungicide treatment; F‡ – fungicide treatment juventus 90 in autumn

Oskars Balodis, Zinta Gaile, Biruta
Bankina, Rita Vītola

FUNGICIDE APPLICATION EFFECT ON YIELD AND QUALITY
FORMATION OF WINTER OIL-SEED RAPE (BRASSICA NAPUS L.)
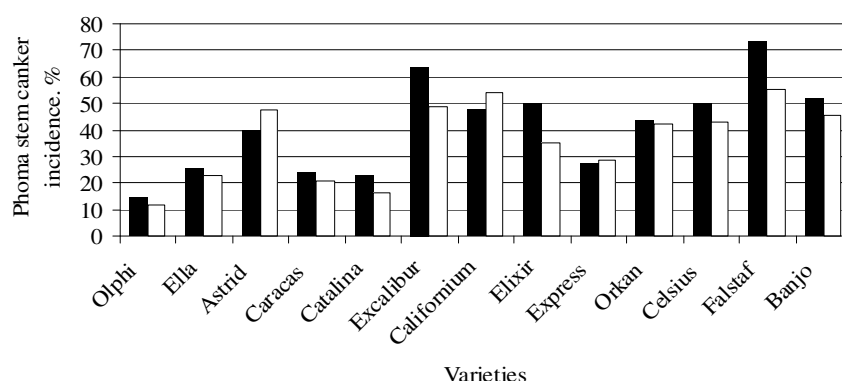
Figure 1. Effect of fungicide application on *Phoma* stem canker of winter oilseed rape in 2006 (■ – control without fungicide; □ – split application of fungicide juventus 90).

Phoma stem canker is a fungal disease which occurs during the following summer vegetative period; it has been left without particular attention in the previous years in Latvia. Our research for the first time indicated that this disease could become a problem for rape growers in Latvia. If fungicide was not used, *Phoma* stem cancer affected 12-74% of stems depending on the cultivar during harvest time (Fig. 1). A slight decrease in disease incidence caused split fungicide treatment (juventus 90; 0.5 L ha^{-1} in previous autumn + 0.5 L ha^{-1} in growth stage 63-64) almost for all cultivars; exceptions were cultivars 'Astrid' and 'Californium' (Fig. 1). Interesting and valuable for further investigation is the noted positive correlation between *Phoma* stem canker incidence and obtained seed yield ($r = 0.496 = r_{0.01} = 0.496$; $n = 26$). Since investigations on development cycle of *Phoma* stem canker in Latvia have only started, a further research on best fungicide use pattern for control of this disease is also needed. The incidence of *Alternaria* pod spot was insignificant (check – 4%, after fungicide treatment – 2%) in 2006. Development of the fungus *Alternaria* spp. on siliques is equally influenced by the air temperature and moisture in July when winter rape silique ripening period occurs. Lack of precipitation was noted in Vecauce in the summer of 2006, especially in July, thus decreasing the incidence of *Alternaria* pod spot. *Sclerotinia* stem rot (*Sclerotinia sclerotiorum*) did not occur in winter rape crop in the experimental year 2006. One percent of infected plants were found only in treated with fungicide plots of cultivar 'Ella' and in untreated plots of cultivar 'Banjo'. Similarly, for *Alternaria* blight, the weather conditions were also unsuitable for crop infection with *Sclerotinia*

sclerotiorum during rape flowering stage.

Yield, its structure elements and quality

Values of winter rape yield structure elements have not been well documented in Latvia before; our experiments are in-between the first who pay attention to yield structure. Analyses of rape yield structure elements showed that fungicide application did not affect significantly neither seed number per silique ($p = 0.08$), nor seed number per plant ($p = 0.43$), nor mean plant productivity ($p = 0.38$), but a tendency was noted that fungicide treatment at least slightly increased the above mentioned indices (Table 3). Fungicide application did not affect significantly also the silique number per plant ($p = 0.76$). Similarly, a significant cultivar influence was not observed on seed number per silique ($p = 0.12$), seed number per plant ($p = 0.45$), and mean plant productivity ($p = 0.47$). Used cultivar significantly affected only the silique number per plant ($p = 0.02$). In the first research year (2006) we did not find a significant correlation between any of above mentioned rape yield structure elements and seed yield. N.Thurling (1974) in absolutely different growing conditions (in Australia) reported significant positive correlation between the number of silique per plant and seed yield, number of silique-bearing branches per plant and seed yield, and silique per branch and seed yield. Similarly to N.Thurling (1974), we also found a significant negative correlation between the number of seeds per silique and number of siliques per plant ($r = /-0.633/ > r_{0.05} = 0.632$, $n = 10$), which could be attributed to yield component compensation.

Investigation results in Lithuania indicated that the best seed yield is obtained when crop density at harvest is 40.9-46.7 plants per 1 m^2

18

Oskars Balodis, Zinta Gaile, Biruta
Bankina, Rita Vītola

FUNGICIDE APPLICATION EFFECT ON YIELD AND QUALITY
FORMATION OF WINTER OIL-SEED RAPE (BRASSICA NAPUS L.)

Table 3

Effect of fungicide juventus 90 on structure elements of winter rape yield, 2006

Varieties	Seed number per plant		Seed number per silique		Mean plant productivity, g		Silique number per plant	
	C†	F‡	C†	F‡	C†	F‡	C†	F‡
Excalibur	2558	2058	22	21	10.38	10.24	111	109
Californium	2276	3153	22	35	9.07	12.84	114	83
Elixir	3013	3897	19	25	12.27	15.08	142	149
Orkan	2584	2258	28	29	10.38	8.88	92	75
Falstaf	2034	2796	23	24	7.85	10.34	89	113
Average	2493	2832	23	27	9.99	11.48	109	106
$LSD_{0.05}$	880		4.5		3.40		23	

C† – check without fungicide treatment; F‡ – fungicide treatment: split application of juventus 90

(Malinauskas, 2005). Average crop density at the rape harvest in our experiments was close to that, and we assessed it being optimal (check – on average 36 stems m^{-2}; with fungicide treatment – 41 stem m^{-2}). A slight (by 6%) significant impact ($p = 0.009$) of fungicide application was noted on crop density; also cultivar impact on this parameter was noted as significant (by 23%; $p = 0.01$).

No significant impact ($p = 0.403$) of fungicide application was noted on 1000 seed weight (average for check – 4.31 g, average with fungicide treatment – 4.28 g), but 1000 seed weight was significantly ($p < 0.001$) influenced by the cultivar. Other research (Treikale et al., 2006) showed 1000 seed weight increase when fungicide is applied. Interesting is correlation between 1000 seed weight and seed yield. When we analysed all 13 cultivars included in the experiment ($n = 26$) significant correlation between these parameters was not found, which is in accordance with the results of N.Thurling (1974). When we analysed only those five cultivars for which other structure elements were estimated (Table 3), a significant positive correlation was found ($r = 0.641 > r_{0.05} = 0.632$, $n = 10$).

A small fungicide treatment (by 2 %; $p = 0.0004$) and strong cultivar (by 83 %; $p < 0.001$) effect was noted to volume weight: average volume weight of treated with fungicide rape was 680 g L^{-1}, but of untreated – 677 g L^{-1} ($LSD_{0.05} = 2$ g L^{-1}).

High average seed yields (check – 5.37 t ha^{-1}, with fungicide – 5.80 t ha^{-1}) were obtained in our experiment. A significant impact ($p < 0.001$) of fungicide application was observed on seed yield (increase + 0.43 t ha^{-1}, $LSD_{0.05} = 0.18$ t ha^{-1}) (Fig. 2). This is in accordance with

other research where use of growth regulators in autumn (Miliuviene et al., 2004; Treikale et al., 2006) improved the seed yield; also fungicide application during summer vegetation period (at full flowering) improve the seed yield (Treikale et al., 2006). Cultivar influence (by 62%) on seed yield was significant ($p < 0.001$), too. On average, most productive varieties were 'Excalibur' – 6.46 t ha^{-1}, 'Astrid' – 6.53 t ha^{-1}, and 'Banjo' – 6.46 t ha^{-1}. Seed yield was significantly increased by fungicide application for varieties 'Astrid', 'Elixir', 'Express', and 'Orkan', but for seven varieties ('Olphi', 'Ella', 'Caracas', 'Catalina', 'Excalibur', 'Celsius', and 'Falstaf') increase in yield with fungicide application was observed, but it was not statistically significant at the 95% confidence level. For two varieties ('Californium' and 'Banjo'), increase in seed yield with fungicide application was not observed at all (Fig. 2).

Crude protein and oil content in seeds was not affected significantly by fungicide application ($p > 0.05$). Average protein content in seeds depending on the cultivar varied from 195.7 g kg^{-1} to 216.8 g kg^{-1}, but on average for rape without fungicide treatment crude protein content was 202.5 g kg^{-1}, and with fungicide treatment – 204.4 g kg^{-1}. Oil content in seeds on average was 469.8 g kg^{-1} without fungicide treatment, but 470.0 g kg^{-1} if fungicide was used. Other research (Treikale et al., 2006) reported increase in oil content when fungicide was used.

As so high seed yield was obtained even without fungicide treatment (5.37 t ha^{-1}), the yield increase (0.43 t ha^{-1}) was too small to economically motivate fungicide application. Despite agronomic improvements (improved fitometric indices in autumn and winterhardiness, decreased *Phoma* stem canker incidence,
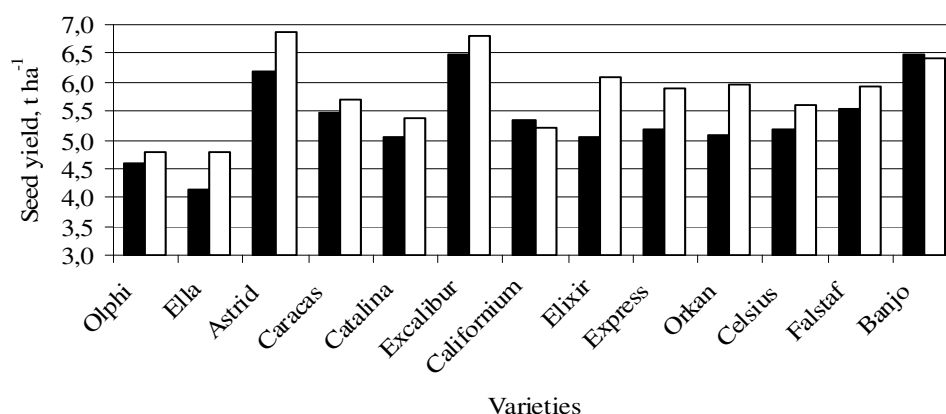
Figure 2. Seed yield of winter oilseed rape depending on variety and fungicide application, t ha^{-1}, 2006 ■ – control without fungicide; □ – split application of fungicide juventus 90).

increased seed yield), economic calculation showed that on average fungicide application in 2006 was not profitable: when fungicide was applied, proceeds per every invested LVL were decreased if compared with the untreated control; also product cost per 1 t increased when fungicide was applied.

Conclusions

The main benefit of our first years' investigations is clarifying of some further research directions. Split fungicide (juventus 90 s.c. – metconasol 90 g L^{-1}) application affected rape plant biometric indices during autumn – decreased the height of growth point and increased the number of leaves. Beneficial impact of fungicide was noted also on winterhardiness. Other important indicators for good rape wintering, such as chemical composition of main root column and growth bud, should be investigated in future.

From observed three rape diseases, only incidence of *Phoma* stem canker was considerable in 2006. Fungicide application decreased the incidence of this disease, but life cycle of the disease should be investigated in Latvian conditions and, depending on it, a better fungicide application scheme should be worked out. Fungicide use did not affect significantly the rape yield structure elements in 2006. Although split fungicide application increased the rape seed yield and showed a positive effect on winterhardiness increase and disease incidence decrease, economical profitability was not observed. Research should be continued for clarifying all above-mentioned problems more deeply.

Acknowledgement

References

1. Becka D., Vasak J., Kroutil P., Stranc P. (2004) Autumn growth development of different winter oilseed rape variety types at three input levels. Plant and Soil Environment, 50, pp. 168-174.
2. Gaveliene V., Novickiene L., Miliuviene L. (1998) The effect of growth regulators on wheat and rape wintering. Scientific works of Lithuanian Institute of Horticulture and Lithuanian University of Agriculture. Horticulture and vegetable growing, 17(3), pp. 195-206.
3. Gaveliene V., Novickiene L., Brazauskiene I., Miluviene L., Pakalniškyte L. (2002) Relationship of rape growth and crop production with plant growth regulators and disease. Vagos. Mokslo Darbai (Proceedings of Lithuanian University of Agriculture), 56 (9), pp. 7-11.
4. Gaveliene V., Novickiene L., Brazauskiene I., Miluviene L., Kazlauskiene D. (2005) Possibilities to use growth regulators in winter oilseed rape growing technology. 2. Effects of auxin analogues on the formation of oilseed rape generative organs and plant winterhardiness. Agronomy Research, Volume 2, No. 1, pp. 9-19.
5. Huang Y-J., Fitt B.D.L., Jedryczka M., Dakowska S., West J.S., Gladders P., Steed J.M., Li Z-Q. (2005) Patterns of ascospore release in relation to phoma stem canker epidemiology in

England (*Leptosphaeria maculans*) and Poland (*Leptosphaeria biglobosa*). European Journal of Plant Patology, 111, pp. 263-277.

6. Leach J.E., Stevenson H.J., Rainbow A.J., Mullen L.A. (1999) Effects of high plant population on growth of winter oilseed rape (*Brassica napus*). Journal of Agriculture Science, 132, pp. 173-180.

7. Malinauskas D. (2005) Peculiarities of winter rape growth, development and ripening in central Lithuania. Summary of Doctoral Dissertation, Lithuanian University of Agriculture, Kaunas, 26 p.

8. Miliuviene L., Novickiene L., Gaveliena V., Brazauskiene I., Pakalniskyte L. (2004) Possibilities to use growth regulators in winter oilseed rape growing technology. 1. The effect of retardant analogues on oilseed rape growth. Agronomy Research, 2, pp. 207-215.

9. Thurling N. (1974) Morphological Determinants of Yield in Rapeseed (*Brassica campestris* and *Brassica napus*). II Yield Components. Australian Journal of Agriculture Research, 25, pp. 711-721.

10. Treikale O., Pugačova J., Afanasjeva I. (2006) Fungicīdu lietošanas pamatojums intensīvā ziemas rapša audzēšanas tehnoloğijā (Motivation of fungicide use for intensive oil-seed rape growing technology). Lauka izmēğinājumi un demonstrējumi 2005.- Ozolnieki, 68.-74. lpp. (in Latvian).

11. Velicka R., Rimkeviciene M., Marcinkeviciene A., Raudonis S. (2005) Chemical composition of crown bud and rape wintering in crop of different density. Proceedings of LLU, 13, pp. 46-54.

12. Velicka R. (2003) Rape. Summary of the monograph, presented for habilitation confer. Lithuanian University of Agriculture, Kaunas, 78 p.

13. West J.S., Fitt B.D.L., Leech P.K., Biddulph J.E., Huang Y.-J., Balesdent M.-H. (2002) Effect of timing of *Leptosfaeria maculans* ascospore release and fungicide regime on phoma leaf spot and phoma stem canker development on winter oilseed rape (*Brassica napus*) in Southern England. Plant Pathology, 51, pp. 454-463.

CHOICE OF SPECIES AND VARIETIES OF WHEAT FOR ORGANIC FARMING

Petr Konvalina, Jan Moudrý
University of South Bohemia, Czech Republic
E-mail: konvalina@zf.jcu.cz

Abstract

Cereals, the yield of which is strongly influenced by a well-selected variety, belong to the most important crops of organic farming, grown on arable land. At first a questionnaire study was executed among organic farmers in 2006 to gain information concerning the choice of variety, structure of growing, and yield of cereals in the Czech Republic. The actual cultivars of wheat are bred to be suitable for intensive farming. Therefore, not all the actual cultivars are suitable for organic farming. The methodology of tests of the suitability of cultivars for organic farming was elaborated and tested in 2006. Particular morphological, biological and agricultural features were evaluated. Selected Austrian cultivars, which were recommended for in organic farming system and breeded strains were tested. It is difficult to achieve a sufficient protein content in grain in the organic farming system. The fact that the protein content in landraces of wheat is higher than the protein content in modern breeded varieties was confirmed. These varieties adapted to local conditions very well. Most of the evaluated varieties contain more crude protein in grain than modern varieties and may achieve a very good-quality production, but on a lower yield level the same as varieties of emmer.

Keywords: organic farming, varieties, wheat, emmer.

Introduction

The actual varieties are bred in order to have a favourable genetic base for intensive method of growing, when considerable amounts of industrial fertilizers are used - soluble nitrogenous ones (Zídek et al., 1992), herbicides, fungicides, insecticides, regulators of growth, etc. (Arncken et al., 2002). The varieties are adapted to the technologies of growing, harvest and processing (Zídek et al., 1992).

Concerning organic farming, the yield is much more influenced by the interaction of the genotype and the environment than the yield in conventional farming system. Therefore, evaluation of suitability of certain varieties for a particular station is the most important principle of the choice of varieties (Moudrý, 2003). Nevertheless, testing of varieties for concrete station conditions would be very expensive (Wolfe, 2002). Therefore, it is not necessary to set up a methodology of the evaluation of suitability of varieties only on breeders' level, but also in conditions of organic farms. According to Wolfe (2002), the varieties suitable for organic farming are characterized by high nutrient use efficiency, high competitiveness to weeds, resistance to diseases and pests, and the required qualitative parameters' of production.

Landraces cannot compete with modern bred cultivars from the point of view of yield, but they have a lot of valuable features and qualities, therefore, they should be taken into account too. They are characterised by high nutritive and dietetical values (Michalová et al., 2003). They were chosen and selected by natural conditions of a certain area with a little contribution of a farmer (Belay et al., 1995). These materials are adapted to the local environment very well and are genetically variable (Holubec, 2001). Obsolete cultivars and landraces are able to compensate unfavourable environmental conditions, and they provide a more stable yield, but the level of yield is lower than the level of yield of modern varieties (Dotlačil, 2000). These varieties are characterised by higher level of the creation of root system, they adopt nutrients better from the soil, therefore they need less additional diet (soluble nutrients) and are more competitive to weeds because they are higher and create more tillers (Zídek et al., 1992). The varieties with the high level of adaptation may be used as sources of genes for the breeding in organic farming system (Deslaux, 2005). They are able to provide good results of the on-farm conservation or growing in the conditions of low-input systems (Dotlačil, 2000).

Emmer wheat (*Triticum dicoccum* Schrank) belong to glumeous varieties of wheat. The tradition of its growing and use in human diet is very old (Marconi and Cubadda, 2005). Considering the requirements for variability and good quality of food products have been considerably increasing, the interest in such

varieties has been increasing too (Hammer and Perinno, 1995; Olsen, 1998; Nielsen and Mortensen, 1998). The renewed interest in emmer wheat comes from the countries where agriculture is on a high level. On the other hand, the surface of emmer wheat has been decreasing in the countries where agriculture has been still developping (Marconi and Cubadda, 2005). Some varieties of emmer are suitable for marginal regions and organic farming system. Modern varieties are not able to develop their production capacities there, because they have been selected for other land and climatic conditions. Growing of emmer wheat may be economically contributing for a farm (Marconi and Cubadda, 2005).

Materials and Methods

Contemporary situation in the Czech Republic.

In May and June 2006, a questionnaire study 'Varieties of cereals in organic farming system' covering the whole territory of the Czech Republic was carried out. The respondent were chosen from the database of the association of organic farmers called PRO-BIO (including 50% of all organic farms in the Czech Republic). There was a condition for them to grow cereals. There were 81 farms addressed (about 50% of the associations growing cereals in organic farming system in the Czech republic).

Modern varieties of winter wheat.

In 2005-2006, small-parcel trials with modern varieties recommended for organic farming system and bred varieties of winter wheat were set up and carried out (the varieties came from the breeding station at Saatzucht Edelhof in Austria). The methodology for the evaluation of suitability of the varieties for organic farming systems has been tested there (the methodology has been designed according to the Classificator of genus *Triticum* L.). The crop stands were set up in two rotations, particular morphological, biological and economic features were studied and evaluated during the vegetation period. The evaluated varieties and strains were marked as follows: Capo=the control variety (A), Eurofit (B), Clever (C), Ludwig (D), SE 304/05 (1), SE 320/05 (3), SE 322/04 (4), SE 403/03 (5), and SE 408/04 (6).

Landraces and obsolete cultivars.

The range of 42 landraces, obsolete cultivars and facultative wheats was chosen from the gene sources of wheat (*Triticum aestivum* L.) of the Gene bank at the Research Institute in Prague-Ruzyně. They are supposed to contain a high proportion of protein in grain. The

other 10 modern cultivars were chosen as control varieties too. The varieties were sown in rows at two stations - České Budějovice (CB) and Gene bank at the Research Institute in Prague-Ruzyně (RI) - and were studied and evaluated according to the arranged Classificator of genus *Triticum* L., the crude protein content was analysed by NIR spectroscopy method, Perstorp Analytical–Nirssystems 6 500 aparatus.

Emmer wheat.

The range of 10 varieties was chosen from the gene sources of emmer wheat (*Triticum dicoccum* Schuebl) of the Gene bank at the Research Institute in Prague-Ruzyně. These varieties are supposed for use in organic farming systems (according to the evaluation of genetic resources). The varieties were sown in rows at two stations (CB, RI) and were studied and evaluated according to the arranged Classificator of genus *Triticum* L.

The characteristics of the trial stations: RI – altitude of 364 m; mean air temperature of 7.9 °C; total precipitation of 525.9 mm; sunshine duration of 1668.3 hours, pH ($CaCl_2$) of 7.3; P - 78 mg kg^{-1}; K - 210 mg kg^{-1}; Mg - 148 mg kg^{-1}; Ca - 4360 mg kg^{-1}. CB – altitude of 388 m; mean air temperature of 8.2 °C; total precipitation of 620 mm; sunshine duration of 1564.3 hours; pH ($CaCl_2$) of 6.3; P - 138 mg kg^{-1}; K - 155 mg kg^{-1}; Mg - 163 mg kg^{-1}; Ca - 1557 mg kg^{-1}.

Results and Discussion

Contemporary situation in the Czech Republic.

According to the questionnaire study carried out among organic farmers in the Czech republic and information concerning the available varieties, lack and unsufficient range of the varieties, which are suitable for local land and climatic conditions, belong to the most important problems of organic growing of cereals in the Czech Republic. Wheat is the most common variety of cereals (Fig. 1) (spring wheat - 35%, spelt - 22%, winter wheat - 17%). Most of the respondent would appreciate low input varieties. Their most important and most required qualitites are: good health conditions, competitiveness to weeds, and suitability for land and climatic conditions of a certain farm. The most common problems of growing are: crop stand is overrun with weeds, and low or fluctuating yield. In the Czech Republic the average yield of all the groups of cereals was 2.7 t ha^{-1} (50% of the conventional farming yield, 5.47 t ha^{-1} in 2005) in 2005 (Zimolka et al., 2005).
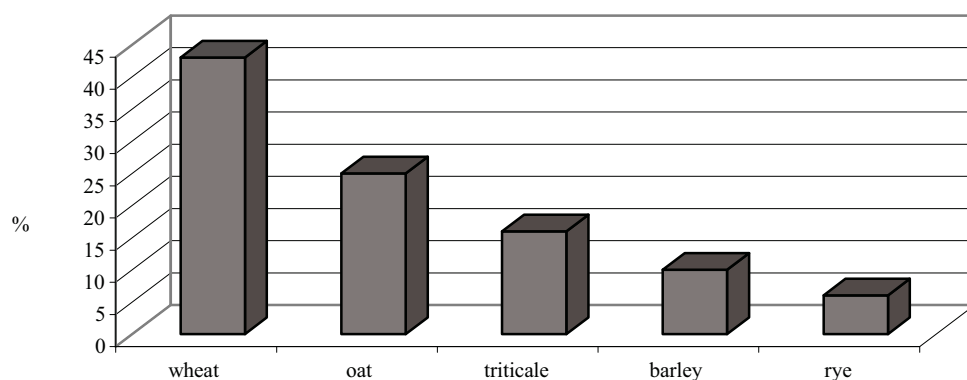
Figure 1. The structure of cereal species growing in organic farming system of the Czech Republic.

Modern varieties of winter wheat.

The evaluated genotypes at location CB (Table 1) have a loosely spreading-prostate tuft shape. The varieties of Capo (A), Ludwig (D) and all new breeded tribes meet the criteria of the methodology regarding the length of plant and upper internode. 2 varieties do not meet the criteria regarding the situation of a flag leaf at the beginning of heading. Its width seems to be a problematic feature (6 varieties do not meet this criterion). The varieties comply with the requirements for the length and density of a spike. On the other hand, 6 varieties are not able to create a semi-erect or erect spike in the stage of full ripeness and 7 varieties are not able to provide a pyramidal or cylindrical shape of a spike. Almost all the genotypes fulfil the requirements concerning the shape of caryopsis and traces. Just a half of the varieties and strains meet the criterion of a smooth and matted or glossy caryopsis surface. Light brown or yellow colour was achieved only in few varieties.

The varieties had all the evaluated biological features (Table 1). Considering the development of summer weather and low infection pressure, no diseases were noticed in the crop stands of these varieties. It is necessary to take into account the fact of a lower pressure of diseases in organic farming system than in conventional one (Lammerts van Bueren, 2002).

Concerning the evaluation of economic features (spike productivity) (Table 1), all the tested varieties contained an average amount of spikelets in a spike. The number of grains in a spikelet and spike was said to be average or high too. Thousand grain mass (TGW) did not achieve the required level of 44 g in 2 varieties. Only one variety of Capo (A) met the criterion of volume weight >760 g l^{-1}. The decrease in the volume weight was caused by late harvest and wet weather (which is also confirmed by Zimolka et al., 2005). Only the strains of SE 408/06 (6) provided higher total yield (4.8 t ha^{-1}) 0.3 t ha^{-1} more than the control variety (4.5 t ha^{-1}).

Landraces.

A lot of authors claim that organic farming system has a negative effect on the technological quality of what, especially regarding the crude protein content (Moudrý, Prugar, 2002). We have to reckon on the deficit of crude protein content of 2-3% in comparison with conventional varieties of wheat (Capouchová, 2004). Generally, landraces of wheat contain much more crude protein than modern cultivars. High protein content in grains of particular landraces was described e.g. by Yang and Liang (1995), Liu (1995) or Dotlačil (2000).

The average crude protein content in grain (14.4%) was achieved in all the varieties grown on the station in CB. CV (Coeficient of variation) of protein content was 9.5%. Landraces were characterised by a higher crude protein content in grain (14.8%) compared to modern varieties (12.7%). The protein content was higher on the second station in RI (17.7%), CV of crude protein content was 7.7%. Landraces, obsolete cultivars and facultative wheats were also characterised by higher protein content in grain (18.0%) compared to modern varieties (16.6%) (Table 2).

The average theoretical yield of crude protein per hectare reached the level of 566 kg ha^{-1} on the station in CB; CV – 28.7%. Landraces provide lower theoretical yield (534 kg ha^{-1}) than modern varieties (697 kg ha^{-1}). The average theoretical yield of crude protein was also higher on the second station (760 kg ha^{-1}) and CV was lower there (24.1%). Landraces also provided lower theoretical yield (755 kg ha^{-1})

Table 1

Prewiev of proposal of the methodology of variety testing for organic farming and results of the evaluation of winter wheat varieties

Morphological characters			
evaluated character		description	scale
plant	tuft shape at tillering	loosely spreading, prostate	> 56º
	plant height	medium	81-95 cm
	lenght of upper internode	medium, long	> 30 cm
flag leaf	position at the beginning of heading	erect, horizontal	15-90º
	length	medium, long	>15 cm
	width	medium, very broad	>1.5 cm
spike	position at full ripeness	semi-erect, horizontal	<45º
	shape	pyramidal, cylindrical	-
	length	long, very long	>10.5 cm
	density – spikelets/10 cm	intermediate, dense	21-21 spikelets.10 cm^{-1}
	awnedness	awnless, semi-awned	21 mm to > spike length
caryopsis	shape	very elongated, egg-shaped	
	surface	smooth, opaque, shining	
	colour	yellow, amber-yellow	
	crease shape	shallow, narrow	
Biological characters			
evaluated character		description	
vegetation period		very early, medium	
lodging – resistance		high, very high	
diseases – resistance: *Erysiphe graminis* (plant, spike), *Puccinia recondita*, *Septoria nodorum*, *Fusarium* spp., *Tiletia caries*			
Economical characters			
evaluated character	description		scale
spike – number of spikelets	medium		16-21
spike – number of grains	medium, high		18-43
spikelet – number of seeds	medium, high		2.5-4
1 000 grain weight (TGW)	high, very high		>44 g
volume weight	minimum. qualitative group B-bread		>760 g l^{-1}
grain yield to the standard			>100%
Note: X – unsuitable variety, - suitable variety			

than modern varieties (799 kg ha^{-1}).

Higher crude protein content in dry matter of grain and higher crude protein yield per hectare, which were achieved on the station of RI, were caused by better land and climatic conditions and better nutritive state of the soil (confirmed also by Petr et al., 1987). The differences in protein content in grain between these two stations are supposed to show a higher stability of landraces (the difference in protein content for landraces and facultative wheats – 3.2%, for modern varieties – 3.9%). It is not any general rule – the differences between the reactions of the varieties are stated in Table 3; low reaction – Kundan (16.7% and 18.4%), considerable reaction – Bage (14.4% and 19.4%). All two tested facultative wheats (Postoloprtská and Rosamova česká červená) were characterised by high protein

Table 2

Evaluation of crude protein content (%) and theoretical crude protein yield (kg ha^{-1})

Evaluated character	Parametre	Station					
		CB			RI		
		V[1]	K+P[2]	M[3]	V[1]	K+P[2]	M[3]
Crude protein in grain (%)	Mean (%)	14.4	14.8	12.7	17.7	18.0	16.6
	Standard Deviation	1.4	1.2	0.8	1.4	1.3	1.1
	CV (%)	9.5	7.9	6.2	7.7	7.1	6.8
Theoretical yield of crude protein (kg ha^{-1})	Parametre	Station					
		CB			RI		
		V[1]	K+P[2]	M[3]	V[1]	K+P[2]	M[3]
	Mean (kg ha^{-1})	566	534	697	760	755	779
	Standard Deviation	162.5	148.6	158.7	182.6	179.2	205.4
	CV (%)	28.7	27.8	22.8	24.1	23.7	26.4

Note: [1]all the varieties; [2] landraces; [3]modern varieties

content. According to the results of the studies and tests, it is necessary to evaluate protein content in different conditions and regions and to get knowledge and experience of the reaction of varieties to the environment and conditions.

The list of varieties and concrete data concerning crude protein content and theoretical yield is seen in Table 2. Crude protein content was the main criterion for the selection of varieties. According to Fossati et al. (2005), baking quality of wheat is a complex feature, therefore, crude protein content should be used as a simple indicator of the quality. According to Table 3 (crude protein in grain/theoretical yield of crude protein), the varieties of Kundan (CB 16.7 %/605 kg ha^{-1}; RI 18.4 %/1,066 kg ha^{-1}), Praga (CB 15.7 %/1,078 kg ha^{-1}; RI 18.0 %/844 kg ha^{-1}), and Vega (CB 16.4 %/772 kg ha^{-1}; RI 19.3 %/698 kg ha^{-1}) were supposed to be the most perspective varieties of all. The other varieties, which are marked down, also achieved good results. The varieties, presented in Table 3, were also supposed to be good from the point of view of their morphological, biological, and economical characters.

Emmer wheat.

Table 4 shows the evaluation of economic characters of emmer varieties of wheat. For tested varieties, TGW was 31.1 g, and CV - 13.9%, harvest index – 0.35 on average, CV - 12.3%. Spike grain mass was a fluctuating feature – 0.95 g on average, CV - 28.5%. The number of grains per spike reached 30.19 and the number of spikelets - 20.24, CV was 19% (the same in both cases). On the other hand, number of grains per spikelet was the most stable feature (1.5). According to Table

4, the varieties of D 10 No. 8909 (yield of 6.12 t ha^{-1}), D9 Sort. Schiemann (yield of 4.56 t ha^{-1}), and D2 Ruzyně (yield of 4.28 t ha^{-1}) are supposed to be the most pespective. Emmer varieties of wheat produce very good-quality grains with very high protein content (confirmed by several authors), which may achieve 20% (Marconi and Cubadda, 2005).

Particular morphological and biological characters were also studied of the varieties. Generally, emmer wheat is suitable for organic farming system from the point of view of its morphological and biological characters. It also has a suitable character of growth and is competitive to weeds. No occurrence of diseases was observed in the field trials.

Conclusions

According to the questionnaire study, the availability of a variety on the market is the main criterion for the choice of varieties in organic farming system. Therefore, suitability for land and climatic conditions of farms, health conditions and qualitative parametres of varieties are not the most important indicators.

The methodology of the evaluation of wheat varieties for organic farming system was successfully conceived and tested during the experiments. Modern varieties of winter wheat were tested on the basis of this methodology. The controlled variety of Capo (A) seemed to be the most suitable one for organic farming system. On the other hand, the variety of Ludwig (D) seemed to be the less suitable one. There are some perspective genotypes among new breeded strains.

According to the results of the testing

Table 3

Crude protein content in dry matter of grain (%) and theoretical crude protein yield (kg ha^{-1})

Variety	Station				Variety	Station			
	CB		RI			CB		RI	
	P^1	V^2	P^1	V^2		P^1	V^2	P^1	V^2
Landraces and facultative wheats									
Slovenská skora	**16.6**	**599**	18.4	666	Iona	15.6	339	16.9	**1,160**
Svaloefs Diamant II	14.8	514	**18.9**	687	Jefferson	14.3	362	16.4	**949**
Touko	13.8	350	16.2	585	Kharkivs'ka 41	13.7	**648**	17.6	**1,017**
Manitoba	14.1	510	17.1	626	Tritinaldia Kroměříž	**17.4**	441	**20.7**	751
Bage	14.4	**672**	**19.4**	699	Ratborska	14.9	542	16.6	785
Rio Negro	15.4	550	18.4	465	Vega	**16.4**	**772**	**19.3**	698
Baroota Wonder	14.6	530	**19.5**	**915**	Podboranka	**15.8**	570	**18.9**	689
Almadense	13.7	499	17.5	**1,012**	Praga	**15.7**	**1,078**	18.0	**844**
Webster	14.8	535	17.6	827	Dětěnická bílá hladká	14.4	**680**	18.3	664
Turkmenskaja	**16.5**	410	18.4	666	Hodoninská bezosinná	14.6	532	17.8	646
Kolchoznica	**15.9**	**576**	16.6	601	Kostomlatská sametka	14.3	363	16.8	428
Sawtana	15.3	554	17.8	644	Přerovská PK	14.0	509	17.2	811
Local..	15.0	381	**20.1**	719	Selecty tvrdá bělka	15.2	550	17.9	646
Barleta Benvenuto	14.6	525	17.5	636	Staroveská bezosinná	13.4	338	15.7	738
Hopps	**15.7**	399	18.2	664	Ruzyňská II	12.8	**749**	17.5	**1,003**
Kenya Farmer	14.9	379	**18.9**	684	Dobrovická 3	14.8	376	**19.3**	**911**
Hokoku	14.9	538	17.7	642	**Zlatka**	14.9	544	**20.2**	**1,168**
Dalnevostocnaja 10	15.1	544	17.5	631	Oktavia	12.3	575	**19.5**	707
Kundan	**16.7**	**605**	18.4	**1,066**	Jara	11.9	**699**	18.0	**1,044**
Hopea	13.3	337	16.7	606	Sylva	13.6	**792**	14.5	837
Postoloprtská přesívka	**15.7**	566	**19.4**	487	Rosamova česká červená	**15.9**	401	**19.0**	684
Modern varieties									
Average of 10 varieties	12.7	**697**	16.6	779					

Note: ^{1}crude protein content in grain; ^{2} theoretical yield of crude protein (kg ha^{-1})
Upper Quartile: crude protein – 15.67% (CB), 18.92% (RI); theoretical yield of crude protein– 576 kg ha^{-1} (CB), 844 kg ha^{-1} (RI);

of landraces, some varieties showed higher crude protein content in grain than modern varieties, therefore, they could provide a sufficient theoretical crude protein yield. These varieties may provide very good-quality production, but on lower level of yield. Their morphological and biological characters are supposed to be positive too. There are some varieties with sufficient economic characters among emmer varieties of wheat too. Therefore, they are suitable for low

Table 4

Economical characters of evaluated emmer varieties

Variety	TGW (g)	Harvest index	Spike – grain mass (g)	Number of grains per spike	Number of spikelets	Number of grains per spikelet	Yield (t ha^{-1})
D 1 Horny Tisovnik	**34.0**	**0.39**	0.86	25.67	13.60	**1.9**	3.44
D 2 Ruzyne	29.0	0.35	**1.07**	**37.01**	**22.85**	**1.6**	**4.28**
D 3 Tapioszele 1	28.5	**0.39**	0.59	20.58	16.10	1.3	2.36
D 4 Tapioszele 2	32.5	0.32	1.00	**34.68**	**23.55**	1.5	4.00
D 5 Mestnaja	**34.0**	0.34	0.73	23.12	14.45	**1.6**	2.92
D 6 Kromeriz	30.0	0.33	0.88	26.42	21.85	1.2	3.52
D 7 Kahler Emmer	23.5	0.27	0.68	31.85	21.50	1.5	2.72
D 8 May-Emmer	26.5	0.37	0.98	**37.50**	**22.85**	1.5	3.92
D 9 Sort. Schiemann	**37.0**	0.31	**1.14**	30.96	**24.20**	1.3	**4.56**
D 10 No.8909	**36.0**	**0.41**	**1.53**	34.12	21.45	**1.6**	**6.12**
Mean	31.1	0.35	0.95	30.19	20.24	1.50	3.78
Standard Deviation	4.33	0.04	0.27	5.92	3.95	0.2	1.09
CV (%)	13.9	12.3	28.5	19.6	19.5	13.3	28.5

Note: Upper Quartile: TGW – 34 g; harvest index – 0.39; spike – grain mass –1.07 g; number of grains per spike – 34.68; number of spikelets – 22.85; number of grains per spikelet – 1.6; yield – 4.28 kg ha^{-1}

input farming systems and on-farm conservation of the genetic sources. Growing of these varieties could contribute to a sustainable development of the region, support landscape function of agriculture and trends of healthy diet.

Acknowledgements

References

1. Arncken Ch., Kunz P., von Wistinghausen B. (2002) Samenbau (Seed production on organic farming). In: Leitfaden zur biologisch-dynamischen Landwirtschaft, FiBL, Frick pp. 1-33 (in German).

2. Bareš I., Sehnalová J., Vlasák M., Vlach M. (1985) Descriptor list genus Triticum L. Genetics resources 21, VÚRV Praha-Ruzyně, 78 p.

3. Belay G., Tesemna T., Bechere E., Mitiku D. (1995) Natural and human selection for purple-grain tetraploid wheats. Genet. Res. Crop Evol., 42, pp. 387-150.

4. Capouchová I. (2004) Rozdíly v kvalitě ozimé pšenice (Quality diferences of winter wheat). Zemědělský týdeník (Agriculture news), 12, pp. 10-11 (in Czech).

5. Deslaux D. (2005) Participatory plant breeding methods for organic cereals. In: Lammets van Bueren E.T., Goldringer I. and Ostergard H. (Eds) Organic Plant Breeding Strategies and the Use of Molecular Markers, Proceedings of the COST SUSVAR/ECO-PB Workshop, 17-19. January, Driebingen, pp. 17-23.

6. Dotlačil L., Hermuth J., Tisová V., Brindza J., Debre F. (2000) Yield Potential and Stability in Selected Winter Wheat Landraces and Obsolete Cultivars of European Origin. Plant Production, 46, pp. 153-158.

7. Fossati D., Kleijer G., Brabant C. (2005) Practical breeding for bread quality. In: Lammets van Bueren E.T., Goldringer I. and Ostergard H. (Eds) Organic Plant Breeding Strategies and the Use of Molecular Markers, Proceedings of the COST SUSVAR/ECO-PB Workshop, 17-19. January, Driebingen, pp. 31-35.

8. Hammer K., Perinno P. (1995) Plant genetic resources in South Italy and Sicily: studies towards in situ and on farm conservation. Plant Genetic resources Newsletter, 103, pp. 19-23.

9. Holubec V. (2001) Mizející krajové formy tradičních plodin v ČR/Československu (Evanescent landraces of traditional crops in Czech republic). In: Michalová A. (Ed): Pěstování a využití některých opomíjených a netradičních plodin v ČR (Growing of obsolete cultivars in Czech republic). Genetics resources 84, VÚRV Praha-Ruzyně, pp. 98-100 (in Czech).

10. Lammerts van Bueren E.T. (2002) Organic Plant Breeding and Propagation: Concepts and Strategies. PhD Thesis, Wageningen University, The Netherland, 196 p.

11. Liu L. (1995) Local varieties of winter wheat with a high protein content. Zouwu Pinzhong Ziyuan, 4, pp. 41-42.

12. Marconi M., Cubadda R. (2005) Emmer wheat. In: Abdel-Aal E-S. M. and Wood, P. (Eds.): Speciality grains for food and feed. American Association of Cereal Chemists, Inc. St. Paul, Minesota, U.S.A., pp. 63-108.

13. Michalová A., Vala I., Gabrovská H., Hutař M. (2003) Nutriční kvalita minoritních obilnin (Nutrition quality of minority cereals). In: Michalová A. (Ed) Genetics resources 88, VÚRV Praha-Ruzyně, pp. 19-23 (in Czech).

14. Moudrý J. (2003) Polní produkce (Field production). In: Urban J., Šarapatka B. (Eds.) Ekologické zemědělství (Organic farming). MŽP, Praha, pp. 103-126 (in Czech).

15. Moudrý J., Prugar J. (1999) Kvalita rostlinných produktů ekologického zemědělství (Quality of bioproducts). ÚZPI, 5/1999, 40 p. (in Czech).

16. Nielsen F., Mortensen J.V. (1998) Ecological cultivation of Emmer and Giant Durum. Gron Viden, Markburg, 4, pp. 194-196.

17. Olsen C.C. (1998) Old cereal species – growing emmer and durum wheat withou pesticides. Gron Viden, Markburg, 4, pp. 196-199.

18. Petr J., Baier J., Bureš, R. (1987) Počasí a výnosy (Weather and yield). SZN, Praha, 368 p. (in Czech).

19. Wolfe M.S. (2002) Plant Breeding, Ecology and Modern Organic Agriculture. In: Lammerts van Bueren E.T. and Wilbois K.P. (Eds) Organic Seed Production and Plant Breeding – strategies, problems and perspectives. proceedings of ECO-PB 1st International sympozium on organic seed production and plant breeding, 21.-22. November, Berlin, pp. 18-24.

20. Yang J.Z., Liang Q. (1995) Wheat germplasm with high protein content and resistance to drought Crop Genetic Resources, 44, pp. 15-25.

21. Zídek T., Lokaj Z., Moudrý J., Rozsypal R., Rusek J., Veselý D. (1992) Nechemická ochrana rostlin (Nonchemical plant protection). MZe, Praha, 112 p. (in Czech).

22. Zimolka J., Edler S., Hřivna L., Jánský J., Kraus P., Mareček J., Novotný F., Richter R., Říha K., Tichý F. (2005) Pšenice – pěstování, hodnocení a užití zrna (Wheat – growing and using of grain). Profi Press, Praha, 220 p. (in Czech).

SPRING BARLEY YIELD, GRAIN QUALITY AND FACTORS AFFECTING THEM

Zita Brazienė, Juozas Kaunas
Rumokai research station, Lithuanian Institute of agriculture
E-mail: rumokai@post.omnitel.net

Abstract

Effects of nitrogen fertilizers and weather conditions on spring barley *(Hordeum vulgare L.)* yield and grain quality were investigated at the Rumokai Experimental Station of the Lithuanian Institute of Agriculture in the period of 1998 2000 and 2003-2004. The soil of the experimental site was Hapli-Epihypogleyic Luvisol. Analyses were made with fertilisers rates of 0 and 90 kg ha^{-1}.

The data of analyses indicated a positive and reliable correlation between the yield of spring barley and the amount of precipitation in May (rate of correlation was 0.70**) and a negative and reliable correlation with the amount of precipitation in June and July (rates of correlation were -0.80** and -0.29* respectively). A reliable, though weak correlation was found between the application of nitrogen fertilisers and the yield of grains.

The amount of precipitation in April and the spring barley leaf diseases had a considerable negative effect on 1000 grain weight and grain size. Strong correlation was identified between the amount of precipitation in May and June and the protein content in grain. Nitrogen fertilisers promoted protein accumulation in grain.

Keywords: spring barley, nitrogen fertiliser, precipitation, yield, grain quality.

Introduction

Growing of spring barley *(Hordeum vulgare L.)* is an old tradition in Lithuania, nevertheless, the barley yield and quality are dependant on a wide range of factors. Climatic conditions, growing technologies, diseases, and genetic characteristics of varieties are among the main factors, which influence the grain yield and quality indices (Antanaitis and Švedas, 2000; Petrauskas and Leistrumaitė, 2001; Tamm and Tamm, 2002).

Proper fertilisation of spring barley results in an increased yield, resistance of plants to diseases and pests, and improved quality of grains. From the very start of growing, barley shall receive easily accessible nutrients. In the phases of tillering and stem development, intensive formation of vegetative and generative constituents of barley takes place and the only source of this element at the said time is the soil. If shortage of nutrients is witnessed during the vegetation of plants, some sprouts are lost and no development of additional stems takes place, further resulting in lesser number of grains in an ear and grain size. Availability of sufficient content of nitrogen 15-20 days after germination is of utmost importance. In case of its shortage at the indicated time, ear formation is negatively affected (Bogomazov et al., 1997). Fertilisation procedure shall take into account agrochemical analyses of the soil, purpose of growing, properties of variety, and expected yield. Basing on the reserve of nutrients available in the soil, one may initiate forecasts of the yield and programming of fertilisation aimed at getting the planned yield (Krištaponytė, 2002). Numerous software programmes of fertiliser norms are developed. They are relied on in selecting even more efficient fertilisation norms (Švedas and Tarakanovas, 2000).

Meteorological conditions are also important for the grain yield and quality. The related reference material presents the data on the dependence of spring barley yield on precipitation in June and August (Dmitrenkova, 2004). Protein content in grain is dependant on the variety characteristics, raising technology, and meteorological conditions (Tamm and Tamm, 2002; Gluchovcev, 1996). Analyses of the malt variety 'Trumpf' revealed finer and more protein-containing barley grains during sunny summers if compared with wet and moderate sunny summer time (Gluchovcev, 1996). It has been found that protein content in barley grains is mostly influenced by nitrogen fertilisers rather than other factors while fractional composition of grains is mode- dependant on ambient conditions (Tamm, Tamm, 2002). Volume weight of grains and 1000 grain weight is primarily the index of a variety; however, they are also influenced by hydro-thermal coefficient of vegetation period, by the time of drilling, fertilisation, and plant protection measures (Ivoilov et al., 2003; Pasynkov, 2002).

The analyses are aimed at the determination of the influence of meteorological conditions and nitrogen fertilisers on the yield of spring barley grains and quality indices.

Materials and Methods

The field experiments took place at the Rumokai Experimental Station of the Lithuanian Institute of Agriculture in the period of 1998-2000 and 2003-2004. The soil of the experimental site was Hapli-Epihypogleyic Luvisol. Precrop — sugar beets. The background of the experiments was fertilized with phosphorus and potassium fertilizers at a rate of 60 kg each of active ingredient per hectare. Nitrogen fertiliser was applied at the rate of 0 kg ha^{-1} and 90 kg ha^{-1} of active ingredient. The analysed variety of spring barley was 'Alsa', derived at the Lithuanian Institute of Agriculture.

Drilling of barley took place during the first decade of May (and in the third decade of April in 2000), the seed rate accounted for 4.5 million viable seeds per hectare. At the start of stem development (30-31 BBCH), herbicide Dialen was sprayed - 1.5 - 2.0 l ha^{-1}. The harvesting took place during the second decade of August.

Plant samples for biometric analysis were taken before harvesting from four sites (0.25 m^2) of each experimental plot. At harvesting, grain samples were taken for chemical analyses and for 1000 grain weight determination.

Package for statistical data processing 'ANOVA' was used for statistical analysis (Tarakanovas, 2002).

Meteorological conditions

It was dry and warm during the second half of April and at the start of May 1996 (Tables 1 and 2). Heavy rains started in the second half of May, and germination of the remaining nongerminated grains took place. The weather in June was cool and dry. Cool weather was also typical of July and precipitation increased: the volume of precipitation in July was near the level of several years' average.

The spring of 1997 was cool and with a sufficient level of precipitation. Cool and rainy weather proceeded in May leading to tillering of crops. The summer of that year was warm and dry, thus the weather was unfavourable for diseases.

The spring of 1998 was warm with a sufficient amount of precipitation. The third decade of April was without precipitation, and warm and sunny weather prevailed. It was warm, though rainy in May and June. The amount of precipitation was 1.8 times higher than long-term average. The weather in August was cool and rainy, and unfavourable for harvesting.

The year 1999 was characterised by an early spring. The average monthly temperature in April was 3.4 °C higher than the average temperature of many years. Cooler weather came at the beginning of May. The third decade of May was characterised by dry, warm and even hot days extending during the whole period of barley vegetation. In July the weather was warm and dry enough, and rapid maturing of the crops took place, which further resulted in an early harvesting.

The spring of 2000 was exceptionally early. The average weather temperature in April was 5.7 °C higher than the average of many years and a single rainy day was reported during the whole month. July was exceptionally rainy – the amount of precipitation was 4.4 times higher than the average of many years.

April of 2003 was cooler than the average of many years. The amount of precipitation was

Table 1

Air temperature during the growth period of spring barley in Rumokai, 1996-2000, 2003-2004

Years	Month				
	April	May	June	July	August
Average of 1924-2003	6.1	12.2	15.5	17.6	16.4
1996	7.9	13.6	14.9	16.1	18.3
1997	4.9	11.7	16.7	18.6	19.2
1998	9.0	13.7	17.5	16.6	15.3
1999	9.5	9.6	18.9	22.1	16.6
2000	11.8	13.1	16.3	16.7	16.8
2003	5.4	13.1	16.2	20.0	17.8
2004	7.4	8.7	13.2	16.1	17.6

Table 2

Precipitation du ring the growth period of spring barley in Rumokai, 1996-2000, 2003-2004

Years	Month				
	April	May	June	July	August
Average of 1924-2003	40.0	53.0	71.0	90.0	96.0
1996	29.0	61.3	39.9	104.4	12.2
1997	39.2	80.2	21.6	39.4	23.0
1998	65.1	30.0	126.5	159.5	111.9
1999	26.8	18.8	178.0	44.4	69.5
2000	8.9	38.3	143.0	395.6	91.5
2003	37.6	43.8	55.9	86.8	66.3
2004	44.4	62.0	94.2	86.8	74.2

close to the average of many years. May, June and July were warm with sufficient amount of precipitation.

April of 2004 was quite early and with sufficient amount of precipitation. Average weather temperature in May, June and July was lower than the average of many years. Amount of precipitation in April, May and July was close to the average of many years. Rainy June was reported.

Results and Discussion

Leaf diseases had negative influence on the grain yield and quality of spring barley. In the experimental years, spring barley was most affected by *Drechslera sorokiniana* (Sacc.) Subram., *Drechslera teres* (Sacc.) Shoem. *Ito* and *Septoria* spp. The most intensive development of diseases was traced in 1998 (Table 3).

The most voluminous yield of grains was registered in the years 1996 and 1997 (Table 4), Which was due to favourable moisture content during the germination and vegetation periods and due todry weather conditions during heading. The least grain yield was reported in 1999 due to the attack of the thrips *(Limothrips denticornis)* and rainy weather in June, which reduced the number of grains in barley ears. The grain yield was very much influenced by meteorological conditions. Statistical calculations revealed that the major impact on the grain yield was due to precipitation in May and June (Table 5).

The precipitation in May had direct correlation with the grain yield (correlation coefficient - 0.70**). The precipitation in June stimulated the development of diseases and reduced the productivity of barley (correlation coefficient - -0.80**). Besides, precipitation of this month had negative influence on the number of grains in ears, and a direct positive correlation was established between the number of grains and the yield (correlation coefficient - 0.59**). However, during all years of the analyses the application of nitrogen fertilisers increased the grain yield (correlation coefficient - 0.35*).

Table 3

Leaf disease development at the stage of barley milky ripeness (71-73 BBCH), Rumokai, 1996-2000, 2003-2004

Years	Nitrogen fertilizer rates		LSD_{05}
	0 kg ha^{-1}	90 kg ha^{-1}	
	Leaf disease severity, %		
1996	18.6	22.8	2.19
1997	25.1	26.0	3.72
1998	35.5	36.9	2.78
1999	15.9	18.8	4.01
2000	4.5	6.0	1.02
2003	14.7	16.2	2.02
2004	17.4	18.5	1.89

Table 4

Effect of nitrogen fertilizers on grain yield and 1000 grain weight, Rumokai, 1996-2000, 2003-2004

Years	Nitrogen fertilizer rates		LSD$_{05}$
	0 kg ha^{-1}	90 kg ha^{-1}	
	grain yield, t ha^{-1}		
1996	5.30	5.86	0.555
1997	5.01	6.76	1.045
1998	4.56	4.92	0.411
1999	2.14	3.27	0.241
2000	2.96	3.93	0.480
2003	4.57	5.47	0.456
2004	3.75	4.64	0.502
	1000 grain weight, g		
1996	50.6	49.1	2.53
1997	48.6	47.8	2.12
1998	41.6	41.1	0.85
1999	46.7	47.5	1.69
2000	54.8	53.5	1.22
2003	49.8	49.2	1.6
2004	44.7	43.2	1.86

Leaf disease decreased the grain yield, correlation coefficient was -0.33*.

1000 grain weight was the largest in 2000 (Table 4), which was due to the sparse crop of that year. 1000 grain weight had strong correlation with precipitation in April (correlation coefficient was -0.93**). The sufficient amount of moisture during drilling stimulated both germination of grains and density of crop, so the weight of grains decreased. 1000 grain weight was also influenced by precipitation in July (correlation coefficient - 0.41*) – larger amount of precipitation during grain filling stimulated the increase of the grain weight. 1000 grain weight had strong correlation with leaf diseases – correlation coefficient was -0.74**.

Nitrogen fertilisers reduced the 1000 grain weight. An excessive reduction in the grain size was found in 2004, for which the decisive factor was intensive development of diseases of leaves and barley lodging.

An important index of the barley grain quality is grain size. Though the improvement of the said index is possible due to grain sorting, it is also

Table 5

Correlation between spring barley yield, quality parameters and factors affecting them, Rumokai, 1996-2000, 2003-2004

Characteristic	Precipitation in April, mm	Precipitation in May, mm	Precipitation in June, mm	Precipitation in July, mm	Leaf disease	Nitrogen fertilizers
Grain yield, t ha^{-1}	0.36*	0.70**	-0.80**	-0.29*	-0.33*	0.35*
1000 grain weight, g	-0.93**	0.35*	-0.16	0.41	-0.74**	-0.07
Grain size, %	-0.80**	0.34*	-0.12	0	-0.66**	-0.22
Protein content in grain, g kg^{-1}	0	-0.75**	0.74**	-0.14	0.03	0.36*

* - 0.05 probability level. . . .
** - 0.01 probability level . . . .

dependant on the raising technology, seasons of the year, meteorological conditions, and variety specifics. The yield of large-size grains (large size grains mean the items left on 2.5x20 mm mesh screen after sieving) during the research period accounted for 73.2-90.8 percent (Table 6). Larger grains were observed in the harvest of 1997 and 2000. The developed diseases and laying-flat of the crop in 1998 resulted in a lower value of the index.

The grain size was highly affected by meteorological conditions and development of leaf disease. The precipitation in April stimulated the spring barley crop density and reduced the grain size (correlation coefficient – -0.80**). Leaf disease reduced the grain size – correlation coefficient was -0.66**.

The data in the reference material inform that the decisive factors effecting the protein content in spring barley are meteorological conditions and the soil micro-variety rather than the genetic potential of a plant (Mašauskienė et al., 2001). Our analyses also revealed that protein content in the grains was very much influenced by meteorological conditions (Table 6). It was dry and hot, at the grain formation stage in 1999. Besides, the soil was abundant in mineral nitrogen before drilling that year (50.30 kg ha^{-1}) and for that reason the grains of spring barley had large amount of protein (149-158 g kg^{-1}).

Statistical analyses indicated an average reverse correlation link between precipitation in May and protein content in grains, and a direct link between precipitation in June and protein content in grains. Average negative correlation was determined between the grain yield and the protein content in the grains – the larger yield, the less protein content in the grains. All years of analyses revealed that nitrogen fertilisers increased the protein content in grains by 2.8-13.8 %.

Conclusions

1. Precipitation in May and June essentially influenced the grain yield. After application of nitrogen fertilisers at 90 kg ha^{-1} norm, a larger yield of grain was obtained during all years of study.
2. 1000 grain weight was the largest in 2000. Precipitation in April and leaf disease reduced the 1000 grain weight (correlation coefficients were -0.93** and -0.74**).
3. The grain size was highly affected by meteorological conditions and development of leaf disease. The precipitation in April stimulated the spring barley crop density and reduced the grain size (correlation coefficient – -0.80**). Leaf disease reduced the grain size – correlation coefficient was -0.66**.

Table 6

Effect of nitrogen fertilizers on grain size and protein content in grain, Rumokai, 1996-2000, 2003-2004

Years	Nitrogen fertilizer rates		LSD$_{05}$
	0 kg ha^{-1}	90 kg ha^{-1}	
	Grain size, %		
1996	86.1	78.9	1.36
1997	90.0	88.5	0.8
1998	75.6	73.2	1.83
1999	88.5	87.5	1.75
2000	90.8	87.1	1.45
2003	87.5	85.3	1.05
2004	89.1	87.2	1.66
	Protein content in grain, g kg^{-1}		
1996	118	121	0.7
1997	107	122	7.0
1998	127	138	5.8
1999	149	158	8.8
2000	118	132	15.1
2003	119	131	9.8
2004	123	135	7.7

4. A large amount of protein in grains was obtained in 1999, when the lowest yield of grains was obtained. An average strong negative correlation was found between the grain yield and protein content in the grains – the better the yield, the less protein content in grains. An average strong reverse correlation was determined between precipitation in May and protein content in grains, and a direct correlation was found between precipitation in June and protein content in grains.

References

1. Antanaitis Š., Švedas A. (2000) Miežių derliaus ir kokybės ryšys su dirvožemio savybėmis ir tręšimu (Barley yield and quality in relation) t o soil properties and fertilisation. Žemdirbystė, 72, pp. 19-33. (in Lithuanian).

2. Dmitrenkova Y.A. (2000) Climate influence on agricultural crops yield in the republic of Belarus. Natural resources, 1, pp. 26-35.

3. Krištaponytė I. (2002) Maisto medžiagų poreikio programuotam derliui normatyvai, skaičia vimo metodika ir kompiuterinė tręšimo sistemų sudarymo programa (The normatives of the nutrient matters requirement of the expected yield, the methodology of calculation and computer programme of the fertilization systems). Naujausi agronomijos tyrimų rezultatai, pp. 44-46. (in Lithuanian).

4. Mašauskienė A., Paplauskienė V., Leistrumaitė A. (2001) Veislės įtaka vasarinių miežių grūdų kokybės ir derlingumo variacijai bei šių rodiklių tarpusavio priklausomumui (The effect of cultivar on the variation of spring barley grain guality and yield, and correlation among these indicators). Žemdirbystė, 73, pp. 194-209. (in Lithuanian).

5. Petrauskas P., Leistrumaitė A. Vasarinių miežių kolekcines medžiagos atsparumas ligoms (Resistance of spring barley collection to diseases). Žemdirbystė, 75, pp. 279-288. (in Lithuanian).

6. Švedas A., Tarakanovas P. (2000) Tręšimo planavimas Kompiuterinė programa 'Tręšimas' (The fertilization planning. The computer programme „The fertilization"). Akademija, LT 34 p. (in Lithuanian).

7. Tamm I., Tamm U. (2002) Genetic and environmental variacijon of malting barely and oat grain quality characteristics. Žemdirbystė, 78, pp. 51-57.

8. Tarakanovas P. (2002) Biologinių bandymų duomenų transformavimas taikant kompiuterinę programą 'ANOVA' (Data transformation of biological experiments using a computer programme 'Anova') Žemdirbystė, 77, pp. 170-180. (in Lithuanian).

9. Богомазов Н.П., Шильников И.А., Нетребенко Н.Н. (1997) Влияние удобрений и погодных условий на урожай и качество пивоваренного ячменя на черноземе выщелоченном в Белгородской области (The effect of fertilization and weather conditions on the yield and quality of malting barley on leached chermozems at the region Belgorod), Агрохимия, 2, стр. 60-65. (in Russian).

10. Глуховцев В.В. (1996) О селекции и использовании пивоваренных сортов ярового ячменя в Поволжие (About the selection and the use of malting barley varieties at the region Povolzje). Сельскохозяйственная биологи, 3, стр. 32-39. (in Russian).

11. Ивойлов А.В., Копылов В.И., Самойлова О.Н. (2003) Реакция сортов ячменя на внесение минералных удобрений в зоне неустойчивого увлажнения (The response of barley varieties under fertilization with mineral fertilizers at the unstable humidity region). Агрохимия, 9, стр. 30-41. (in Russian).

12. Пасынков А.В. (2002) Урожайность и пивоваренные качества зерна различных сортов ячменя в зависимости от доз и соотношения азотных и калийных удобрений (The grain yield and quality of different barley varieties in relation to nitrogen and potash fertilizers rates). Агрохимия, 7, стр. 25-31. (in Russian).

GRAIN CHEMICAL COMPOSITION OF SPRING BARLEY GENOTYPES

Mara Bleidere[1]*, Ilze Grunte*[2]
[1]Latvia University of Agriculture
[2]State Stende Cereal Breeding Institute
E-mail: maara.bleidere@gmail.com

Abstract

The objective of the study was to examine the range of variation in chemical composition of different barley types. Field experiments were carried out at the State Stende Cereal Breeding Institute from 2004 to 2006. Grain samples of 52 spring barley (*Hordeum vulgare* L.) genotypes, including two-row, six-row, covered and hulless genotypes were analysed for starch, crude protein, crude fat, crude fibre, crude ash and phosphorus. On the average, the six-row barley genotypes had a significantly larger content of crude protein (152.0 g kg^{-1}), crude fibre (53.5 g kg^{-1}), crude ash (24.4 g kg^{-1}) and phosphorus (4.7 g kg^{-1}) but less starch (590.4 g kg^{-1}) than the two-row barley genotypes (626 g kg^{-1}). The hulless barley grain contained significantly more crude protein (149.4 g kg^{-1}), crude fat (25.4 g kg^{-1}) and phosphorus (4.7 g kg^{-1}) than covered ones. The largest coefficient of variation was found for crude protein of covered barley (15.0%), for crude fibre of hulless barley (13.8%) and for phosphorus of six-row barley (18.0%) genotypes. Consequently, energetic value was slightly higher in the hulless barley with waxy type of endosperm, because of the higher fat (27.1-28.3 g kg^{-1}) and starch content (622.3-680.7 g kg^{-1}) and less crude fiber (17.3-17.4 g kg^{-1}) and crude ash (18.9-21.2 g kg^{-1}) content.

Keywords: spring barley, chemical composition, genotypes, variation.

Introduction

Whole and minimally processed spring barley (*Hordeum vulgare* L.) grain is fed to farm animals primarily as an energy source and also to supply protein, vitamins and minerals. Because of the high digestibility of barley, it can be used most effectively in the pig feeding, but it is also a valuable component in concentrates for ruminants and poultry (Hickling, 1999).

Historically, the quality requirements for feed barley have been somewhat subjective and inconsistent. Greater attention has been paid to physical than to nutritional characteristics. The nutrient composition of barley is the subject for a degree of variation that makes accurate diet formulation difficult. This variation in nutrient content is generally attributed to differences among cultivars as well as to variation in growing conditions. The inherent genetic variability of the components in barley provides the opportunity for breeders to alter the kernel composition in many ways. Several studies have described the range in the chemical composition of barley. In recent years, research has been increasingly directed at the improvement of the feeding value of spring barley and this has resulted in the discovery of genotypes with improved grain chemical composition (Aman et al., 1985; Barneveld, 1999; Bowman et al., 1997); Kong et

al., 1995. The value ranges reported by Aman et al., (1985) are starch, 48-67%, crude protein, 9-16%, crude fiber, 2.5-6.0%, crude fat 2.7-3.7% and crude ash 1.8-2.9%. Such differences in chemical constituents among different barley varieties most likely explain why the digestible energy (DE) content of barley has been found to vary up to 20%, or approximately 2510 kJ of DE kg^{-1} of DM (Fairbairn et al., 1999). The variation in the energy content of barley reduces the precision of diet formulation, resulting in less predictable animal performance, and possibly increased feed costs and lower carcass quality.

Barley can be classified as two-row and six-row types depending on spike morphology. The difference in spike type is controlled primarily by a single gene *vrs1* with the two-row type being dominant. This *vrs1* gene has remarkable effect also on many other characteristics. Two-row genotypes contained more protein, starch and crude fat (Kong et al., 1995; Welch, 1978), and less crude fibre than six-row genotypes (Fregeau-Reid et al., 2001). In several studies non significant difference between two-row and six-row genotypes was stated if grain chemical composition was compared (Aman et al., 1985; Aman and Newman, 1986).

In covered barley, the flowering glumes are fused and adhere strongly to seed with a

cementing substance. In hulless barley, fusion of the flowering glumes does not occur and the hull falls off during threshing (Newman and Newman, 1991). The comparison of covered and hulless barley has supposed that hulless barley generally contains more protein, starch, and β-glucan (Bhatty, 1999). Aman and Newman (1986) found that the grains of hulless barley contained significantly higher starch and lower crude fibre content than grains of covered barley. In this investigation there were no differences in crude protein, crude fat and crude ash content between these two types of barley. Whereas Foley et al. (2006) found that crude ash content for the hulless barley was considerably lower than for covered barley, but Welch (1978) reported that hulless barley varieties contained significantly higher crude fat and crude protein content compared to covered barley. Ash content for covered genotypes was significantly higher than for hulless. Coefficient of variation of crude ash content for hulless genotypes was high - 20.4%, but for hulled it was 8.0% (Oscarssons et al., 1996).

Spring barley varieties with waxy endosperm (contain starch with 97-100% of amylopectin) are caused by a single recessive gene (*wx*). Waxy barley has been tested for use as animal feed (Washington et al., 2000). Comparative studies on grain chemical components between waxy and normal starch genotypes are limited. Waxy barley had a higher β-glucan content than varieties with normal starch (Oscarsson et al., 1997; Bleidere, 2006). High β-glucan associated with waxy types tends to reduce nutrient digestion in pigs and increase sticky feaces in poultry. Nevertheless,

energy was slightly higher in the waxy genotypes because of the higher fat and starch values with less fibre and ash (Miller et al., 1994).

The objective of this study was to examine the range of variation in chemical composition of different barley types, selected on the basis of their different characteristics – two-row and six-row, covered and hulless types.

Materials and Methods

There were chosen 52 barley genotypes that represented a broad range of germplasm (two-row, six-row, covered, and hulless) of different origin (Table 1). Thirty-eight genotypes of covered spring barley, from which 28 with two-row and 10 with six-row ear types, and 14 hulless genotypes were used in this study. Only two-row hulless genotypes were included in this investigation. Hulless barley genotypes 'Merlin', 'Candle', 'Sumire Mochi', and 'Wanubet' have waxy endosperm.

The genotypes were grown at the State Stende Cereals Breeding Institute from 2004 to 2006. The soil at the site was sod-podzolic sandy loam, humus content – 12-15 mg kg^{-1}, soil pH – 6.0-6.7, precrop – potatoes, available for plants P – 88-94 mg kg^{-1}, and K – 103-122 mg kg^{-1}. Plot size was 2 m^2, 2 replicates, seed rate - 400 seeds per m^2. The plots were fertilized with N60 P15 K40 kg ha^{-1}.

Barley protein usually varies inversely with the starch content exhibiting the greatest fluctuation of the major nutrients (Welch, 1987). Wide variation is often observed between genotypes in crude protein content (Newman and McGuire,

Table 1

Spring barley genotypes used in the study

Barley type	n	Genotype, origin country
Two-row, covered	28	Ansis, Abava, Sencis, Kristaps, Rasa, Linga, Idumeja, Balga, Ruja, Gate, Malva, Klinta (Latvia); Hanka, Annabell, Danuta, Justina, Polygena (Germany); Austrian early, Landsorte Aus Tirol (Austria); Primus II, Pongo, (Sweden); Lysimax (Denmark); Hatvani 45/25 (Hungary); Cork, Century (Great Britain); Lechtaler (Portugal); Grimmet (Australia); 379 (Chile)
Six-row, covered	10	Druvis (Latvia); Colsess IV, July (Denmark); B90A, RNB-367 (Nepal); Zoapila, Puebla (Mexico); IV/192 (Macedonia); Valluno (Bolivia); Chosen (North Korea)
Two-row, hulless	14	L 302 (Latvia); KM 2084 (the Czech Republic); SW 1291 (Sweden); McGwire, Gainer, Candle (Canada); X-4 (Lithuania); Orzo Nudo di Altamura (Italy); 2474, Clho 7799 (Guatemala); C.P.I. 22817 (Russia); Sumire Mochi (Japan), Merlin, Wanubet (USA)

Table 2

Variation in grain chemical composition of different types of spring barley, g kg^{-1} (2004-2006)

Constituent	Mean value	Standard deviation	min value	max value	Coefficient of variation, %
Two-row					
Starch	620.6*	19.0	581.6	650.0	3.1
Crude protein	128.6	16.8	109.9	170.7	13.1
Crude fibre	45.9	3.8	34.9	53.1	8.2
Crude ash	22.9	1.1	21.0	25.4	4.7
Crude fat	23.3	2.2	19.7	29.4	9.5
P	3.9	0.3	3.2	4.7	8.9
Six-row					
Starch	590.4	17.4	563.0	621.0	3.0
Crude protein	152.0*	19.6	118.8	196.2	12.9
Crude fibre	53.5*	3.3	49.3	59.2	6.1
Crude ash	24.4*	1.1	22.6	26.1	4.6
Crude fat	22.8	1.3	20.1	24.3	5.9
P	4.7*	0.9	3.7	5.4	18.0
Covered					
Starch	612.7	22.8	563.0	650.0	3.7
Crude protein	134.7	20.2	109.9	196.2	15.0
Crude fibre	48.3*	4.5	40.6	59.2	9.3
Crude ash	23.3*	1.3	21.0	26.1	5.5
Crude fat	23.2	2.0	19.7	29.4	8.7
P	4.1	0.5	3.2	5.4	12.8
Hulless					
Starch	630.1*	30.9	585.5	680.7	4.9
Crude protein	149.4*	18.7	118.4	177.0	12.5
Crude fibre	23.8	3.3	17.3	28.6	13.8
Crude ash	21.2	1.8	18.8	23.9	8.3
Crude fat	25.4*	2.4	21.2	30.7	9.4
P	4.7*	0.4	4.1	5.2	8.4

* difference significant at $p < 0.05$

1985). The results of investigation of different types of barley genotypes showed that crude protein content was significantly higher for six-row barley genotypes than for two-row barley genotypes (Table 2). The mean value for six row barley was 152.0 g kg^{-1} (*min* value - 118.8 g kg^{-1}, *max* value - 196.2 g kg^{-1}), but for two-row genotypes – 128.6 g kg^{-1} (*min* value - 109.9 g kg^{-1}; *max* value - 170.7 g kg^{-1}). The significant difference was found also between hulled and hulless barley in crude protein content (mean values - 134.7 and 149.4 g kg^{-1} respectively). Crude protein content ranged from 109.9 to 196.2 g kg^{-1} for covered genotypes, and from 118.4 to 177.0 g kg^{-1} for hulless ones.

Barley contains varying quantities of structural carbohydrates defined as fiber. The total quantity is principally affected by the presence or absence of hulls. Barley fiber has little or no energy value for nonruminant animals thus it may create digestive problems, especially in poultry (Newman and McGuire, 1985). The mean value of crude fiber content for six-row barley (53.5 g kg^{-1}) was significantly higher than for two-row barley (45.9 g kg^{-1}) (Table 2). This is in agreement with results of Kong et al. (1995). In his study, the difference between two-row barley genotypes in fiber content was rather high – from 34.9 to 53.1 g kg^{-1}. The fiber content of hulless barley was two times smaller than that for covered barley: 23.8 and 48.3 g kg^{-1} respectively. Thus, our study reflects the same advantages of hulless barley as described earlier by Hickling (1999). Therefore hulless barley has better feed quality for

animals compared to hulled cultivars (Newman, 1991).

Barley lipid content is rather low compared to that of oats (Barneveld, 1999), ranging from 20 to 30 g kg^{-1} in most commercial cultivars (Newman and McGuire, 1985). The greatest portion of the lipid in the barley kernel is in the endosperm (Shewry and Morell, 2001). Welch (1978) also studied crude fat content in different types of barley. The crude fat content varied from 19 to 41 g kg^{-1} among 86 varieties. In Oscarsson et al. (1996) study, crude fat content ranged from 21 to 37 g kg^{-1}. There was a significantly higher crude fat content for two-row as compared with six-row barley varieties tested by Welch (1978). In our study, mean values of crude fat content for six-row and two-row covered genotypes were 22.8 and 23.3 g kg^{-1} respectively and the difference was not significant (Table 2). Crude fat content for hulless barley ranged from 21.2 to 30.7 g kg^{-1} with the mean value of 25.4 g kg^{-1}. This value was significantly higher than for covered barley (23.2 g kg^{-1}).

Ash consists mainly of inorganic compounds. The major mineral compounds in barley flour are phosphorus and potassium, while iron and zinc are major trace minerals (Bhatty and Christison, 1975). Phosphorus is the mineral element that contributes the most to diet cost (Newman and Newman, 1991). According to results of Oscarsson et al. (1996), the ash content for barley ranged from 13 to 21 g kg^{-1} and was the lowest in the hulless type. In this study there were significant differences between all types of barley in crude ash content (Table 2). Higher crude ash content was for six-row (24.4 g kg^{-1}) and covered barley (23.3 g kg^{-1}) types than for two-row (22.9 g kg^{-1}) and hulless (21.2 g kg^{-1}) ones. There was a significant difference also in phosphorus content between two-row and six-row barley types (mean values - 3.9 and 4.7 g kg^{-1} respectively) and between covered and hulless barley (4.1 and 4.7 g kg^{-1} respectively).

The coefficient of variation was the lowest for starch (3.0 to 4.9%) and the highest for crude protein (12.5 to 15.0%) (Table 2). Between genotypes, rather high genotypic variability was stated also for crude fiber of covered and hulless barley types (9.3 and 13.8% respectively) as well as in phosphorus content for six-row barley (18%). Genotypic variability was generally higher for hulless type of barley for most of the parameters measured.

Prior to analysis, a representative grain sample from both replications was ground in a Perten cyclone mill to pass a 0.8 mm screen. Dry matter content of the ground grains was determined by oven-drying at 130 °C for 2 h (LVS ISO 712-2003). Crude protein content (N x 6.25) was determined by Kjeldahl method (LVS 277). Starch content (ISO 10520), crude fiber content (ISO 5498), crude fat content (ISO 6492), crude ash content (LVS 276:2000), and P (ISO 6492) content were determined. In this paper, all chemical analyses are reported on a dry matter basis.

ANOVA procedures were used for data analysis. Significance level was determined at $p < 0.05$ between two-row and six-row, covered and hulless genotypes. The value of genotypic variability for traits was determined and expressed by coefficient of variation of traits as mean values for genotypes included in the research.

Results and Discussion

The variation in chemical composition of different types of spring barley is presented in Table 2. The differences in chemical composition of different barley types may be explained by genetic make-up since all varieties were grown under the same environmental conditions. The main components of the barley samples were starch and crude protein. Starch content ranged from 581.6 to 650.6 g kg^{-1} for two-row barley, and from 563.0 to 621.0 g kg^{-1} for six-row ones. The mean value of starch content for two-row barley (620.6 g kg^{-1}) was significantly higher than for six-row barley (590.4 g kg^{-1}). The starch is the most abundant energy source for most domestic animals. To maximize starch utilization, high small intestinal digestibility of barley starch is desirable for mono-gastric animals. In ruminants, starch in cereals also serves as an important source of energy for microbial growth and has therefore great impact on the feed protein value (Svihus, 2005). Aman and Newman (1986) found that hulless barley was characterized with significantly higher starch content. Also in this study, mean value of starch for hulless barley genotypes was a significantly higher than for covered ones.

Hulless barley with normal and waxy starch was also analyzed for chemical composition (Table 3). A high total β-glucan content in waxy barley has been reported previously (Oscarsson, 1996; Oscarsson et al., 1997; Bleidere, 2006). The results of this study showed that barley varieties with waxy endosperm are characterized with noticeable differences in the content of chemical components. The starch content for waxy barley variety 'CD Candle' corresponded to max value (680.7 g kg^{-1}) of this component

Table 3

Content of chemical components of some barley genotypes, g kg^{-1}(2004-2006)

Variety	Characteristics	Starch	Crude protein	Crude fat	Crude fibre	Crude ash	P
Ansis	2-row, covered	634.7	115.7	24.6	45.0	21.6	3.83
Idumeja	2-row-covered	612.9	132.7	22.5	46.9	23.3	3.90
Druvis	6-row, covered	621.0	118.8	20.1	55.8	22.6	3.73
Gainer	2-row, hulless	660.4	133.0	24.0	22.2	19.1	4.27
L 302	2-row, hulless	627.6	159.8	21.2	22.4	22.8	5.17
Merlin	2-row, hulless,waxy	658.4	130.9	27.1	24.8	20.9	4.63
Wanubet	2-row, hulless, waxy	622.3	136.8	27.4	17.4	18.9	4.53
Candle	2-row, hulless, waxy	680.7	118.4	28.3	17.3	21.2	4.60

between all genotypes included in this study. Crude fat for waxy barley varieties 'Merlin', 'Wanubet' and 'Candle' was considerably higher (27.1-28.3 g kg^{-1}) than for hulless barley and covered barley with normal endosperm (20.1-24.6 g kg^{-1}). Crude fiber for waxy varieties 'Wanubet' and 'CD-Candle' was less (17.4 and 17.3 g kg^{-1} respectively) as compared with other hulless varieties 'Gainer' and 'L 302' (22.4 and 24.8 g kg^{-1} respectively).

The data presented in this paper demonstrate clearly a notable variation of important components in barley grain. Variations in proximate composition, mainly in starch, crude protein, and fiber could affect the actual digestibility and metabolic energy values of feed, and this point is worthy of further investigation. Equations to predict the metabolic energy in poultry and pig feed have been proposed based on chemical composition of the feed, mainly content of crude protein, crude fat, crude fibre, ash content, starch, and sugar (Sibbald, 1987; Fairbairn et al., 1999). Consequently, the energy was slightly higher in the hulless barley, especially with waxy type of endosperm, because of the higher fat and starch content and less fiber and ash.

Conclusions

The data presented in this paper demonstrated considerable variation in chemical composition of different types of barley. Six-row barley contained significantly larger amount of crude protein (152.0 g kg^{-1}), crude fibre (53.5 g kg^{-1}), crude ash (24.4 g kg^{-1}) and phosphorus (4.7 g kg^{-1}) but less starch (590.4 g kg^{-1}) than the two-row barley (620.6 g kg^{-1}). The grain of hulless barley had significantly higher crude protein (149.4 g kg^{-1}), crude fat (25.4 g kg^{-1}) and phosphorus content (4.7 g kg^{-1}) than covered ones. Mean values of crude fiber (48.3 g kg^{-1}) and crude ash (23.3 g kg^{-1}) were significantly higher for covered barley genotypes than for hulless barley types. The highest value of genotypic variability was stated for crude protein of covered barley (15.0%), for crude fibre of hulless barley (13.8%) and for phosphorus of six-row barley (18.0%). The lowest coefficient of variation was found in starch content (3.0 to 4.9%) for all types of barley. Consequently, energetic value was slightly higher in the hulless barley with waxy type of endosperm, because of the higher fat (27.1-28.3 g kg^{-1}) and starch content (622.3-680.7 g kg^{-1}) and less crude fiber (17.3-17.4 g kg^{-1}) and crude ash (18.9-21.2 g kg^{-1}) content. These differences in grain chemical content may be utilized in barley breeding programs particularly to produce varieties for specific purposes, also for feed.

References

1. Aman P., Newman C.W. (1986) Chemical composition of some different types of barley grown in Montana, USA. Journal of Cereal Science, 4, pp. 133-141.
2. Aman P., Hesselman K., Tilly A.-C. (1985) The variation in chemical composition of Swedish barleys. Journal of Cereal Science, 3, pp. 73-77.

3. Barneveld S.L. (1999) Chemical and physical characteristics of grains related to variability in energy and amino acid availability in ruminants: a review. Australian Journal of Agricultural Research, 50, pp. 651-666.

4. Bhatty R.S. (1999) The potential of hulless barley. Cereal Chemistry, Vol. 76, pp. 589-599.

5. Bhatty R.S., Christison G.I., (1975) Chemical composition and digestible energy of barley. Canadian Journal of Animal Science, 55, pp. 759-764.

6. Bleidere M. (2006) Variation in endosperm β-glucan content of different spring barley genotypes. Proceedings of International scientific conference "Research for rural development", Jelgava, Latvia, pp. 7-11.

7. Bowman J.G.P., Surber L.M.M., Daniels T.K., Daniels J.T., Kirschten D.P., Cote N.T., Blake T.K. (1997) Variation in feed quality characteristics in the world barley collection. Proceedings of Western Section, American Society of Animal Science, 48, Available at: http://hordeum.oscs.montana.edu/cowdocs/cow697.htm, 25.02.2005.

8. Fairbairn S.L., Patience J.F., Classen H.L., Ziljastra R.T. (1999) The energy content of barley fed to growing pigs:characterizing the nature of its variability and developing prediction equations for its estimation. Journal of Animal Science, 77, pp. 1502-1512.

9. Foley A.E., Hristov A.N., Melgar A., Ropp J.K., Etter R.P., Zaman S., Hunt C.W., Huber K., Price W.J. (2006) Effect of barley and its amylopectin content on ruminal fermentation and nitrogen utilization in lactating dairy cows. Dairy Science, 89, pp. 4321-4335.

10. Fregeau-Reid J., Thin-Meiw C., Ho K., Martin R.A., Konishi T. (2001) Comparison of two-row and six-row barley for chemical composition using doubled-haploid lines. Crop Science, 41, pp. 1737-1743.

11. Hickling D.R. (1999) Does the feed industry have barley quality needs? Proceedings of the Canadian Barley Symposium'99, Winnipeg, Manitoba, Canada, pp. 55-58.

12. Kong D., Choo T.M., Jui P., Ferguson T., Therrien M.C., Ho K.M., May K.W., Narasimhalu P. (1995) Variation in starch, protein and fibre of Canadian barley cultivars. Canadian Journal of Plant Science, 75, pp. 865-870.

13. Miller M.C., Froseth J.A., Wyatt C.L., Ullrich S.E. (1994) Effect of starch type, total beta-glucan, and acid detergent fibre level on the energy content of barley (*Hordeum vulgare* L.) for poultry and swine. Canadian Journal of Animal Science, 74, pp. 679-686.

14. Newman C.W. and Newman R.K. (1991) Characteristic of the ideal barley for feed. In: Barley Genetic VI. Proceedings of the Sixth International Barley Genetic Symposium, Volume II, Helsingborg, Sweden, pp. 925-939.

15. Newman C.W., McGuire C.F. (1985) Nutritional quality of barley. In Book: Barley, Ed. by Donald C. Rasmusson, Wisconsin, USA, pp. 403-428.

16. Oscarsson M., Andersson R., Salomonsson A.-C and Aman P. (1996) Chemical composition of barley samples focusing on dietary fibre components. Journal of Cereal Science, 24, pp. 161-169.

17. Oscarsson M., Parkkonen T., Autio K., Aman P. (1997) Composition and microstructure of waxy, normal and high amylase barley samples. Journal of Cereal Science, 26, pp. 259-264.

18. Shewry P.R., Morell M. (2001) Manipulating cereal endosperm structure, development and composition to improve end-use properties. Advances in Botanical Research, 34, pp. 166-236.

19. Sibbald I.R. (1987) Bioassay of true metabolizable energy in feedstuffs. Poultry Science, Vol. 58, pp. 668-673.

20. Washington J.M., Box A., Karakousis A., Barr A.R. (2000) Developing Waxy Barley cultivars for food, feed and malt. In: Munk L. (eds) Barley Genetics VIII. Sixth International Barley Genetic Symposium, Munksgaard International Publishers Ltd., Copenhagen, Denmark, pp. 303-306.

21. Welch R.W. (1987) Genotypic variation of oil and protein barley grain. Journal of Science Food and Agriculture, 29, pp. 953-958.

THE EVALUATION OF EFFECTIVENESS OF *RHIZOBIUM LEGUMINOSARUM* IN FIELD BEANS *(VICIA FABA)*

Anita Ansevica, Ina Alsina, Laila Dubova
Latvia University of Agriculture
E-mail: anita.ansevica@llkc.lv, ina.alsina@llu.lv

Abstract

The vegetation pot experiment was conducted at the Institute of Soil and Plant Sciences of the Faculty of Agriculture of the Latvia University of Agriculture. The aim of the experiment was to investigate the effectiveness of five *Rhizobium legumonosarum* strains stored in the period from the 18th of August till the 20th of October 2006 in the collection of the Latvia University of Agriculture. Three of the five mentioned *Rhizobium legumonosarum* strains were included in the international *Rhizobium* database 'IBP World Catalogue of *Rhizobium* collections'. Taking into consideration the results of the experiment it has been pointed out that all *Rhizobium* strains were active and inoculated plants formed nodules on the roots. Inoculation with *Rhizobium* strains increased the proportion between shoots and roots' weight. It has been found that the dry matter content of the inoculated plants increased in comparison with the untreated ones. In addition, negative correlation between the dry matter and the protein content has been observed.

Keywords: *Vicia faba, Rhizobium leguminosarum.*

Introduction

Only prokaryotes can use nitrogen reserves from the earth's atmosphere. The bacteria of the *Rhizobium* family form nodules on legume roots. When forming symbiosis these bacteria convert the inert form of nitrogen (N_2) to the organic nitrogen. Afterwards, the organic nitrogen incorporates it into proteins, nucleic acids, and other cellular component parts. The encouragement of the development of *Rhizobium*-legume symbioses definitely increases the incorporation of the biologically fixed nitrogen into soil ecosystems. In agricultural systems, the bulk of the biological nitrogen fixation is derived from the cultivation of legumes. These symbioses can be concluded to provide well over half of the biological source of the fixed nitrogen (Tate, 1994).

Each year at the end of the vegetative period and after the decomposition of plants, soil becomes enriched with nitrogen from 100 to 300 kg per hectare (Schiegel, 2000).

It is popularly assumed that the enrichment with the symbiotically fixed nitrogen in soil was detected a long time ago. It is widely known that it could be observed by the employment of different agrotechnical methods, namely the rotation of crop and fallow. By means of symbiosis plants provide bacteria with nutrition elements (mostly sugars) and ensure favourable conditions for the bacteria living in the nodules. After the decomposition of plants, the more viable bacteria return into soil. The fixation of nitrogen occurs in the bacteroids. A total of 95% of fixing nitrogen in the form of ammonia incur into cytoplasm of a host plant (Tate, 1994).

It is known that some problems of fixing biological nitrogen are still current in the intensive conditions under chemical processes. In case of the positive symbiosis, the protein synthesis incorporates the fixed nitrogen, thus, increasing the amount of the yield and its quality. The inoculation of the seed material with active nitrogen fixing bacteria strains before sowing has a significant meaning for the increase of the legume yield. It is also important to note that, nitrogen fixing bacterial treatment appears to be quite profitable for the practical usage in agriculture.

The aim of the investigation was to detect the effectiveness of five *Rhizobium legumonosarum* strains in field beans *vicia faba* for the practical use in agriculture. Three of these strains were included in the international *Rhizobium* database. The tasks were to detect fresh mass, dry matter, and accumulated protein content in the dry matter of field beans. The effectiveness of nitrogen fixing bacteria was expressed in the increase of the fresh mass of the plants and the total amount of nitrogen in the dry matter.

Materials and Methods

the experiment was conducted in the greenhouses of the Institute of Soil and Plant Sciences of the Faculty of Agriculture of the

Latvia University of Agriculture. The purpose of the experiment was to detect the effectiveness of *Rhizobium* strains in field beans. The experiment was performed in four replicas in 5 L Mitcherlich type pots which had been filled with heated washed river sand, fertilized with Kemira GrowHow NPK 0-12-24-(1.5 Mg) – (13 S) and microelements. Nitrogen was added as ammonium nitrate form 0.024 g per 1 kg of sand for inoculated plants and ten times more (0.24 g kg^{-1}) for the control (plants did not inoculate with *Rhizobium leguminosarum* strains in the control variant).

The field beans were sowed in Mitcherlich type pots. Before that, the seeds had been inoculated with *Rhizobium leguminosarum* strains 23, 109, 113, 408, and 501. *Rhizobium leguminosarum* strains No. 23, 109 and 113 were incorporated in the international database (IBP World Catalogue of *Rhizobium* collections, 1973).

All the vegetation pots were placed in a greenhouse with day temperature 20–25 °C and night temperature over 12 °C. Since October, the plants were illuminated by means of artificial light twice a day: in the mornings and in the evenings in order to obtain a total photoperiod of 14 hours.

The experiment was finished at 62–64 (German scale) or at 203 of the development stage (British BCPC scale) for field beans (Latvijas valsts Augu aizsardzības centrs, 1997).

The fresh mass was detected by weighing field beans at 62–64 (German scale) or at 203 of the development stage (British BCPC scale) on electronical scale with ±0.001 error. The dry matter of field bean shoots was detected at 62 – 64 (German scale) or at 203 of the development stage (British BCPC scale) at 80 °C in the thermostat till constant weight (Ермаков, 1972).

The content of protein was determined by Kjeldahl method at the Analytical Laboratory for Agronomy Research of the Latvia University of Agriculture.

For data processing mathematical statistical methods (dispersion and correlation) were used.

Results and Discussion

The activity of *Rhizobium leguminosarum* strains characterizes the yield and nitrogen accumulated in it.

The highest fresh mass was obtained in the variants where strain No. 113 was used (52.78 g), fresh mass was increased by 12% compared with the control (47.1 g). The lowest fresh mass was observed when strain No. 23 (39.14 g) was used; fresh mass decreased by 17% as compared with the control (Fig. 1).

The plants where strain No. 113 (53.98 g) was used, demonstrated the highest root mass. The root mass increased by 10% as compared with the control (49.22 g). The plants where strains No. 408 (38.49 g) were used, demonstrated the lowest root mass. The root mass decreased by 22% as compared with the control. The plants where strain No. 408 was used, demonstrated the highest root and shoot ratio, as compared with the control increased by 25%. The plants where

$RS_{0.05}$ shoots 8.55 $RS_{0.05}$ roots 7.98
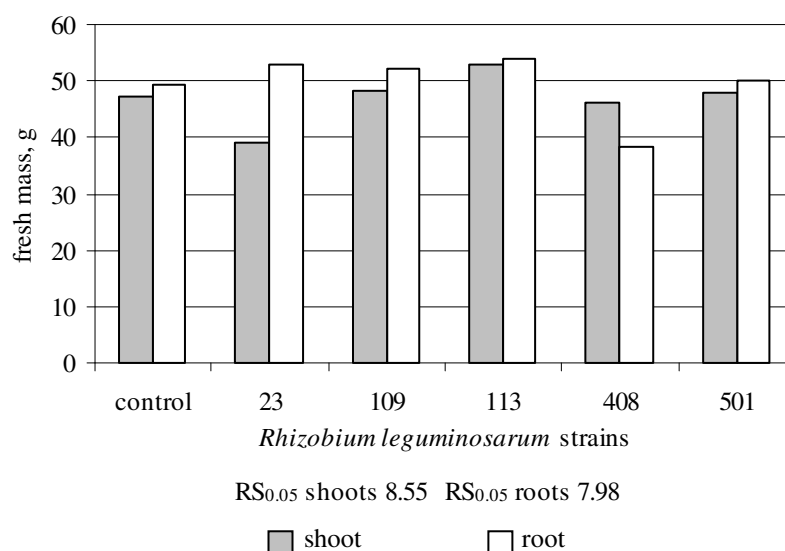
Figure 1. Fresh mass of field beans depending on the used *Rhizobium leguminosarum* strains.
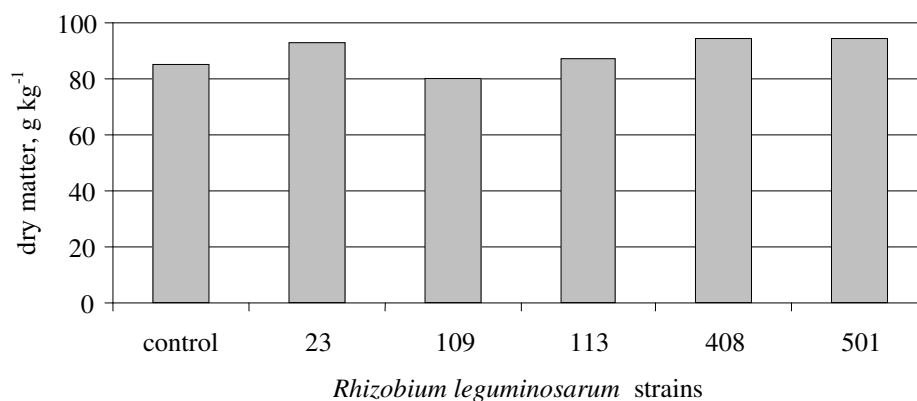
Figure 2. Dry matter of field beans depending on the used *Rhizobium leguminosarum* strains.

strain No. 23 was used, demonstrated the lowest root and shoot ratio, as compared with the control decreased by 23%.

Observation results of field bean roots have illustrated that all *Rhizobium leguminosarum* strains were active and formed nodules on the roots.

The acquired data processing showed that the fresh mass of the shoots, the mass of the roots and the ratio between shoots and roots were considerably affected by the inoculation.

The dry matter content was dependent on the development stage and the growing conditions.

The field beans where strain No. 408 ($94 \, \text{g kg}^{-1}$) was treated, demonstrated the highest dry matter content. The dry matter increased by 12%, as compared with the control ($85 \, \text{g kg}^{-1}$) (Fig. 2.). The lowest dry matter demonstrated plants treated with strain No. 109 ($80 \, \text{g kg}^{-1}$). The dry matter decreased by 6%, as compared with the control.

Data processing showed that inoculation significantly affected the dry matter content.

The protein content in the dry matter was dependent on the seed treatment of the field beans with different *Rhizobium leguminosarum* strains. The highest protein content was observed in the variants where strain No. 23 ($205 \, \text{g kg}^{-1}$) was used: as compared with the control ($179 \, \text{g kg}^{-1}$), the protein content in the dry matter increased by 17% (Fig. 3.). The lowest protein content in the dry matter was observed where strains No.
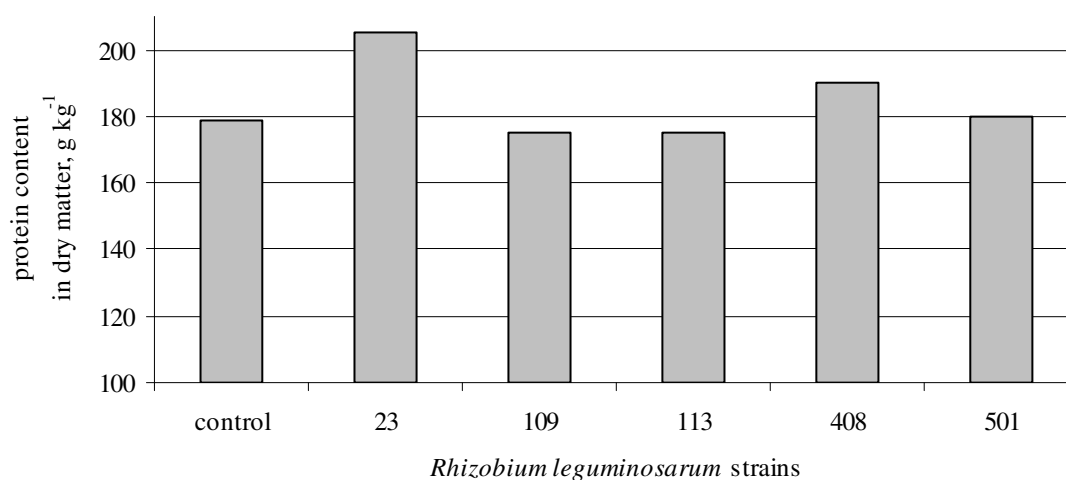
$RS_{0.05} = 5.88$

Figure 3. Protein content in the dry matter of field beans depending on the used *Rhizobium leguminosarum*.

109 (175 g kg^{-1}) and 113 (175 g kg^{-1}) were used, the protein content decreased by 2%, as compared with the control.

Data processing showed that the protein content in the dry matter was significantly affected by the inoculation. There was also observed the negative correlation between the dry matter of shoots and the protein content. The obtained data proved that the best results have been achieved by the employment of *Rhizobium leguminosarum* strain No. 23, whereas strain No. 109 was less effective.

Conclusions

1. The best results for the practical exploitation in agriculture demonstrated strain No. 23. There was observed the highest protein content in field beans. However, strain No. 109 appeared to be less effective;

2. Seed inoculation with *Rhizobium leguminosarum* increases the ratio between shoots and roots;

3. Seeds of field beans inoculated with *Rhizobium leguminosarum* have higher dry matter content than those of the control.

Acknowledgement

References

1. IBP World Catalogue of *Rhizobium* Collections (1973) ed. by Skinner F.A., pp. 243-245.
2. Latvijas valsts Augu aizsardzības centrs (1997) Eiropas un Vidusjūras augu aizsardzības organizācijas (EAAO) Augu attīstības stadiju noteicējs (European and Mediterranean Sea plant protection organisation Key book of plant development stages) Rīga, pp. 55-65. (in Latvian).
3. Schlegel H.G. (1992) Allgemeine Mikrobiologie (Applied Microbiology) 7 überbarbeite, Georg Thieme Verlag Stuttgart, NewYork, 504 p. (in German).
4. Tate R.L. (1994) Soil Microbiology, John Wiley and Sons, Inc., 409 p.
5. Ермаков А.И., Арасимович В.В., Смирнова – Иконникова М.И., Ярош Н.П., Луковникова Г.А. (1972) Методы биохимического исследования растений (The methods of biochemical plant research), издателъство Колос, Ленинград, стр. 22. (in Russian).

THE EARLINESS AND SUGAR CONTENT OF LATGALE'S MELONS

Andris Bāliņš[1], *Ina Alsiņa*[1], *Līga Lepse*[2]

[1]Latvia University of Agriculture
E-mail: andretti6@inbox.lv
[2]Pūre Horticultural Research Centre
E-mail: Liga.Lepse@puresdis.lv

Abstract

The research was done in 2006 with the aim to observe the earliness and sugar content of melons (*Cucumis melo* L.) in Tukums region of Latvia. Five lines of Latgale's melons ('8', '14', 'S4(3)', '5(2)', and '4(3)') and five varieties ('Noir des Carmes', 'Ogen', 'Vedrantais', 'Cantaloup de Bellegarde', and 'Jaune Canaris') from South Europe were grown in high plastic tunnels: five plants from each line and variety. The most appropriate melon line for growing in Latvia conditions was selected according to earliness and sugar content. The study showed that Latgale's melons (Latvian origin) are most suitable for growing in high plastic tunnels under Latvia's conditions. Also some of South Europe melon varieties proved to be suitable for growing in Latvia conditions. All Latgale's melon lines were earlier than South Europe varieties. The highest sugar content was observed in Latgale's melon line '8' (113 g kg^{-1}) and in South Europe varieties 'Jaune Canaris' (110 g kg^{-1}) and 'Cantaloup de Bellegarde' (96 g kg^{-1}). The research demonstrated that in Latvia successful cultivation of melons is possible by using high plastic tunnels.

Keywords: *Cucumis melo*, sugar content, earliness, refractometer.

Introduction

Melons (*Cucumis melo* L.) are divided into four groups by earliness. There are early ripening melons, which reach maturity in a month since pollination and late ones (the period from pollination till harvest takes up to 6 months). Winter melons reach maturity only after harvesting during the storage period (IPGRI, 2003).

The early maturity melons are need for Latvia climatic conditions. Winter melons do not reach maturity under Latvia's climatic conditions.

Sugar accumulation is a very important physiological process that determines the quality of the melon fruit. Sugar content is determined with refractometer (Ермаков, 1972). According to the literature, sugar content in melon fruits can reach up to 130–180 g kg^{-1} according to Brix scale (Lester, 2004). Melon fruits start to ripen from the inside and blossom end. A melon that has 110 g kg^{-1} of sugar content can taste twice as sweet as a melon of 100 g kg^{-1} of sugar content. The melons sometimes do not taste all that sweet even when their sugar content makes up 160 g kg^{-1}. The reason for that is that these melons are so packed with flavor components that are often carried in an acidic base that the acid reduces the effective sweetness of the melon (Sugiyama, 1999). Sugar content in melons usually is determined by using Brix refractometer.

The objective of the study was to determine which lines and varieties of melons from those grown in Latvia, have the shortest vegetation period and the highest sugar content.

Materials and Methods

The research was done in Pūre Horticultural Research Centre of Tukums region in 2006. Five lines of Latgale's melons ('8', '14', 'S4(3)', '5(2)', and '4(3)') and five varieties of South Europe melons ('Noir des Carmes', 'Ogen', 'Vedrantais', 'Cantaloup de Bellegarde', and 'Jaune Canaris') were used. Five plants were planted from each line and variety.

The melons were sown on April 22 in pots of 8 cm in diameter, in peat substrate with pH$_{KCl}$ 5.5±0.5, N – 100-140 mg kg^{-1}, P – 48-74 mg kg^{-1}, and K – 158-241 mg kg^{-1}. The seedlings were grown in pots in a high plastic tunnel till May 28. Plants were planted in a high plastic tunnel in peat substrate at 0.8 m distance. During the investigations melons were regularly watered and fertilized with Ca (NO$_3$)$_2$ (1200 g m^{-3} of water) and 'Kemira' 10:10:20 (1750 g m^{-3} of water) every second week.

The earliness of melons was determined by the number of days from flower opening till harvesting. The pollination was done naturally.

The sugar content was determined with Brix handling refractometer 'MASTER'. The Brix refractometer is an optical instrument that

measures the sucrose concentration in a sucrose and water solution as a function of the index of refraction of the solution.

The Brix of a melon juice is equivalent to the total measure of the soluble solids in the juice. The soluble solids mostly consist of sugars (sucrose, fructose, and glucose) and therefore Brix is considered basically as percentage of sugar present in the juice. To refer to Brix, the degrees which are equivalent to percentages are used (Courtney, 1998).

Harvesting was done when melons were easily split of from the fruit petiole. Sugar concentration was determined immediately after harvesting.

The vegetation period of 2006 was warm and the temperature in the high plastic tunnel was high (Figure 1), only the 2nd and 3rd decade of May and 1st decade of June were cooler.

The highest temperature was observed in the 2nd and 3rd decade of June and in the 1st decade of July. As melons were grown in the high plastic tunnel, the air temperature promoted the growth and development of melons. Temperature data were taken from the meteorological station of Pūre Horticultural Research Centre.

Differences between measurements of lines and varieties were evaluated according to ANOVA.

Results and Discussion

In 2006, the climatic conditions were very favorable for melon growth. The melon growth was depressed only at the beginning of the vegetation period.

The sum of effective air temperatures in the high plastic tunnel was 2800 °C. It should be noted that melons require the sum of effective temperatures between 2800–3200 °C (Фурса и др., 1985; Борисова и др., 1984).

All Latgale's melons proved to be earlier than South Europe varieties (Figure 2). The earliest Latgale's melon line was '8' and the earliest South Europe melon was 'Cantaloup de Bellegarde', whereas 'Jaune Canaris' was found to be the latest sort. The first Latgale's melon flowers opened on June 21 and the last ones – on July 18. The first South Europe melon flowers opened on July 8 and the last ones – on July 30. Significant differences between genotypes were stated for earliness parameter $F = 30.10 > F_{crit} = 2.12$ (with $P = 95\%$). The research demonstrated that lines '8', 'S4(3)', and '5(2)' are significantly earlier, but varieties 'Ogen' and 'Jaune Canaris' mature significantly later in comparison with average earliness data.

The sugar content in melon fruits is an important parameter. Consumers prefer sweet fruits. Highest content of sugar was observed in
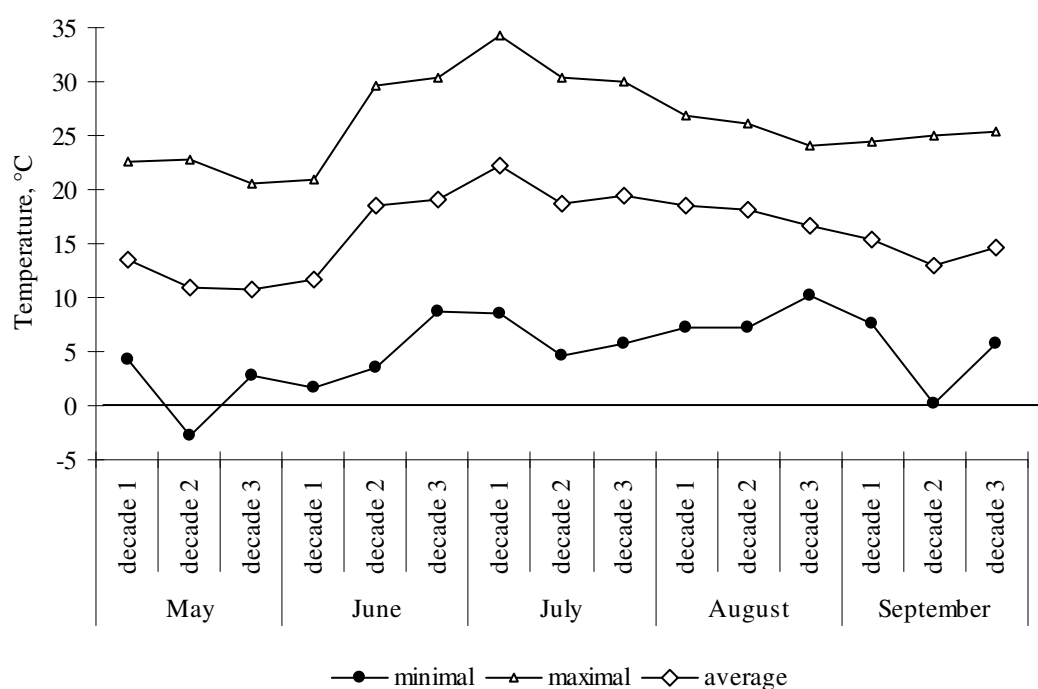
Figure 1. Air temperature data in the plastic tunnel.
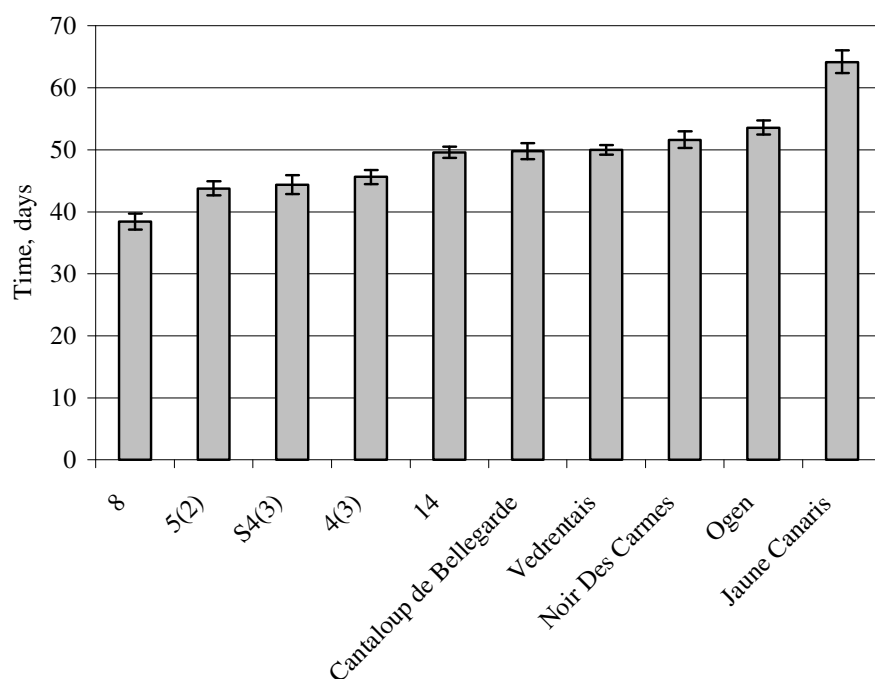
Figure 2. Earliness of melons, days from pollination till harvest.
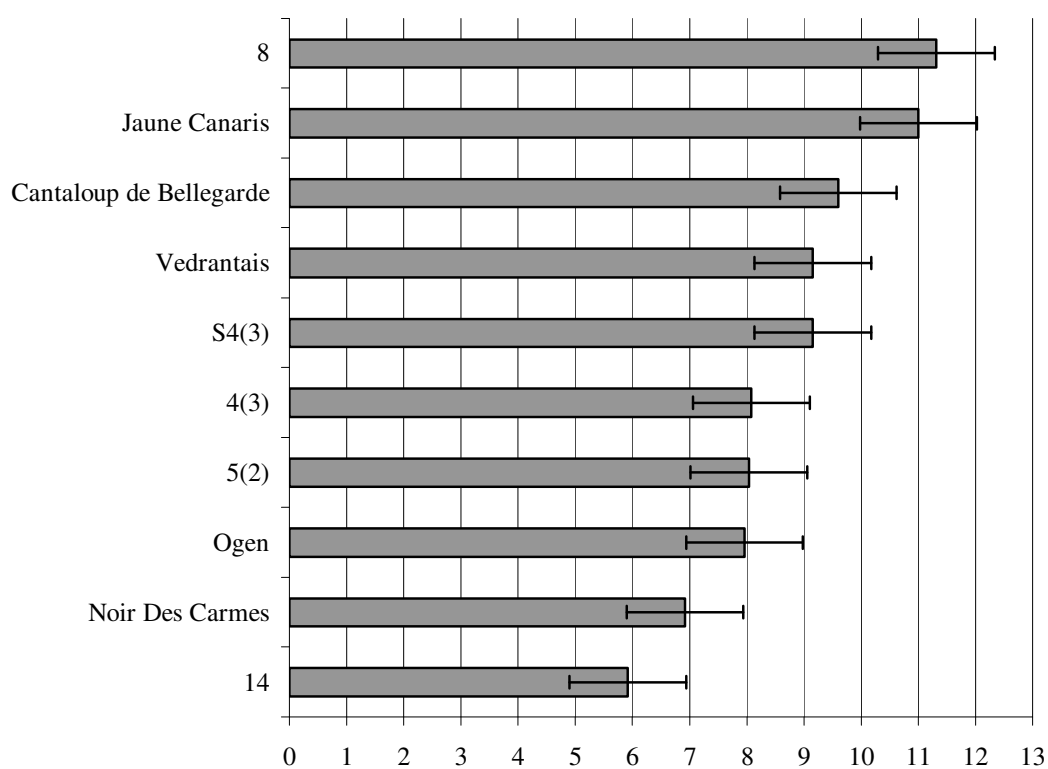
Figure 3. Sugar content in melons (g kg^{-1}).

the Latgale's melon line '8'– 113 g kg^{-1} (Figure 3). Good results were demonstrated by South Europe varieties 'Jaune Canaris' (110 g kg^{-1}) and 'Cantaloup de Bellegarde' (96 g kg^{-1}), however, they tasted not so good as Latgale's melons. A low content of sugar was observed in one of Latgale's melon line – '14' (59 g kg^{-1}) and in varieties 'Noir des Carmes' (69 g kg^{-1}) and 'Ogen' (79 g kg^{-1}).

Significant differences between genotypes were found for sugar content – $F = 5.6999 > F_{crit} = 2.124$ (with $P = 95\%$). As to sugar content, Latgale's melons did not differ much from South Europe varieties: both sorts had melons with a high ('8' and 'Jaune Canaris') and low ('14' and 'Noir des Carmes') sugar content.

No correlation was found between earliness and sugar content in melons ($r = 0.0197$). The melon line '8' with highest sugar content had the shortest maturing period, but the sweetest South Europe variety 'Jaune Canaris' had the largest maturity period. According to the literature, fruits which reach maturity the latest, should be the sweetest (Ермаков, 1972)

The research suggests that melon growing in Latvia in high plastic tunnels can be successful, which probably is one of the reasons why melons in Latvia are mostly grown in family gardens.

Conclusions

1. All Latgale's melon lines were earlier than South Europe varieties and significant differences on average were found between some lines ('8', 'S4(3)', and '5(2)') and varieties ('Ogen' and 'Jaune Canaris').
2. The line '8' and varieties 'Jaune Canaris' and 'Cantaloupe de Bellegarde' showed the highest sugar content (accordingly 113, 110, and 96 g kg^{-1}).

References

1. Courtney A. (1998) Which beverage contains the most sugar? Available at: http://www.selah.k12.wa.us/MS/SciProj98/6TH/Sugar/COURTNEYA.HTML, 16.03.2007.
2. IPGRI (2003) Descriptors for melon *Cucumis melo* L. International Plant Genetic Resources Institute, Rome, 77 p.
3. Lester G.E. (2004) Foliar applied potassium: effects on cantaloupe quality, sugar content and related compounds. International Congress on Plant Nutrition Proceedings, Australia, pp. 49-57.
4. Sugiyama J. (1999) Visualization of Sugar Content in the Flesh of a Melon by Near-Infrared Imaging. Journal of Agriculture Food Chemistry, 7, pp. 2715-2718.
5. Борисова Р.Л., Огінська А.А., Осипова Т.О., Нэмтинов В.I. (1984) Вирощування динь і кавунів у плівкових теплицях в Криму (Melon's and watermelon's growth in greenhouses at Crimea). Овочівництво і баштанництво, 29, с. 25-28. (in Byelorussian).
6. Ермаков А.И. (1972) Методы биохимического исследования растений (Biochemical methods at plant investigation) Колос, Ленинград, 456 с. (in Russian).
7. Фурса Т.Б., Малинина М.И., Артюгина И.Д. (1985) Руководство по апробации бахчевых культур (Handbook for aprobation of squash culture) Агропромиздат, Москва, 181 с. (in Russian).

VARIABILITY OF WILD MARTAGONLILY (*LILIUM MARTAGON* L.) IN THE REGION OF KURZEME

Antra Balode
Latvia University of Agriculture
E-mail: Antra@ram.lv

Abstract

The aim of this research is to evaluate the variability of the martagonlily (*Lilium martagon* L.) found in the wild in the west of Latvia. Latvia is situated in a nature zone between the vegetation of Northern and Central Europe. The country distinguishes itself with a large variety of flora and fauna (total approx. 27,7 thousand species). The genus *Lilium* L. includes approximately a hundred species, subspecies and varieties of species. In northern Europe, one of the best known and longest cultivated of lilies is *L. martagon* L. It is distributed across the largest growing area of most species – from western Portugal throughout Europe and Asia. To evaluate the survival potential of *L. martagon* L. in Latvia, research was carried out in locations at Kurzeme – districts of Ventspils, Kuldiga, and Tukums. The results indicate that the diversity in genotypes varies according to location and distribution. There are differences in phenotypes and color variability from pale to bright violet-pink. Diameter of flower varies between of 3.5 to 6.0 cm. The height of these plants varies up to 114 – 130 cm. The flowering time is in June and July. Wild martagonlily found in these regions is growing in calcareous soils among shrubs in river valleys and semi-shaded deciduous forests. This particular martagonlily is hardy and disease resistant and is recommended as a donor in breeding programs.

Keywords: *Lilium martagon* L., phenological observations, variability, wild species.

Introduction

The genus *Lilium* Linnaeus (L.) belongs to the family *Liliaceae*, which comprises about 200 genera and approximately 2 thousand species. In Latvia there are 22 species of the *Liliaceae* in the wild. The genus *Lilium* L. includes approximately 100 species, subspecies and varieties of species distributed throughout the cold and temperate parts of the northern hemisphere (Beattie and White, 1993). If any species is more important than any other, then *L. martagon* L. may for several reasons be considered the most important. Its range over the two continents is greater than that of any other lily: its spread by naturalizing is extensive; its time under cultivation spans for maybe thousands of years. The species grows naturally up to about 2300 m altitude, in beech forests and wood edges, and always in well-drained but well-watered soils. It can be very variable in morphological characters like color of flowers, the number of flowers per stem, the intensity of spotting on the tepals, and the pubescence of flower buds, also within a single population (Feldmaier and McRae, 1982).

L. martagon L. comprises both native and domesticated populations. It has been discovered that the first *L. martagon* L. of the north blossomed in Bergen, Norway, in 1597, and was introduced to Sweden in 1795 (Lundquist, 2005). Many of the Scandinavian populations are restricted in size and geographically isolated from one another. The largest population in Sweden (at the estate of Ulfåsa) and perhaps in Scandinavia, has however more than 25 thousand individuals (Persson, 2001). It is mentioned that *L.martagon* L. had probably been first brought to England as a garden plant in 1550 – 1565. It has been introduced to North Germany and to Britain simply as an ornamental plant: to Britain after 1548 but shortly before 1568 (Lundquist, 2005). *L. martagon* L. in Latvia was discovered in 1839 (Andrušaitis, 1985), and is the only wild *Lilium* species found in the country.

Compared to other species, *L. martagon* L. has smaller pinkish flowers, but it makes up for the flower size by putting up strong stems with up to 3 to 13 flowers (50 in cultivation). The flower color variation is considerable: in lowland populations - pale or greyish pink, and on higher elevations - dark or muddy pink. The brownish violet spotting is also quite variable. The stem is erect, up to 60 – 120 centimeters tall, up to 180 centimeters in cultivation. There are pendent turk-cap-shaped flowers on a stem (McRae, 1998).

The species of the genus *Lilium* L. is classified and the most authoritative is the classification of Harold F.Comber. In 1949, a revised subclassification of the genus *Lilium* L. was published. Comber considers physical features such as flowers, seeds, the type of

germination, arrangement of the leaves, and the form and growth habit of the bulb. He also gives importance to geographical distribution and to the evolutionary relationships of species and groups. This resulted in seven part categorization. The martagon section comprises such species: *L. martagon* L., *L. distichum* Nakai, L. hansonii Leichtlin, *L. medeoloides* A.Gray, and *L. tsingtauense* Gilg (McRae, 1998). Despite the great variation in form and disposition of the flower there can be no doubt that the species are very closely related. Whorled leaves and hypogeal seed germination indicate this relationship.

In the wild, martagons have the ability to survive for years by being tucked under trees and using bulbs, rhizome, stolon or some other device to protect food reserves. It is a selfincompatible diploid, $2n = 24$, which propagates predominantly by seed-set and only very rarely by bulbils (Lundquist, 1991). It takes 7 – 8 years to flower from seed. *L. martagon* L. is insect-pollinated and at the end of the summer many light-weight seeds are produced and dispersed by wind. The flowers have an unpleasant sweetly fragrant odour – especially at night to attract the night hawk-moth for pollination. The whorled leaves give the plant the ability to secure most of the available light most efficiently; therefore, this situation suits *L. martagon* L. admirably.

The literature gives the following countries where *L. martagon* L. may be found: Portugal, Spain, France and Corsica, Switzerland, Germany, Austria, Italy, Czech, Hungary, Albania, Greece, Poland, Romania, Bulgaria, Turkey, Britain, Belgium, Holland, Denmark, Norway, Sweden, Finland, Russia – Central, South-western and South-eastern regions, and the Baltics. It is mentioned that in the Baltic countries its most northerly site is in Latvia (Fox, 1987; Andrušaitis, 1985). There are conflicting views that the northern latitude is in Estonia (Lundquist, 2005). *L. martagon* L. is found in Lithuania near Vilnius and Trakai in the forest as well as the area of Kedainiai, Ramygala. *L.martagon* L. is an endangered species in Poland (Lundquist, 2005). In the East of the Urals in Asia the lily stretches to 124°E on the Rivers Vilyui and Lena. Its most northerly station in Siberia is 68°40′N on the lower reaches of the River Yenisei. On the south, it is found in northern parts of Mongolia, in the Caucasus, and in the western area of northern Turkey in Asia (Fox, 1987). Over all this vast range it is never far from woodlands. Baranova says the martagonlily is thriving within forest glades, on the edge of the forest and among bushes on herb–covered meadows (Баранова, 1990). It is found that *L. martagon* L. is more polymorphic plant in the wild comprised with other lily species (McRae, 1998). Despite strict protection, the population of *L. martagon* L. has decreased over recent decades under the impact of human activity (Kedra and Bach, 2005). The Red Data Book has currently a certain role in the protection of endangered species. This is one way to act in order to safeguard the future of endangered species. *L. martagon* L. is included in the Red Data Book of Estonia, and habitats are found in deciduous forests, parks, gardens, and courtyards. Causes of the threat factor are: picking, collecting, replanting and forestry activities (Red Data Book of Estonia, 1998). *L. martagon* L. was included in the Red Data Book of Latvia in its previous issue (Andrušaitis, 1985), but not in the recent issue (Andrušaitis, 2003).

Ranging over vast area, *L.martagon* L. includes several distinct taxa. Variety *albiflorum* Vukutinovi frequent in the wild has white flowers spotted in carmine pink. Variety *album* Weston has pure white flowers. Variety *cattaniae* Visiani (synonym var. *dalmaticum*) comes from Dalmatia. It is extraordinarily stately with deep wine-colored unspotted flowers in a large inflorescence. Variety *caucasicum* Mischenko is found around the northeastern coast of the Black Sea in Abkhazia, and in Transcaucasia. The flowers are widely opened in a short, broad trumpet form, rose-lilac in color. Variety *daugava* Malta (synonym var. *koknese* Malta) has been described from botanist Malta in 1934, where it occurs on the dolomite hills near the mouth of the River Daugava. It is mentioned that it is distinctive by its height (up to 200 centimeters) and by short hair on the stem. The leaves are also wider, up to 5 centimeters. The 3 to 10 flowers have strongly reflexed tepals of pale purple - red with dark spots and red hair on the tepals (Fox, 1987; McRae, 1998).

The goal of this research is to estimate wild martagon (*L. martagon* L.) populations in locations of west Latvia – Kurzeme in the regions of Ventspils, Kuldiga, and Tukums.

Materials and Methods

During the growing seasons of 2001, 2003, and 2006, in locations of natural growth areas the following phenological observations were made: the flowering time (date), stem length (cm), flower number per stem, flower diameter and length (cm), shape and color of flower, as well leaves length and bright (cm), and number of leaves
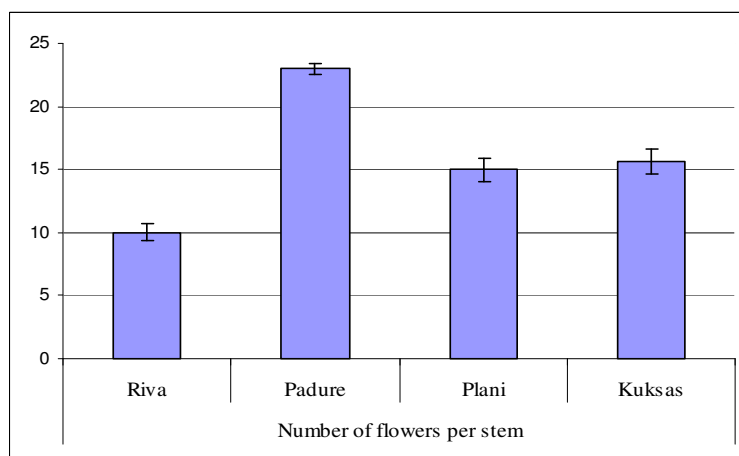
Figure 1. The average number of flowers per stem from different habitats.

in basal whorl. The 10 bulbs of each habitats were estimated and the average was calculated. The initial dates of natural growth areas of martagonlilies in Latvia were obtained at the Institute of Biology of the Latvia University. To evaluate the survival of *L. martagon* L. habitats of this, the only wild-growing lily species in Latvia, the regions of Kuldiga, Tukums and Ventspils, were inspected and phenological observations were carried out.

Results and Discussion

During the three-year research, reliable habitats have been found in various regions, including Kuldiga, Tukums, and Ventspils. If a population is confined to the vicinity of a village, the habitat is questionable. It may have originated from domestic species. The habitats in Padure (in the region of Kuldiga), Plani and Kuksas (in the region of Tukums) would probably be situated in areas of old parks. Their soils are generally clayey. The martagonlily grows on grasslands and among shrubs, but cannot be found in deep forests because sunshine is necessary for its growth. The environment of the habitat differs regionally.

In Padure, near the old palace park, the most dense colony of the martagonlily can be found in the grassland containing *Aegopodium podagraria* L., *Galium mollugo* L., *Campanula patula* L.,
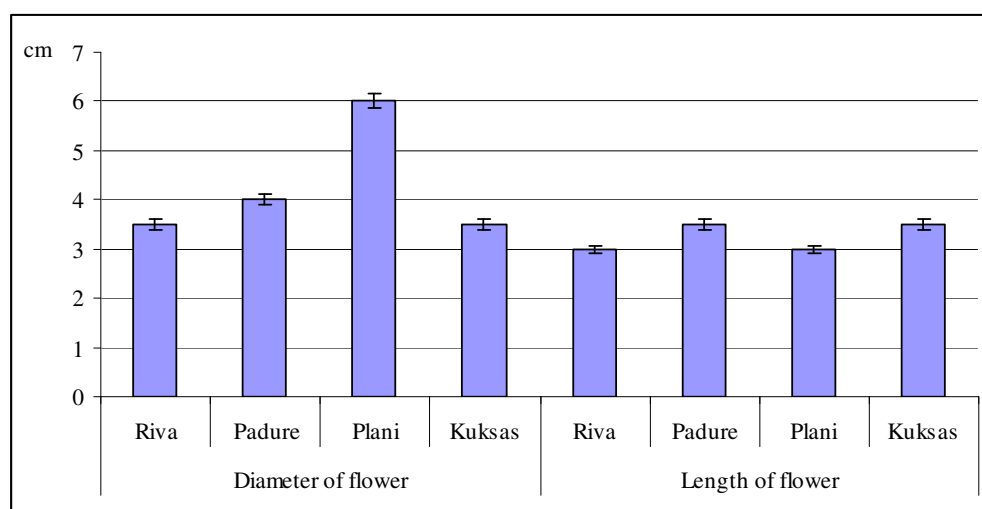
Figure 2. The average diameter of flower and length from different habitats.
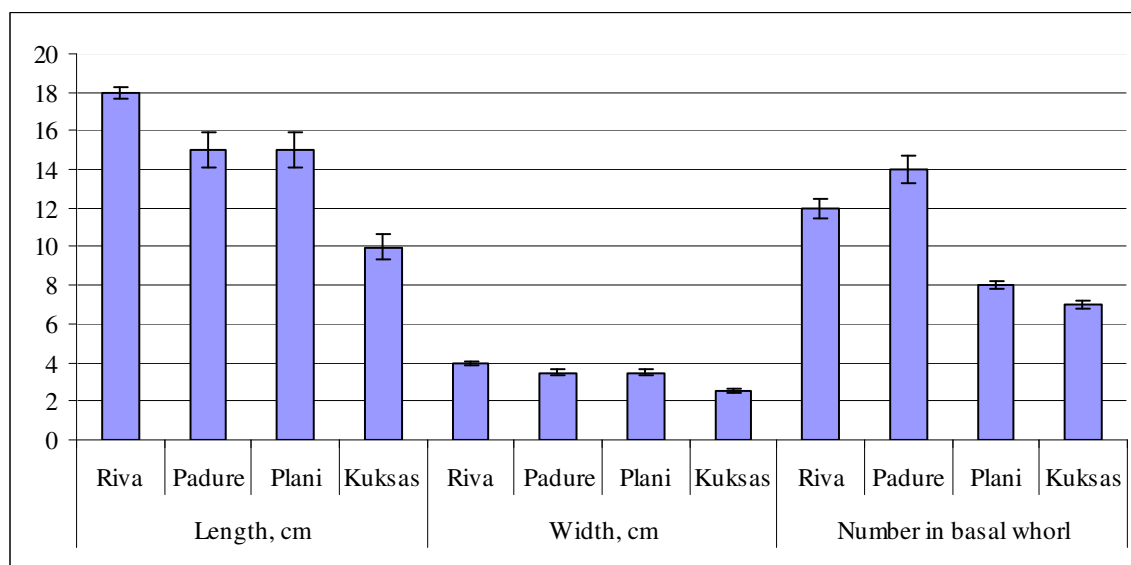
Figure 3. The average length and width of leaves and number in basal whorl from different habitats.

Chaerophyllum aromaticum L., *Convallaria majalis* L., *Dactylis glomerata* L., *Hepatica nobilis* Mill., *Polygonatum multiflorum* (L.) All., *Urtica dioica* L. and others. Probably, when the martagon seeds fell they were in an ideal mixture to ensure germination and growth. That was why there were so many of them.

In Plani and Kuksas the habitat is found in grassland in the vicinity of a manor–house: *Aegopodium podagraria* L., *Dactylis glomerata* L., *Vicia sepium* L. and others, surrounded by the

shrubs and trees – *Acer platanoides* L., *Quercus robur* L., *Tilia cordata* Mill., *Corylus avellana L.,* and *Alnus glutinosa* (L.) Gaertn.

In Riva, there are shrubs and a deciduous forest in the valley of the small River Riva – the habitat of: *Ulmus laevis* Pall. and *Aegopodium podagraria* L., *Gagea lutea* L., *Dryopteris filix-mas* (L.) Schott, *Pteridium aquilinium* (L.) Kuhn., and *Urtica dioica* L. The nature in this habitat is untouched by man.

In regions of Kuldiga, Tukums, and Ventspils,
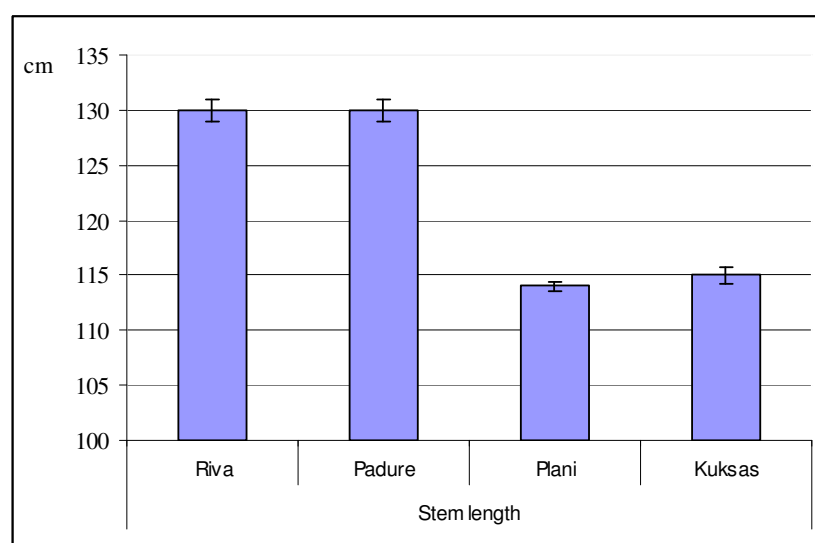
Figure 4. The average stem length from different habitats.

Table 1

Comparison of characteristics of *Lilium martagon* L. from different habitats

Habitats Characteristics	Region			
	Ventspils	Kuldīga	Tukums	
	Rīva	Padure	Plāņi	Kukšas
Flowers:				
Color	Bright violet-pink	vary from brighter to paler violet-pink	bright violet-pink	medium violet-pink
Spotting	Strong violet-red	strong reddish-brown	strong violet-red	small reddish-brown
Pollen	Orange-brown	light-orange	orange	bright orange-brown
Scent	Fragrant	fragrant	fragrant	fragrant
Diameter, cm	3.5	4.0	3.5	6.0
Length, cm	3.0	3.5	3.0	3.5
Shape	Turk-cap-shaped	turk-cap-shaped	turk-cap-shaped	turk-cap-shaped
Direction	Pendulous	sub-pendulous	pendulous	pendulous
Number per plant	10	23	15	16
Time of flowering	19.06.	22.06.	21.06.	21.06.
Leaves:				
Color	Medium green	dark green	medium green	light green
Length, cm	18.0	15.0	15.0	10.0
Width, cm	4.0	3.5	3.5	2.5
Number in basal whorl	12	14	8	7
Shape	Elliptic	oblong-ovate	elliptic-ovate	lanceolate
Stem:				
Length, cm	130.0	130.0	114.0	115.0
Shade	Light green	purplish brown	light brown	light green
Bulb:				
Whole shape	Globose	elongate-ovate	elongate-ovate	elongate-ovate
Shape of scale	Narrow-lanceolate	lanceolate-ovate	lanceolate-ovate	narrow-lanceolate
Color	Yellow	yellow	yellow	yellow
Deepness, cm	20	20	15	10
Habitat:				
Characteristics of habitat	Deciduous woods, scrub, in shade, clayey soil	scrub, meadow clayey soil	scrub, meadow, clayey soil	scrub, in shade, clayey soil
Number of speciment	250	1000	250	180

the direction of flowering is down–facing. The shape of perianth segments varies between lanceolate and elliptic, but the differences are not apparent. The perianth segments vary in degree of reflexing, and, very rarely, do not reflex at all. In the size of the flowers, considerable variation is recognized. The flowers of the plants from Kuksas and Padure are larger than those from Plani and Riva. The perianth segments vary in intensity of pinkish. The perianth segments are characterized by a distinct ground color and by spotting. The intensity of the ground color varies continuously

from pale pink to dark pink. There are many distinctive types of coloring, characterized by the position and extent of coloring and the extent of fading toward the margin of the colored parts and presence or absence of spotting. There are also recognized intermediate types of coloring. It has been observed that several clones are so heavily spotted that the spots are on the verge of forming dark blotches. The color of pollen is usually orange-brown and orange.

Significant differences between the martagonlily in Padure habitat and those found on other sites (Kuksas, Plani, and Riva) were also observed. Martagonlily in Padure habitat varies significantly in flower diameter and color, and also by plant height. In Padure location, generally the flower color is more intensely pink and with stronger spotting than at any other site in Latvia. The appearance of the spots is variable. In Kuksas there were found the most heavily spotted clone and a clone with few spots. The inflorescence form of *L. martagon* L. is typical in the raceme. The most flowers and buds that have been observed on a wild plant are 23 on a stem (Fig. 1). The diameter of flower varies from 3.5 to 6.0 cm, but the length ranges from 3.0 to 3.5 cm (Fig. 2).

The leaves of *L. martagon* L. are formed in whorls ranging from 3 to 4 in each whorl with 7 to 14 leaves. The width of the individual leaf varies from 2.5 to 4 cm. The wider leaves were found in a habitat in Riva (Fig. 3). A color variation was found from a pale violet-pink to a bright violet-pink. Flowering stems range in height from 114 to 130 cm (Fig. 4). This factor seems to depend upon the habitat. In an open, sunny location, the stems are fairly consistent up to 120 – 130 cm in height. The stems were green with definite red mottle at 10 cm near the base. Some specimens had noticeable fine, white pile or hair like fuzz on the stems and some even had the white pile on the leaves. The extremes in height seem to appear in more protected and somewhat shaded locations or where they must compete with vigorous vegetation. The bulb of *L. martagon* L. is concentric and the axis retains the same shape and position each year. The bulbs were found with rudimentary 2 cm stem roots above the bulb. Significant fleshy basal roots were observed. The

bulbs were located about 10 – 20 cm below surface and appeared rooted in clay-like substrata. The scales are small and fragilely attached to the basal plate of the bulb. The color of the scales is yellow.

Table 1 is a summary of characteristics of the plants from different regions. The shade of a stem, pollen color, the spotting of a flower, the feature of the tip of the leaves, and the impression along the veins of leaves are the most distinguishable characteristics. In these respects the plants from Tukums, as well as those from Plani and Kuksas show characteristics that can be easily distinguished.

Conclusions

This study of *L. martagon* L. has been made over the last years and has included plants growing in the wild in three regions of Kurzeme. These observations indicate that *L. martagon* L. is an extremely variable species yet withal these variations it still retains characteristics that distinguish it from other lily species.

It is found that Latvian wild martagonlily varies by genotype in diverse locations of its distribution.

The individuals of each biotope were characterized by stable inherited traits: color, shape and flower diameter, stem length, and bulb color. The color of the *L. martagon* L. flower is basically consistent with some variation. There is variation in the amount of each color in the tepals as well as intensity of color. Spotting is extremely variable, ranging from few small spots in the center to spotting that covers the entire flower to the tips of the tepal. Variability in some morphological traits could be explained with interaction between genotype and the environment.

In our observation it has been found that martagonlily grows mostly in semi-shade (light woodland) and in the calcareous soils – preferably with roots in the shade. Bulbs are growing at about 10 to 20 cm under the ground – important climatic advantage. It is in flower from middle of June to middle of July and seeds ripen from August to September. The scented flowers are hermaphrodite and are pollinated by moths and butterflies.

References

1. Andrušaitis G. (red.) (1985) Latvijas PSR Sarkanā grāmata. Retās un iznīkstošās dzīvnieku un augu sugas (Red Data Book of the Latvian SSR. Rare and endangered species and animals and plants). Zinātne, Rīga, 525 p. (in Latvian).
2. Andrušaitis G. (red.) (2003) Latvijas Sarkanā grāmata. Retās un apdraudētās augu un dzīvnieku

sugas (Red Data Book of Latvia. Rare and endangered species and animals and plants). Vaskulārie augi, 3.sēj., LU Bioloģijas institūts, Rīga, 700 p. (in Latvian).

3. Beattie D.J., White J.W. (1993) Lilium – hybrids and species. In: De Hertogh A.A. and Le Nard M. (eds.) The physiology of flower bulbs, Elsevier Science Publisher, B.V., Netherlands, pp. 423-454.

4. Feldmaier C., McRae J. (1982) Lilies. Eugen Ulmer, Stuttgart, 246 p.

5. Fox D. (1987) Growing Lilies. Ch. Helm, London, 264 p.

6. Lundquist K. (1991) Four-locus S-gene control of self-incompatibility made probable in Lilium martagon (Liliaceae). Hereditas, 114, pp. 57-63.

7. Lundquist K. (2005) Lilium martagon L. Doctoral dissertation, Swedish University of Agricultural Sciences, Alnarp, Acta Universitatis Agriculturae Sueciae, 19, pp. 292-294.

8. Kedra M., Bach A. (2005) Morphogenesis of Lilium martagon L. Explants in Callus Culture. Acta Biologica Crasoviensia. Series Botanica, 47/1, pp. 65-73.

9. McRae E.A. (1998) Lilies. Timber Press, Portland, Oregon, 392 p.

10. Persson H. (2001) Estimating Genetic Variability in Horticultural Crop Species at Different Stages of Domestication. Doctoral thesis, Swedish University of Agricultural Sciences, Alnarp, Agraria, 290, pp. 33.

11. Eesti Punane Raamat. Ohustatud seened, taimed ja loomad (Red Data Book of Estonia. Threatened Fungi, Plants and Animals) (1998) The Commission for Nature Conservation of the Estonian Academy of Sciences, Tartu, 150 p. http://www.zbi.ee/punane/english/index.html Web version.

12. Баранова М.В. (1990) Лилии (Lilies). Ленинград, Агропромиздат, 383 с. (in Russian).

THE INFLUENCE OF ORGANIC ACIDS AND PHYTOGENIC ADDITIVE ON PIGS PERFORMANCE

Imants Jansons, Jānis Nudiens
Latvia University of Agriculture
E-mail sigra@lis.lv

Abstract

A study was conducted to determine efficiency of an organic acids and phytogenic additives on pigs' growth processes and digestive tract microflora. The feed of the control group (C) did not contain the additives. The feed of the organic acid group (A) contained 6 kg of organic acids additive per tonne feed for pigs after weaning, 4 kg per tonne feed for grower pigs, and 3 kg per tonne feed for finished pigs. The feed of the phytogenic additive group (F) contained 0.5% of phytogenic additive per tonne feed for pigs after weaning, and 0.2% per tonne feed for grower and finished pigs. The feed of organic acids plus phytogenic additives group (A+F) contained 6 kg of organic acids additive per tonne feed for pigs after weaning, 4 kg per tonne feed for grower pigs, and 3 kg per tonne feed for finished pigs 0.5% of phytogenic additive per tonne feed for pigs after weaning, and 0.2% per tonne feed for grower and finished pigs. Compared to groups pigs from the group (F) had by 9.7%, group (A+F) - by 8.3 % and from group (A) had by 3.2% higher mass. The bests results of feed conversion were found in the group (A+F) - 2.84 kg, which was by 8.5% less than in the group (C), whereas the group (F) had by 5.1% and group (A) - by 6.7% better results than the control group. The results of Duodenum and Rectum microflora analyses showed that use of organic acid and phytogenic additives reduced Mould Yeast *Staphylococcus sp.* colony formed units (CFU g^{-1}).

Keywords: pigs, organic acids phytogenic additive.

Introduction

Diarrhoea is a common problem in animal production, affecting mostly the young growing animal. High average frequency (6-7%) of all litters born are affected with pre-weaning diarrhoea. Further the risk for developing post-weaning diarrhoea increased if the piglets had gastrointestinal disorders during the suckling period (Svensmark et al., 1989).

Organic acids and some of their salts are added into starter feeds and fattening feeds for piglets in order to improve the performance and stabilize the general health of the animals (Hyden, 1995).

Microbial activity in raw materials and feeds can be eliminated by the use of antimicrobial substances, which either inhibit the growth of the organism (bacteriostatic or fungistatic action) or kill it (bacteriocidal or fungicidal action). Growth of an organism is a consequence of several processes. Inhibition of one or more of those processes results in growth inhibition and possibly kills the animal.

The survival and growth of microorganisms are governed by many parameters, such as temperature, moisture, nutrient availability, and pH. In most cases, enteropathogens have a low tolerance to low (acid) pH whilst commensal microflora tends to prefer a more acid environment. Within the framework of using organic acids, pH is an important criteria. Each microorganism has its own response to acidity: minimum, maximum, and optimal pH level for growth. Altering the ion concentration influences the growth or inhibition of an organism. Bacteria are generally more fastidious and prefer a nearly neutral pH (6.5-7.5), but can tolerate a pH range of 4-9. Yeasts tolerate lower pH values than bacteria. Moulds are to the widest pH range (Axford et al., 2000).

The major disease causing bacteria in animal production are the Gram negative enteric bacteria. These species will colonise the gut and result in either subclinical infections which lower performance or cause clinical scours and enteritis problems that can, in severe cases, lead to death. In case of salmonellae, these organisms can relocate through the mucouse membranes of the gut wall and enter the blood stream. Once in the blood, these organisms can colonise various organs such as liver, spleen, ovary, etc. (Malmquist et al., 1995).

Lactic acid, fumaric acid, propionic acid, citric acid, and their salts have been shown to improve growth rate and feed efficiency in pigs (Peris and Asensio, 2002). Other benefits associated with acidification include improvements in digestive enzyme activity, microbial phytase activity, and increased pancreatic secretion (Dibner, 2004).

The use of herbs as additives in livestock nutrition as an alternative to antibiotics is becoming a new goal in animal production. Natural herbs are being explored as alternatives to antimicrobials (Couladis et al., 2004). In addition to the specific properties of each essential oil (antispasmodic, analgesic, tissue healing, cicatrizing, tonic, relaxing, digestive, hormonal, etc.), they may stimulate the immune defence system (Alexander, 2001).

The mode of action of essential oils is similar to that of antibiotics, but they also act by different mechanisms. In fact, essential oils influence the ecological environment (Langenheim, 1994), preventing survival of microorganisms and reinforcing the patient's terrain. Furthermore, they regulate imbalance in the intestinal flora. Some essential oils may also be useful to treat methicillin-resistant *Staphylococcus aureus.* (Panizzi et al., 1993).

Essential oils are known for their antibacterial activity (Boatto et al., 1994), but they also possess antiviral and antifungal properties, that antibiotics do not have (Arnal-Schnebelena et al., 2004).

Research demonstrates that specific combinations of organic acids plus essential oils of plants can be effective in improving animals performance: weight gain, feed consumption, and feed conversion rates by 10 %, 8% and 2% respectively (Peris et al., 2002).

The aim of the research was to detect organic acids and phytogenic additives projection on pigs' growth intensity and digestive tract microflora.

Materials and Methods

The studies were carried in 2005 year on the pig breeding farm 'Pakalni' of Kraslava region, and in the Biochemistry laboratory of the Research Institute of Biotechnology and Veterinary Medicine 'Sigra'. With the aim to carry out the studies, four groups of pigs were formed. The control group (C) was not given the additives. The feed of the organic acid group (A) contained 6 kg of organic acids additive per tonne feed for pigs after weaning, 4 kg per tonne feed for grower pigs, and 3 kg per tonne feed for finished pigs. The feed of the phytogenic additive group (F) contained 0.5% of phytogenic additive per tonne feed for pigs after weaning, and 0.2% per tonne feed for grower and finished pigs. The feed of organic acids plus phytogenic additives group (A+F) contained 6 kg of organic acids additive per tonne feed for pigs after weaning, 4 kg per tonne feed for

grower pigs, 3 kg per tonne feed for finished pigs 0.5% of phytogenic additive per tonne feed for pigs after weaning, and 0.2% per tonne feed for grower and finished pigs. Organic acids additive contains formic acid, acetic acid, citric acid, phosphoric acid, and calcium. Phytogenic additive includes *Urtica dioica* L. leaves, Q*uercus robur* cortex grinded, *Melissa officinalis* L. leaves, and *Thymus vulgaris* L. leaves. Investigation was made with 60 pigs from 42 days of age till slaughtering at the age of 170 days. Pig mass was detected on the 42th day, 78th day, 114th day after birth, and before slaughtering on 170th day. During the feeding experiment, consumed feed and feed conversion were analysed. Gastric, small intestine and rectum substances were taken for microbial tests after slaughtering. Microbial tests were made by standard methods with differential broths, for Mould, Yeast - Sabour and Dextrose Agar, for *Escherichia coli* - Mac Coney Agar, for Mesophylic aerobic and facultative anaerobic, and Thermophylic aerobic and facultative anaerobic forms – Difco Nutrient Agar, for Lactic acid bacteria – Malt broth.

The data were processed with F – test, MS Excel program.

Results and Discussion

At the beginning of the investigations, when the piglets' start mass was compared, the indices of mass did not show any essential difference ($p > 0.05$) between the groups. At the age of 170 days, pigs mass in the group (C) was 101.79 ± 0.81 kg, in the group (A) - 105.09 kg, in the group (F) - 111.67 ± 1.22 kg, but in the group (A+F) - 110.08 kg on average, which demonstrated that pigs from the group (F) had by 9.7%, from group (A+F) - by 8.3% and group (A) - by 3.2% higher mass than group (C) pigs. An essential difference between groups was found in the group (C) and group (F), and in the group (C) and group (A) ($p < 0.05$).

The daily gain indices (Table 1) for pigs at 42 to 78 days for the group (F) was by 34%, for the group (A) - by 10.1%, and for the group (A+F) - by 15.9% higher than for pigs in the control group. Daily gain indices for pigs at 78 to 114 days for the group (F) was by 11.5%, for the group (A) - by 5.14%, and for the group (A+F) - by 10.9% higher than for pigs in the control group. Daily gain indices for the group (F) pigs was by 4.0%, for the group (A) - by 5.3%, and for the group (A+F) - by 8.2% higher than for pigs in the control group. Daily gain indices for pigs 42 to 170 days for the group (F) was by 12.0%, for the group (A) - by 6.2%, and for the group (A+F) - by 10.5% higher

Table 1

Additives projection on pigs' daily gain dynamics

Traits	Control group (C)	Organic acids additive group (A)	Phytogenic additive group (F)	Organic acids + phytogenic additive group (A+F)
	$n = 15$	$n = 15$	$n = 15$	$n = 15$
	$\bar{x} \pm s_{\bar{x}}$	$\bar{x} \pm s_{\bar{x}}$	$\bar{x} \pm s_{\bar{x}}$	$\bar{x} \pm s_{\bar{x}}$
Daily gain, 42nd-78th day, kg	0.490± 0.018	0.540±0.034	0.657±0.024	0.568±0.029
Daily gain, 78th-114th day, kg	0.673±0.023	0.708±0.025	0.751±0.022	0.747±0.023
Daily gain, 114th-170th day, kg	0.869±0.021	0.915±0.034	0.904±0.017	0.904±0.018
Daily gain, 42nd-170th day, kg	0.694±0.009	0.737±0.011	0.777±0.009	0.767±0.010

than for pigs in the control group.

The best results (Table 2) of feed conversion were found in the group (A+F) 2.848 kg of feed ration were necessary to obtain 1 kg of body mass it was by 8.5% less what in the group (C), the group (F) was by 5.1% and for the group (A) was by 6.7% best results compared to the control group. The results of Duodenum microflora analyses (Table 3) showed that use of organic acid and phytogenic additives reduced Mould colony formed units – CFU g^{-1}. In the control group (C), CFU g^{-1} amount was 5000, but in the group (F) - 25%, in the group (A) - 28%, and in the group (A+F) - 50.6% less. Yeast CFU g^{-1} amount in the control group was 4500 CFU g^{-1} in the group (F) was 33.4 %, in the group (A) - 24.7% and in the group (A+F) - 42.3% less than in the group (C). Staphylococcus species in the control group was 17500 CFU, but in the group (F) - 42.9%, in the group (A) - 41.8%,

and in the group (A+F) - 52% less compared to the group (C). *Escherichia coli* mesophylic forms CFU g^{-1} in the group (F) decreased by 16.2%, in the group (A) - by 16.8% and in the group (A+F) - by 42.4% compared to the group (C). *Escherichia coli* termophylic forms in the group (F) were by 6.2 %, in the group (A) - by 22.7%, and in the group (A+F) - by 30.2% less than in the group (C). Lactic acid bacteria CFU g^{-1} amount in the group (F) increased by 150.4 %, in the group (A) – by 83.2%, and in the group (A+F) - by 198.8% compared to the group (C). The results of Rectum microflora analyses (Table 4) showed that use of organic acid and phytogenic additives reduced Mould colony formed units – CFU g^{-1}. In the control group (C), CFU g^{-1} amount was 4750, but in the group (F) - 31.6%, in the group (A) - 28.4%, and in the group (A+F) - 32.6% less. Yeast CFU g^{-1} amount in the control group was 6600, and in the group (F) - 62.1%, in the group

Table 2

Organic acids and phytogenic additives projection on pigs' feed consumption and conversion

Traits	Control group (C)	Organic acids additive group (A)	Phytogenic additive group (F)	Organic acids + phytogenic additive group (A+F)
	$n = 15$	$n = 15$	$n = 15$	$n = 15$
Feed consumption, kg	276.5	274.0	291.4	279.5
Feed conversion, kg	3.11	2.91	2.93	2.84
Feed conversion, % to control	100	93.31	94.09	91.49

Table 3

The results of pigs' Duodenum microflora analyses

Traits	Control group (C)	Organic acids additive group (A)	Phytogenic additive group (F)	Organic acids + phytogenic additive group (A+F)
Total mesophylic aerobic and facultative anaerobic microorganisms (CFU g^{-1})	505000	42980	865000	133440
Total thermophylic aerobic and facultative anaerobic microorganisms (CFU g^{-1})	15410000	10210000	997500	7060000
Lactic acid bacteria (CFU g^{-1})	138500	253800	346750	413800
Mould (CFU g^{-1})	5000	3600	3750	2470
Yeast (CFU g^{-1})	4500	3390	3000	2600
Escherichia coli mesophylic forms (CFU g^{-1})	740000	426000	620000	616000
Escherichia coli termophylic forms (CFU g^{-1})	805000	622000	755000	562000
Coliforms mesophylic (CFU g^{-1})	215000	93000	5000	102000
Coliforms thermophylic (CFU g^{-1})	155000	132000	55000	54000
Staphylococcus sp. (CFU g^{-1})	17500	10200	10000	8400

Table 4

The results of pigs' Rectum microflora analyses

Traits	Control group (C)	Organic acids additive group (A)	Phytogenic additive group (F)	Organic acids + phytogenic additive group (A+F)
Total mesophylic aerobic and facultative anaerobic microorganisms (CFU g^{-1})	2712500	1422000	1237500	1338000
Total thermophylic aerobic and facultative anaerobic microorganisms (CFU g^{-1})	910000	1078000	2227500	1146000
Lactic acid bacteria (CFU g^{-1})	56000	258000	287500	424000
Mould (CFU g^{-1})	4750	3400	3250	3200
Yeast (CFU g^{-1})	6600	3200	2500	2800
Escherichia coli mesophylic forms (CFU g^{-1})	870000	542000	375000	287400
Escherichia coli termophylic forms (CFU g^{-1})	432500	562000	365000	1644000
Coliforms mesophylic (CFU g^{-1})	110000	90800	-	107600
Coliforms thermophylic (CFU g^{-1})	30000	84200	230000	156200
Staphylococcus sp. (CFU g^{-1})	20000	8800	-	8200

(A) - 51.5%, and in the group (A+F) 57.6% less than in the group (C). Lactic acid bacteria CFU g^{-1} amount in the group (F) increased by 5.1 times, in the group (A) - 4.6 times, and in the group (A+F) - 7.6 times compared to the group (C). *Staphylococcus* species in the control group was 20000 CFU g^{-1}, but in the group (A) - 56.0% and in the group (A+F) - 59.0% less compared to the group (C). *Escherichia coli* mesophylic forms CFU g^{-1}, in the group (F) decreased by 56.9%, in the group (A) - by 37.7%, and in the group (A+F) - by 66.9% compared to the group (C).

Escherichia coli termophylic forms in the group (F) was by 15.6% and in the group (A+F) by 2.9% less than in the group (C).

Conclusions

1. The organic acid and phytogenic additive improved pigs' growth intensity: pigs' daily gain indices at 42 to 170 days from the group (F) was by 12.0%, for the group (A) - by 6.2%, and for the group (A+F) - by 10.5% higher than for pigs in the control group.

2. The best results of feed conversion were in the trial group (A+F), i.e., by 8.5% less than in the group (C), whereas the group (F) showed by 5.1%, and the group (A) - by 6.7% best results compared to the control group.

3. Duodenum and Rectum microflora analyses showed, that use of organic acid and phytogenic additive reduced the Mould CFU g^{-1}, Yeast CFU g^{-1}, *Escherichia coli* mesophylic and termophylic forms CFU g^{-1}, *Staphylococcus* species CFU g^{-1}, and lactic acid bacteria CFU g^{-1} amount compared to the control group.

References

1. Alexander M. (2001) Aromatherapy and immunity: how the use of essential oils aid immune potential, International Aromatherapy, Volume 11, pp. 152–156.
2. Arnal-Schnebelena F.B., Hadji-Minagloub J.F., Peroteauc F., Ribeyred and de Billerbecke V.G. (2004) Essential oils in infectious gynaecological disease: a statistical study of 658 cases. International Aromatherapy Volume 14, Issue 4, pp. 192-197.
3. Axford R.F.E., Bishop S.C., Nicholas F.W., Owen J.B. (2000) Breeding for diseases resistence in farm animals. CABI Publishing, 418 p.
4. Boatto G., Pintore G., Palomba M., De Simone F., Ramundo E. (1994) Iodice, Composition and antibacterial activity of I. helenium and R. officinalis essential oils. Fitoterapia Volume 65, pp. 279–280.
5. Couladis M., Tzakou O., Kujundzic S., Sokovic M. and Mimica-Dukic N. (2004) Chemical analysis and antifungal activity of Thymus striatus, Phytotherapy Research Volume 18, pp. 40–42.
6. Dibner J. (2004) Organic acids: Can they replace antibiotic growth promoters? Feed International, December, pp. 14-16.
7. Hyden M.J. (1995) Feed additives. Roterdam, 42 p.
8. Langenheim J.H. (1994) Higher plant terpenoids: A phytocentric overview of their ecological roles, Chemical Ecology Volume 20, pp. 1223–1280.
9. Malmquist M., Jacobsson K.G., Haggblom P., Cerenius F., Sjoland L., Gunnarsson A. (1995) Salmonella isolated from animals and feedstuffs in Sweden. Acta Veterinaria Scandinavica, Volume 36, pp. 21-39.
10. Panizzi L., Flamini G., Cioni P.L., Morelli I. (1993) Composition and antimicrobial properties of essential oils of flavour mediterranean Lamiaceae. Ethnopharmacol Volume 39, pp. 167–170.
11. Peris S., Asensio J.J. (2002) Organic acids plus botanicals. Feed International, March, pp. 17-19.
12. Svensmark B., Jorsal S.E., Nielsen K., Willberg P. (1989) Epidemiological studies of piglet diarrhoea in intensively managed Danish sow herds. Post-weaning diarrhoea. Acta Veterinaria Scandinavica, No. 30, pp. 55-62.

VETERINARY MEDICINE SCIENCES

RELATIONSHIP OF NEOSPOROSIS INFECTED ANIMALS IN HERDS AND THEIR BLOOD BIOCHEMICAL DATA

Evija Eihvalde, Vita Antāne, Pēteris Keidāns
Latvia University of Agriculture
E-mail: eveihvalde@inbox.lv

Abstract

Neosporosis is an infection disease caused by a single celled parasite *Neospora caninum* that produces cysts in the host organism. The dogs are a definitive host of parasite; cows and other ruminants are intermediate hosts. It causes neuromuscular disorders in dogs and abortions, birth of weak calves and neonatal mortality in cattle. Disease occurs worldwide (Sweden, Germany, Spain, Australia, Canada, USA et al.). Our aim of this study was to clear up how many seropositive animals in two seropositive dairy herds (after bulk milk investigation) in Latvia there are, their relationship and possible changes of their biochemical data. The studies in 2006 between September and November were carried out. In two farms there were 14 seropositive animals (from 67). There was evidence of inheritance of neosporosis infection. No differences were recognized in cows' blood biochemical data between positive and negative animals.

Keywords: cows, neosporosis, serology, blood biochemical data.

Introduction

Neosporosis is an infection disease caused by a single celled, cyst- forming, and coccidian parasite *Neospora caninum*. *N.caninum* was first identified in dogs with neurological disorders in 1984 (Dubey et al., 2002). *N.caninum* has a two-host life cycle. Dogs are the definitive hosts. Cattle and other animals' species such as sheep, deer, monkeys, pigs and foxes are intermediate hosts (Bjorkman, 2003). Seropositive cows frequently have abortion, stillbirth or birth of weak calves. Three infective stages of *N.caninum* – tachyzoites, bradyzoites and oocysts have been identified. Tachyzoites and bradizoites are found intracellular. They can be found in different cell types and organs, but most often they are found in the brain and spinal cord. If the cattle is pregnant, tachyzoites have been found in the placenta. They can rapidly multiply in the host cell, causing cell death and necrotic lesions. Bradyzoites are primarily found in the central nervous system and other neural tissues. They are situated in tissue cysts. Inflammation can be around the cysts. Cysts are found in skeletal muscle in cattle and dogs after natural infection with *N.caninum* (Dubey et al., 2002). Dogs become infectious and shed unsporulated oocysts with their feces two weeks after ingesting infected tissues of intermediate hosts or infected placenta. The intermediate hosts become infected in two ways: horizontal transmission – after intake of oocysts-contamined feed and water, or by eating tissues of infected animals; vertical transmission – during gestation from the cow to its fetus. The presence of dogs on the farm, especially, the coming-in of new dogs, is the risk for horizontal transmission of the cattle. Vertical transplacental transmission of the infection is an important route of infection in many herds (Anderson et al., 2000).

N.caninum infection in cattle has been reported from several countries over the world. However the prevalence of infection in cattle differs between countries and regions. In Europe, between 16% and 83% of dairy herds were confirmed to have *N.caninum* infected animals (Anderson et al., 2000; Bjorkman, 2003). Neosporosis in Latvia was first diagnosed in 2001 in State Veterinary Diagnostic Centre (starting from 1st January 2006. – National Diagnostic Centre). In period until 2005 from investigated aborted cows blood serum samples 16% were seropositive to neosporosis (Eihvalde et al., 2006).

Abortion and death of neonatal calves appear to be the main cause of economic impact. *N.caninum* infection may also affect milk production and reproductive performance in dairy cows. No investigation as to how neosporosis can affect blood biochemical data of cows after infection has been carried out.

Our aim of this study was to detect the number of the seropositive animals in seropositive herds, estimate relationship of seropositive animals and compare blood biochemical data between seropositive and seronegative animal groups.
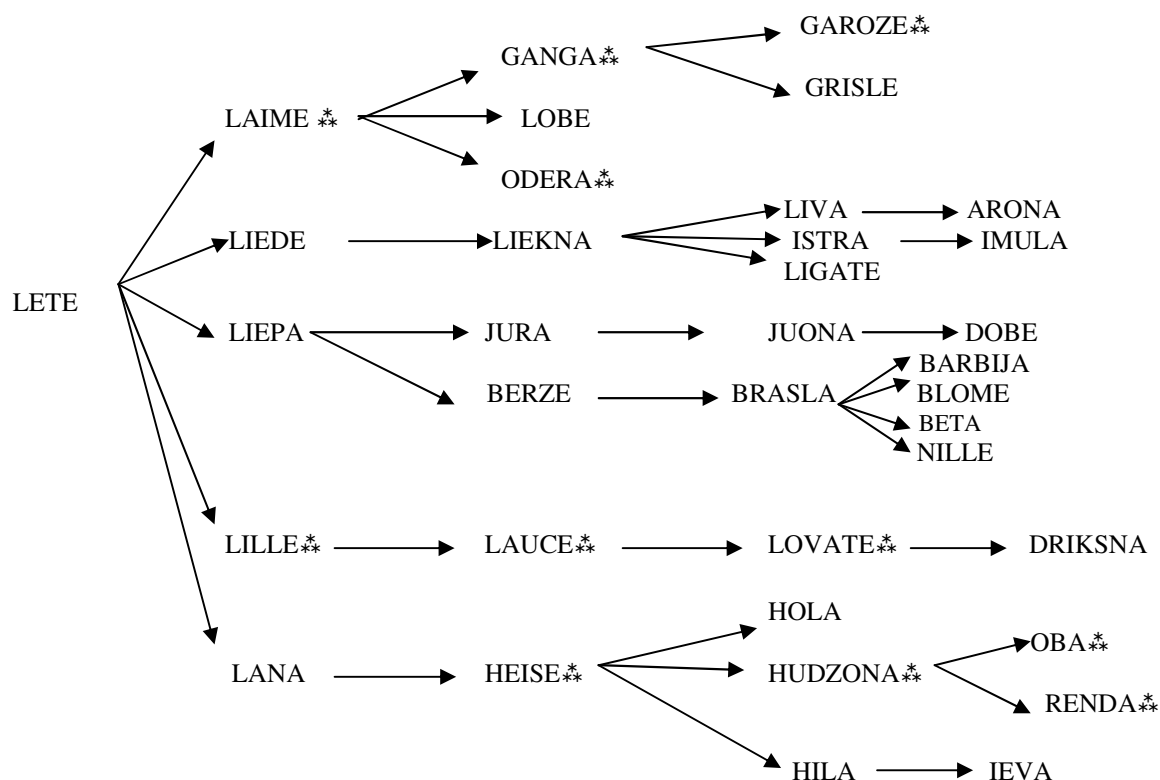
Figure 1. Herd 'A' cows' relationship in the herd and their serological status.
$*^*_*$ - seropositive cows

Materials and Methods

The studies in 2006 between September and November, in two seropositive dairy herds in Riga and Jelgava district were carried out. The herds were choosen after serological examination of bulk milk samples to neosporosis in 2005. All female animals (> 3 months) in herds (67 cows and heifers) were serologically investigated to neosporosis with ELISA (SVANOVIR® Neospora-Ab iscom ELISA, Svanova Biotech AB, Uppsala, Sweden). The animal groups were ordered after serological investigation – seropositive and seronegative cows. The blood serum samples were taken from 20 dairy cows and 8 heifers (14 – seropositive, 14 – seronegative animals) for biochemical investigation. Data management and descriptive statistics were performed by SPSS programme (Arhipova, Bāliņa, 2003).

Results and Discussion

In herd 'A' (Jelgavas district) serologically positive to neosporosis were 24.1% (7 from 29) animals. In this herd cows to neosporosis were investigated until 2003. In 2003 there were 54.5%

seropositive animals. They were not eliminated from the herd, but continued using in breed. In length of time some seropositive cows were culling for various reproductive disorders. The herd relationship among cows and their serological status are shown in Figure 1.

While analyzing the cow family beginning from the cow Lete, it is seen that in the second generation there were 5 daughters. When the herd was under neosporosis investigation in 2003, 2 daughters (Laime, Lille) were found to be positive. As concerns the third generation, their daughters (Ganga, Odera, Lauce) turned out to be positive. Admittedly, Lete's daughter Lana, had been eliminated till investigation was carried out, and her serological status was not known, but in the third generation the cow Heise was seropositive. In next two generations Hudzona, Oba, Renda were seropositive cows. Infection of neosporosis in this herd is retaining and continuing in next generation. Other studies show similar results regarding spread of infection (Anderson et al., 2000; Bjorkman, 2003; Chanlun et al., 2002, Gottstein, 2005).

From 38 investigated animals in Riga district in the herd 'B' seropositive were seven cows,
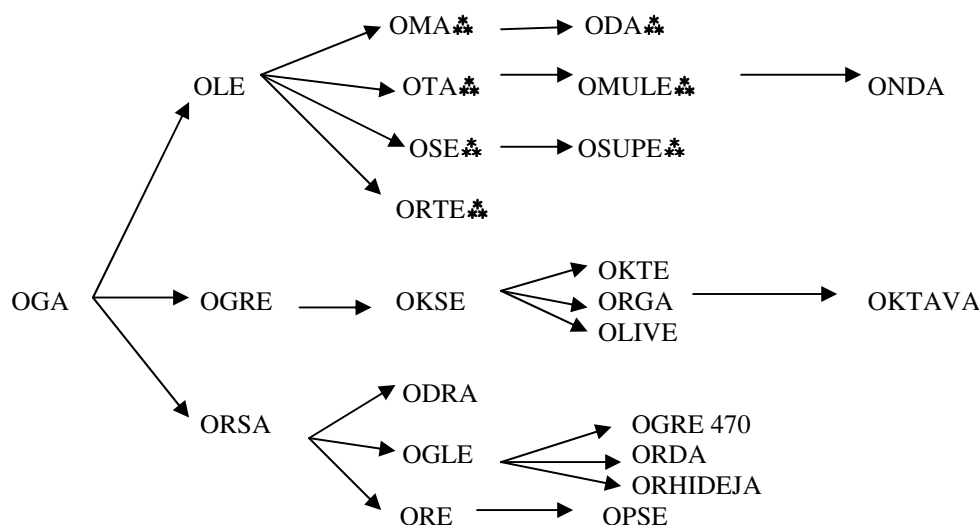
Figure 2. Herd 'B' cows' relationship in the herd and their serological status.
$_*^*{}_*$ - seropositive cows

Table 1

Blood biochemical parameters in seropositive and seronegative cows

Biochemical data	Seropositive cows	Seronegative cows	standard
Glucose, mmol l^{-1}	2.76 ± 0.67	2.97 ± 1.19	2.3-4.1
Creatine kinase,U l^{-1}	150.00 ± 20.78	125.50 ± 14.22	14.4-107.0
Total protein, g l^{-1}	77.30 ± 6.80	75.30 ± 7.93	61.6-82.2
Total bilirubin, μmol l^{-1}	1.97 ± 0.95	1.80 ± 0.85	0.7-14.0
AST, U l^{-1}	89.90 ± 23.95	104.00 ± 27.50	45.3-110.2
Cholesterol, mmol l^{-1}	3.05 ± 1.01	3.82 ± 1.17	1.6-5.0
Urea, mmol l^{-1}	2.93 ± 0.91	2.84 ± 0.99	2.8-8.8
LDH,U l^{-1}	2249.20 ± 273.74	2198.60 ± 189.06	308.6-938.1
Ca, mmol l^{-1}	2.31 ± 0.13	2.44 ± 0.15	2.1-2.8
P, mmol l^{-1}	2.14 ± 0.30	2.18 ± 0.70	1.4-2.5

consequently it constituted 18.4% of seropositive animals. The herd developed from three unconnected cows. Seropositive animals belong to one cow family (see Fig.2). Currently there are 8 cows, 7 of which are seroposotive to neosporosis. Findings indicate that fetus can acquire infection in any pregnancy through placenta (Anderson et al., 2000) because Onda, Omule's daughter, was seronegative to neosporosis.

Between seropositive and seronegative to neosporosis animal groups there is relevant difference ($p < 0.05$) between determined data unascertained (Tab 1). It indicates that parasite *N.caninum* has no direct affect on data such as glucose, creatine kinase, total protein, total bilirubin, aspartate aminotransferase (AST), cholesterol, urea, lactatdehidrogenasis (LDH), calcium and phosphorus. LDH was above

standard that showed activation of hepatocellular enzyme. This can increase if there is extensive degenerated or necrotic damage of muscles (Liepa, 2000). It is known that parasite can cause neural and muscle cells damage. In our study LDH quantity increased in both groups, so this is not connected to parasite influence on organisms.

Conclusions

1. Infection of neosporosis in herds is mainly inherited through placenta (vertical transmission) it is indicated by seropositive animal relationship.

2. In seropositive dairy herds there were 24.1% (Jelgava district herd A) and 18.4% (Riga district herd B) of seropositive animals.

3. Relevant difference ($p < 0.05$) unascertained in determined data such glucose, creatine

kinase, total protein, total bilirubin, aspartataminotransferasis, cholesterol, urea, lactatdehidrogenasis, calcium and phosphorus between seropositive and seronegative to neosporosis animals. LDH was above standard in both groups.

References

1. Anderson M.L., Andrianarivo A.G., Conrad P.A. (2000) Neosporosis in Cattle. *Animal Reproduction Science*. 60-61. pp. 417-431.
2. Arhipova I., Bāliņa S. (2003) Statistika Ekonomikā. Risinājumi ar SPSS un Microsoft Exel. (Statistics in Economics. Solutions with SPSS and Microsoft Excel). Rīga: Datorzinību centrs. 352 p. (in Latvian).
3. Björkman C. (2003) *Neospora Caninum* Infection in Cattle. Farm Animal Reproduction: Reducing Infectious Diseases. Proceedings from a Symposium at The Faculty of Veterinary Medicine, Jelgava, Latvia, Januari 22-23, pp. 8-13.
4. Chanlun A., Näslund K. (2002) Use of Bulk Milk for Detection of *Neospora Caninum* Infection in Dairy Herd in Thailand. Veterinary Parasitology. 110. pp. 35-44.
5. Dubey J.P., Barr B.C., Barta J.R., Bjerkas I., Björkman C., Blagburn B.L., Bowman D.D., Buxton D., Ellis J.T., Gottstein B., Hemphill A., Hill D.E., Hove D.K., Jenkins M.C., Kobayashi Y., Koudela B., Marsh A.E., Mattsson J.G., McAlister M.M., Modry D., Omata Y., Sibley L.D., Speer C.A., Trees A.J., Uggla A., Upton S.J., Williams D.J.& Lindsay D.S. (2002) Redescription of *Neospora caninum* and its Differentiation from Related Coccidia. International Journal for Parasitology. 32. pp. 929-946.
6. Eihvalde E., Keidāns P., Antāne V. (2006) *Neospora Caninum* antivielu noteikšana koppiena paraugos invāzijas izplatības noskaidrošanai Latvijā (Clarification of Prevalence of Infection in Latvia with Determination of Antibodies to *Neospora caninum* in bulk milk samples). Latvijas Lauksaimniecības universitātes Veterinārmedicīnas fakultātes starptautiskās zinātniskās konferences Dzīvnieki. Veselība. Pārtikas higiēna raksti. 2006. – Jelgava: LLU, pp. 66. – 70. (in Latvian).
7. Gottstein B. (2005) Neospora and Neosporosis: an Update on Epidemiology and Diagnosis. Proceedings of the 1st symposium of the Scandinavian- Baltic Society for Parasitology. Vilnius-Lithuana, 26-29 May, Vol.14. pp. 10-15.
8. Liepa L. (2000) Asiņu bioķīmisko rādītāju klīniskā interpretācija govīm (The Clinical Interpretation of Blood Biochemical Data of Cows). Jelgava: LLU, 44 p. (in Latvian).

INCIDENCE OF *YERSINIA ENTEROCOLITICA* 4/O:3 IN PIGS OF LATVIAN ORIGIN AT SLAUGHTERING

Margarita Terentjeva, Aivars Bērziņš, Edgars Liepiņš
Latvia University of Agriculture
E-mail: vmfparthig@llu.lv

Abstract

A total amount of 90 pig tonsil samples were investigated to detect presence of *Y.enterocolitica* 4/O:3. Samples were collected in two large-scale Latvian slaughterhouses from five pig herds during February and March, 2006. Samples were investigated with direct plating onto selective CIN agar plates according to ISO 10273 method, with subsequent cold enrichment for 2 weeks at 4 °C in accordance with NMKL 117 method. *Y.enterocolitica* positive isolates were investigated for pyrazinamidase and lipase activity, indole production and salicine, xylose, trehalose fermentation. Slide agglutination reaction with commercial antisera O:3 was carried out for detection of *Y.enterocolitica* sevovars. Pathogen was isolated from all five herds with 30% mean prevalence. Incidence of *Y.enterocolitica* 4/O:3 depending on herd varied from 20 to 45%. High incidence of *Y.enterocolitica* in pig tonsils indicates that animals are important reservoir of this pathogen in Latvia. Further studies about incidence of *Y.enterocolitica* pathogenic bioserotypes in pig population and contamination pattern with pathogen in slaughterhouses are needed.

Keywords: bioserotype, tonsil, herd.

Introduction

Yersinia enterocolitica is a highly heterogenic bacterium, depending on its biochemical and antigenic properties divided into six biotypes and various serotypes. It is well documented that *Y.enterocolitica* bioserovars correlate with virulence properties, ecological and geographical distribution of microorganism. Only few of them, such as 1B/O:8, 2/O:9, 2/O:5, 27, 3/O:3 and 4/O:3, are pathogenic to human (Bottone, 1999).

Pathogenic *Y.enterocolitica* bioserotypes cause the yersiniosis, a human food-borne disease, characterized by gastro-intestinal disorders and severe post-infection complication such as erythema nodosum, glomerulonephritis, myocarditis or arthritis (Bottone, 1999). Disease is recognized in Latvia with an average incidence 2.3 cases per 100 000 inhabitants during 2001-2005 with a recent trend to increase (Anonymous, 2006).

While bioserotypes 1B/O:8, 2/O:9, O:5, 27, as a causative agent of yersiniosis, are mostly described in the United States and Japan, the most common biovar for Northern and Central Europe is 4/O:3 (Fredriksson-Ahomaa et al., 2006), infection with 2/O:5, 27, 3/O:5, 27, 2/O:9 and 1B/O:8 is rarely reported (Bottone, 1999; Nowak et al., 2006; Schubert et al., 2003).

Epidemiology of yersiniosis is still poorly understood, because *Y.enterocolitica* is seldom recovered from food (De Boer, 1995). However, M. Fredriksson-Ahomaa et al., (1999) reported high prevalence of pathogen on pork offal and minced meat at retail level in Finland. Consumption of pork was identified as a source of sporadic yersiniosis in Norway (Ostroff et al., 1994).

Pigs seem to be the most important reservoir of *Y.enterocolitica* (Kapperud, 1991). Healthy animals harbour pathogen in the lymphatic tissues, especially in tonsils, during life-time without clinical signs (Nowak et al., 2006). T. Nesbakken et al., (2003) showed that bacterium is usually introduced in food chain due to initial contamination with *Y.enterocolitica* in slaughterhouses. Presence of bacterium in pigs at slaughtering opens various opportunities for contamination with *Y.enterocolitica* 4/O:3 to offal and meat with further transmission of pathogen to retail level. No previous studies on occurrence of pathogenic *Yersinia* bioserotypes and epidemiology of *Y.enterocolitica* were undertaken in Latvia. However, detection of *Y.enterocolitica* carriers, especially pathogenic, is important factor for understanding the epidemiology of yersiniosis (Asplund et al., 1998).

The aim of study was to detect incidence of *Y.enterocolitica* 4/O:3 in pigs of Latvian origin at slaughtering.

Materials and Methods

A total amount of 90 pig tonsil samples were collected from five pig herds in two large-

Table 1

Incidence of *Y.enterocolitica* 4/O:3 in pigs at slaughtering

Herd localization	No. of samples	*Y.enterocolitica* 4/O:3 positive samples (%)
East Kurzeme	10/3(30)	3(30)
Ziemeļzemgale	20/4 (20)	4(20)
Dienvidrietumu Latgale	20/5 (20)	5(20)
Dienvidaustrumu Latgale	20/9 (45)	9(45)
Ziemeļzemgale	20/5 (25)	5(25)

scale slaughterhouses, located in different parts of Latvia during February – March, 2006. All samples were taken aseptically from randomly selected pluck sets. Tonsils were put into sterile stomacher bag and were transported to the Faculty of Veterinary Medicine, Latvia University of Agriculture.

Samples were investigated during April-September, 2006. An amount of 10 g of sample were homogenised in peptone buffered water (Oxoid, Basingstoke, Hampshire, UK), resuscitated for 1 h at 22 °C, and plated out on to cefsulodin-irgasan-novobiocin agar plates (CIN, Yersinia selective agar, Oxoid, Basingstoke, Hampshire, UK) according to ISO method 10273:2003. Agar plates were incubated for 48 h at 30 °C. Three presumptive colonies with typical 'bull-eye like' appearance - red centre and transparent surrounded margins were tested for urea hydrolysis and oxidase reaction. Urea-positive and oxidase-negative isolates were confirmed with API 20E kit (BioMérieux, Marcy l'Etoile, France). *Y.enterocolitica*-negative samples were cold enriched in agreement with NMKL method, Nr. 117 at 4 °C for 2 weeks with plating out on CIN agar at 8th and after alkali treatment with potassium hydroxide at 15th day of incubation with subsequent confirmation with API 20E.

Confirmed *Y.enterocolitica* isolates were tested for pyrazinamidase activity, indole production, tween-esterase reaction, fermentation of xylose, trehalose and salicin according to G. Wauters et al., 1987. Indole, tween-esterase, xylose, salicine and pyrazinamidase activity negative and trehalose positive isolates were investigated for slide agglutination with commercial *Y.enterocolitica* antisera O:3 (Sifin, Berlin, Germany).

The mean prevalence for each herd was calculated.

Results and Discussion

Y.enterocolitica 4/O:3 was isolated from all five investigated herd. Prevalence of *Y.enterocolitica* was varied from 20% in herd located in Ziemeļzemgale and Dienvidrietumu Latgale to 45% in Dienvidaustrumu Latgale (Table 1).

The mean prevalence – 26 (28)% for *Y.enterocolitica* 4/O:3 is close to previously reported on high prevalence of pathogenic *Y.enterocolitica* bioserotypes in slaughtered pigs, especially 4/O:3 in Europe (Table 2).

Almost all *Y.enterocolitica* isolates belong

Table 2

Reported incidence of *Y.enterocolitica* 4/O:3 in pig tonsils at slaughtering

Country	No. of samples	Incidence	Reference
Norway	24	15(63)	Nesbakken et al., 2003
	50	30(60)	Fredriksson-Ahomaa et al., 2000
Netherlands	86	33(38)	De Boer and Nouws, 1991
Italy	150	22(14.7)	Bonardi et al., 2003
	106	43(41)	De Guisti et al., 1995
Germany	210	60(28.8)	Nowak et al., 2006
	50	30(60)	Fredriksson-Ahomaa et al., 2001

to bioserogroup 4/O:3, with exception of herd located Ziemeļzemgale, where one indol, xylose, salicine, trehalose positive, Tween-esterase negative isolate was found. Pattern of biochemical reaction is typical to biotype 2, but slide agglutination reaction with antisera was not performed, so it was not possible to detect this isolate serotype.

Presence of biotype 2 indicates that other pathogenic bioserovars can be found in Latvia; however, initial reservoir of this pathogen is still unclear (Fredriksson-Ahomaa, 2006).

High prevalence of *Y.enterocolitica* indicates that pig tonsils can serve as the potential source of contamination of by-products and meat during evisceration and dressing in the abattoirs with following introduction of pathogen into retail market. Presence of *Y.enterocolitica* 4/O:3 is frequently reported on carcasses and offal at the slaughterhouse (Gurtler et al., 2005; Fredriksson-Ahomaa et al., 2001; Nesbakken et al., 2003). It is not possible to avoid completely from contamination with pathogen during routine slaughtering and hygienic procedures, but is more difficult to prevent distribution of *Y.enterocolitica* from tonsils in herds with high prevalence (Nesbakken et al., 2006). Further epidemiological studies on contamination pattern in abattoirs in Latvia are needed.

Previous observations indicate that *Y.enterocolitica* 4/O:3 can establish the long-term reservoir within pig herd (Nesbakken et al., 2006; Skjerve et al., 1998). An animal may become the carrier of pathogen within short-time contact with infected pigs from *Yersinia*-positive herd just before slaughtering: during transportation, staying in the waiting pens or at the ante-mortem inspection at the slaughterhouse, resulting in positive tonsils at slaughtering. In our study none of the herds was free from *Yersinia*. As samples were taken from pluck set on the slaughter line, it is not excluded that animals were carriers before slaughtering because pigs were held at the lairage in the same room where animals from other herds stayed.

Yersinia – negative and positive herds should be recognized by an official veterinarian in order to avoid contact between animals and provide adequate plant sanitation after slaughtering. Information about presence of pathogen should be delivered to the slaughterhouse with food chain according to European Community Regulation EC 854/2004. The elimination of *Y.enterocolitica* from the herd is long and cost-expensive process (Nesbakken et al., 2006), thus the improvement of slaughtering techniques and meat hygiene practices are essential.

Our study on occurrence of *Y.enterocolitica* should be continued with many Latvian herds involved to get more reliable information about epidemiological situation in pig population in Latvia. However, it is obvious that pathogenic *Y.enterocolitica* 4/O:3 is the most frequently isolated from pigs of Latvian pig at slaughtering.

Conclusions:

1. High prevalence of *Y.enterocolitica* 4/O:3 in pigs of Latvian origin at slaughtering indicate that further contamination form pig tonsils may occur during slaughtering and processing of the pig offal and carcasses in slaughterhouses;
2. Information about *Yersinia*- positive herds should be provided before the animal slaughtering as food chain information in accordance to EC Regulation 854/2004;
3. Investigation should be continued to get more reliable information about incidence of pathogenic *Y.enterocolitica* bioserovars in Latvian pigs.

References

1. Anonymous (2006) Zoonoses Report of Latvia 2004/2005. Ministry of Agriculture, Food and Veterinary Service, pp. 31-32.
2. Asplund K., Hakkinen M., Okkonen T., Vanhala P., Nurmi E. (1998) Effects of Growth-promoting Antimicrobials on Inhibition of *Yersinia enterocolitica* O:3 by Porcine Ileal Microflora. Journal of Applied Microbiology, 85, pp. 164-170.
3. Bonardi S., Brindani F., Pizzin G., Lucidi L., D'Incau M., Liebana E., Morabito S. (2003) Detection of *Salmonella* spp., *Yersinia enterocolitica* and Verocytotoxin-producing *Escherichia Coli* O157 in Pigs at Slaughter in Italy. International Journal of Food Microbiology, 85, pp. 101-110.
4. Bottone E.J. (1999) *Yersinia enterocolitica*: Overview and Epidemiological Correlates. Microbes and Infection, 1, pp. 323-333.
5. De Boer E., Nouws J.F.M. (1991) Slaughter Pigs and Pork as a Source of Human Pathogenic *Yersinia enterocolitica*. International Journal of Food Microbiology, 12, pp. 375-378.

6. De Boer E. (1995) Isolation of *Yersinia enterocolitica* from Foods. Contribution to Microbiology and Immunology, 13, pp. 71-73.
7. De Giusti M., de Vito E., Serra A., Quattrucci B., Boccia A., Pacifico L., Ranucci A., Ravagnan G., Chiesa C. (1995) Occurrence of Pathogenic *Yersinia enterocolitica* in Slaughtered Pigs and Pork Products. Contribution in Microbiology and Immunology, 13, pp. 126-129
8. Gurtler M., Alter T., Kasimir S., Linnebur M., Fehlhaber K. (2005) Prevalence of *Yersinia enterocolitica* in Fattening Pigs. Food Protocols, 68, pp. 850-854
9. International Organization of Standardization (2003) Microbiology of Food and Animal Feedings Stuffs- Horizontal Method for the Detection of Presumptive Pathogenic *Yersinia enterocolitica* (ISO 10273: 2003), pp. 1-15.
10. Fredriksson-Ahomaa M., Hielm S., Korkeala H. (1999) High Prevalence of yadA - positive *Yersinia enterocolitica* in Pig Tongues and Minced Meat at Retail Level in Finland. Journal of Food Protection, 62, pp. 123-127.
11. Fredriksson-Ahomaa M., Björkroth J., Hielm S., Korkeala H. (2000) Prevalence and Characterization of Pathogenic *Yersinia enterocolitica* in Pig Tonsils from Different Slaughterhouses. Food Microbiology, 17, pp. 93-101.
12. Fredriksson-Ahomaa M., Bucher M., Hank C., Stolle A., Korkaela H. (2001) High Prevalence of *Yersinia enterocolitica* 4:O3 on Pig Offal in Southern Germany: a Slaughtering Technique Problem. Systematic and Applied Microbiology, 24, pp. 457-463.
13. Fredriksson-Ahomaa M., Stolle A., Korkeala H. (2006) Molecular Epidemiology of *Yersinia enterocolitica* Infections. FEMS Immunology and Medical Microbiology, 47, pp. 315-329.
14. Kapperud G. (1991) *Yersinia enterocolitica* in Food Hygiene. International Journal of Food Microbiology, 12, pp. 53-66.
15. NCFA (Nordic Committee on Food Analysis) (1996) *Yersinia enterocolitica*. Detection in Food. Method NMKL No. 117., Nordic Committee on Food Analysis, Espo, Finland
16. Nesbakken T., Eckner K., Høidal H.K., Røtterud O.J. (2003) Occurrence of *Yersinia enterocolitica* and *Campylobacter* spp. in Slaughter Pigs and Consequences for Meat Inspection, Slaughtering and Dressing Procedures. International Journal of Food Microbiology, 80, pp. 231-240.
17. Nesbakken T., Iversen T., Eckner K., Lium B. (2006) Testing of Pathogenic *Yersinia enterocolitica* in Pig Herds Based on the Natural Dynamic of Infection. International Journal of Food Microbiology, 111, pp. 99-104.
18. Nowak B., Mueffling T., Caspari K., Hartung J. (2006) Validation of a Method for the Detection of Virulent *Yersinia enterocolitica* and their Distribution in Slaughter Pigs from Conventional and Alternative Housing Systems. Veterinary Microbiology, 117, pp. 219-228.
19. Ostroff S.M., Kapperud G., Huteagner L.C., Nesbakken T., Bean N.H. (1994) Sources of Sporadic *Yersinia enterocolitica* Infection in Norway: a Prospective Case-control Study. Epidemiology and Infection, 112, pp. 133-141.
20. Schubert S., Bockemühl J., Brendler U., Heesemann J. (2003) First Isolation of Virulent *Yersinia enterocolitica* O:8, Biotype 1B in Germany. European Journal of Clinical Microbiology and Infection Diseases, 22, pp. 66-68.
21. Skjerve E., Lium B., Nielsen B., Nesbakken T. (1998) Control of *Yersinia enterocolitica* in Pigs at Herd Level. International Journal of Food Microbiology, 45, pp. 195-203.
22. Wauters E., Kandolo K, Janssens M. (1987) Revised biogrouping scheme of Yersinia enterocolitica. Contributions in Microbiology and Immunology, 9, pp. 14-21.

FOOD SCIENCES

EFFECT OF SELENIUM ON THIAMINE, RIBOFLAVIN AND PANTOTHENIC ACID CONTENT IN DIFFERENT GRAINS

Mara Duma, Daina Karklina
Latvia University of Agriculture
E-mail: Mara.Duma@llu.lv

Abstract

The effect of selenium on the content of thiamine (vitamin B_1), riboflavin (vitamin B_2), as well as pantothenic acid (vitamin B_5) in wheat (*Triticum aestivum* L), hulless barley (*Hordeum vulgare* L.) and hullless oats (*Avena sativa* L.) grains during germination were investigated.

The winter wheat grain variety 'Zentos', hulless barley and hulless oats were used for study. Grains were soaked for 120 hours totally in solutions containing selenium from 10 to 200 mg l^{-1} in the form of sodium selenate (Se^{+6}). Grains with moisture content of 43%-44% were let to sprout at ambient temperature of 18 ± 2 ºC. The content of B_1, B_2 and B_5 vitamins in germinated grains were determined using standard methods.

Laboratory studies showed that changes in vitamin B_1, B_2 and B_5 content depend on selenium concentration and kind of grains.

Selenium additives promote biochemical activity of vitamin B_1 and content of this vitamin decreases after 5 days' germination in all investigated grains at all applied selenium concentrations. Selenium concentrations of 10 and 25 mg l^{-1} promote forming of vitamin B_2 in wheat, barley and oat grains. The changes in vitamin B_5 content depend on selenium concentration and kind of grains.

Keywords: selenium, wheat, barley, oats, germination, B vitamins.

Introduction

Whole grains are universally recommended as an integral part of the diet. They are an important source of nutrients that are in short supply in our diet, including digestible carbohydrates, dietary fibre, resistant starch, trace minerals, certain vitamins, and other compounds of interest in disease prevention, including phytoestrogens and antioxidants (Slavin, 2004).

The major constituents of different kinds of cereals are fairly uniform. Noteworthy variations are the higher lipid content of oats and lower starch content in barley and oats. Wheat, barley and oats also differ in vitamin B content. Oats are the richest in thiamine ($\sim$ 7 mg kg^{-1}) and pantothenic acid ($\sim$ 14 mg kg^{-1}), the content of riboflavin is higher in barley (Belitz, Grosch, 1986).

Wheat grains are high in dietary fibre, low in fat, have $\sim$ 7–20 g 100 g^{-1} protein, and are concentrated sources of starch, high in vitamins (especially B vitamins), and good source of minerals (Kulp et al., 2000).

The practice of sprouting is widely used to improve the nutritional value of grains. It is known that germination increases the level of amino acids, some vitamins, and minerals (Lintschinger et al., 2000). Germination has an important effect on the water-soluble vitamin composition, and sprouted grains usually contain different levels of some vitamins (ascorbic acid, thiamine, riboflavin, niacin and pantothenic acid) compared to levels in the corresponding dry grains. These changes depend on the type of grain and sprouting conditions, such as time, temperature, the presence or absence of light during sprouting process or the composition of soaking and rinsing media (Yang et al., 2001).

Using selenium-containing solutions for grain soaking during germination it is possible to fortify grains with this microelement (Lintschinger, 1997). Selenium (Se) is an essential trace element for man and its biological functions are carried out by selenoproteins, several of which are parts of the antioxidant enzymes that protect cells against the effects of free radicals (Ganther, 1999).

Because of the good nutritional source for protein, vitamins as well as microelement selenium from grains, the present study investigates the effect of selenium additives on changes in thiamine, riboflavin and pantothenic acid content during germination of wheat, barley and oat grains using solutions with different selenium concentrations.

Table 1

Tiamine, riboflavin and pantothenic acid content in grains before germinating

Type of grains	Vitamin concentration, mg kg^{-1}±SD		
	Thiamine	Riboflavin	Pantothenic acid
Wheat	3.80 ± 0.03	1.17 ± 0.01	41.93 ±0.04
Barley	3.66 ± 0.05	1.75 ±0.02	48.33 ±0.04
Oats	7.22 ±0.01	1.51 ±0.06	17.23 ± 0.01

Materials and Methods

The research was performed at the Laboratories of the Department of Chemistry at the Latvia University of Agriculture and at the Laboratory of Biochemistry and Physiology of Animals at the Institute of Biology of University of Latvia.

The winter wheat grain variety 'Zentos', hulless barley and hullless oat grains were germinated for 5 days. Grains (100 g) were soaked in 500 ml of solutions containing 10, 25, 50, 100 and 200 mg l^{-1} of selenium in form of selenate at ambient temperature of 18±2 °C for 6 h and shaken every 30 min. The solution was then drained off and samples were germinated for 5 days under natural light conditions at 18±2 °C. Every 24 h the grains were moistened with corresponding solution and carefully shaken.

Control samples without selenium additives were prepared for comparison of obtained results.

After germinating all grains, which were soaked in selenium-containing solutions, 3 times were washed with 500 ml deionized water to prevent contamination of the surface of grains with the solution containing selenium. After that, the grains were put into plastic packs and stored at -18 °C in a freezer for 24 h, then dried and ground.

The amounts of B$_1$, B$_2$ and B$_5$ vitamins were determined by standard methods – AOAC Official Standard Method 986.27, AOAC Official Standard Method 970.65 and AOAC Official Standard Method 961.14 respectively. For comparing obtained results during germination and for evaluation of selenium influence on B vitamins content, the concentration of B1, B2 and B5 vitamins were determined in grains before germinating.

The germination was performed in duplicate and analysis was carried out in triplicate. The data given here are the mean values of the measurements ± standard deviation (SD).

The data was analyzed statistically using SPSS for Windows and MS Excel for Descriptive Statistics (mean values, standard deviation) and for Correlation and Regression Analysis.

Results and Discussion

The results obtained indicated that germination modified the nutritional composition of grains, which was dependent on the type of grains.

The content of B$_1$, B$_2$ and B$_5$ vitamins in grains before germination are showed in Table 1.

The research data on changes in thiamine content in wheat, barley and oat grains after 5 days' germination, using solutions with different selenium concentrations as well as control solution without selenium additives is presented in Figure 1.

It is known that during germination the content of thiamine decreases, because it is an essential constituent of all cells since it is a cofactor for two enzyme complexes involved in citric acid cycle – pyruvate dehydrogenase and α-ketoglutarate dehydrogenase (Belanger et al, 2004).

Comparing the content of vitamin B$_1$ in grains before soaking and in grains germinated in control solution we found that it decreased by 12.11% in wheat grains, by 66.94% in barley, and by 28.19% in oats. Figure 1 shows that selenium additives have influence on thiamine content in all investigated grains after 5 days' germination. After soaking grains in solution containing selenium of 10 mg l^{-1}, the content of vitamin B$_1$ decreases by 53.9% in wheat grains, by 69.7% - in barley, and by 35.6% - in oats comparing with B$_1$ vitamin content in grains before soaking. With increased concentration of selenium in solution, the content of B$_1$ vitamin decreases. The highest decreasing is obtained using solution with selenium concentration of 200 mg l^{-1}: after 5 days' germination the content of B$_1$ vitamin decreases by 97.4% in wheat grains, by 99.7% - in barley, and by 67.2% - in oats comparing with vitamin content in grains before soaking.
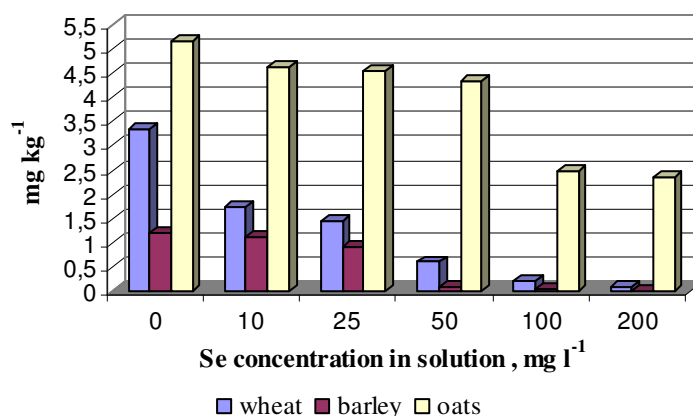
Figure 1. Thiamine concentration in germinated grains.

Linear correlations, i.e., $y = -0.0124x + 2.0372$ ($R^2 = 0.59$), $y = -0.006x + 0.9462$ ($R^2 = 0.62$), and $y = -0.0146x + 4.8612$ ($R^2 = 0.84$) for wheat, barley, and oats respectively, which allowed defining the correlation of vitamin B_1 content and selenium concentration in solution, have been estimated.

We can conclude that microelement selenium has influence on thiamine concentration in germinated grains and it depends on type of grain and on the concentration of selenium.

The changes in riboflavin and pantothenic acid content in germinated grains depending on selenium concentration in soaking solution are showed in Figures 2 and 3.

The obtained results conform to the results

described in literature on the changes in vitamin B_2 content during germinating (Zielinski et al., 2005).

The results show that the content of vitamin B_2 increases after 5 days' germinating and selenium additives influence the content of vitamin B_2 in grains. The content of vitamin B_2 increases in wheat, barley and oats after soaking grains in solutions with selenium concentration of 10 and 25 mg l^{-1}. The highest increase we observed with wheat grains – by 41.9% comparing with vitamin B_2 content in grains before soaking. After this research selenium concentration and vitamin B_2 content correlations in different grains have been estimated and linear equation obtained,
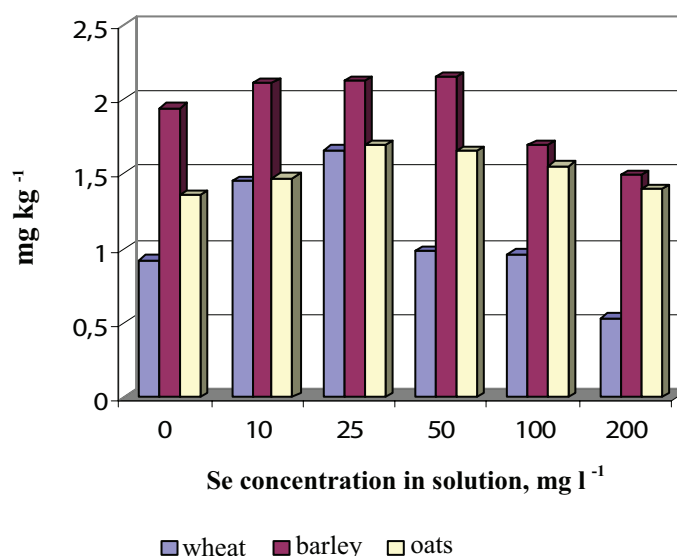

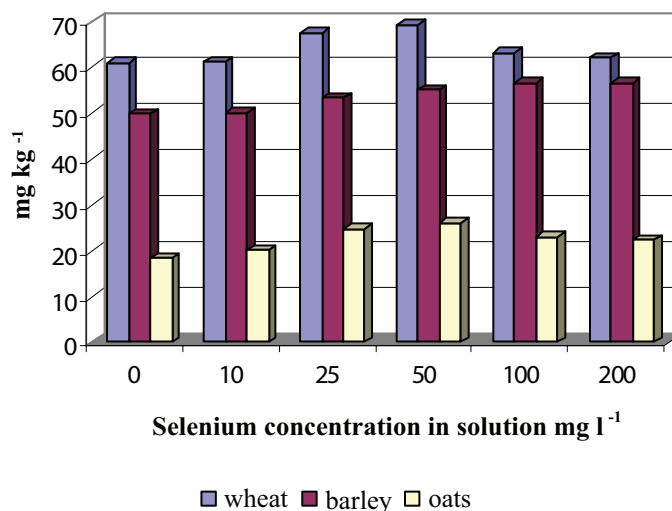
Figure 2. Riboflavin concentration in germinated grains.

Figure 3. Pantothenic acid concentration in germinated grains.

i.e., $y = -0.0039x + 1.3382$, $y = -0.0034x + 2.1355$ and $y = -0.0004x + 1.5415$ for wheat, barley, and oats respectively. The strong positive correlation between selenium concentration in solution and B_2 vitamin content in wheat ($R^2 = 0.51$) and barley grains ($R^2 = 0.76$) have been determined.

Figure 2 shows that changes in vitamin B_2 content depend not only on selenium concentration, but also on the kind of grains. It can be explained with the different chemical composition of wheat, barley, and oat grains.

The content of panthotenic acid in different grains is higher than content of thiamin and riboflavin. The obtained results show that during germination the content of B_5 vitamin increases by 45.2%, 3.2% and 7.1% in wheat, barley and oat grains after soaking in solution without selenium additives. Analyzing the obtained data statistically, we found linear equations: $y = -0.0056x + 64.411$, $y = -0.034x + 51.359$, and $y = 0.0088x + 21.877$ for wheat, barley, and oats respectively. The strong positive correlation between selenium concentration in solution and B_5 vitamin content in barley have been determined ($R^2 = 0.66$).

Figure 3 shows that the highest increasing in vitamin B_5 content is observed in wheat and oat grains (65.4% and 52.0% respectively) at selenium concentration of 50 mg l^{-1}. All applied selenium concentrations promote forming of vitamin B_5 in

barley (totally by 17.3%).

Conclusions

1. Microelement selenium has influence on thiamine content in germinated grains, which is dependent on type of grain. Selenium concentration of 200 mg l^{-1} gives the highest decrease – after 5 days' germination the content of B_1 vitamin decreases by 97.1% in wheat grains, by 99.2% - in barley and by 54.4%- in oats.

2. Selenium additives of 10 mg l^{-1} and 25 mg l^{-1} promote forming of riboflavin in wheat, barley, and oat grains.

3. The content of pantothenic acid increases during germination, and selenium additives promote increase in vitamin B_5 content in wheat and oat grains at selenium concentrations of 10, 25 and 50 mg l^{-1} but prevent increasing of this vitamin content in these grains at higher selenium concentrations 100 and 200 mg l^{-1}.

4. All applied selenium concentrations promote increase in pantothenic acid content in barley.

Acknowledgements

References

1. Belitz H.D., Grosch W. (1986) Food Chemistry. Springer-Verlag Berlin, 497 pp.
2. Belanger F.C., Leustek T., Chu B., Kriz A.L. (1995) Evidence for the thiamine biosynthetic pathway

in higher-plant plastids and its developmental regulation. Plant Molecular Biology, Vol.29. No.4, pp. 809-821.

3. Ganther H.E. (1999) Selenium metabolism, selenoproteins and mechanisms of cancer prevention: complexities with thioredoxin reductase. Carcinogenesis, Vol. 20, No. 9, pp. 1657-1666.

4. Kulp K., Joseph G., Ponte Jr. (2000) Handbook of Cereal Science and Technology, Macel Dekker, New York Basel, pp. 57-68.

5. Lintschinger J., Fuchs N., Moser H., Jäger R., Hlebeina T., Markolin G., Gössler W. (1997) Uptake of various trace elements during germination of wheat, buckwheat and quinoa. Plant Food Hum.Nutr., 50, pp. 223-237.

6. Lintschinger J., Fuchs N., Moser J., Kuehnelt D, Goessler W. (2000) Selenium-Enriched Sprouts. A raw material for fortified cereal-based diets. J.Agric.Food.Chem., 48, pp. 5362-5368.

7. Slavin J. (2004) Whole grain and human health. Nutrition Research Reviews. No.17, pp. 99-110.

8. Yang F, Basu TK, Ooraikul B. (2001) Studies on germination conditions and antioxidant contents of wheat grain. Int.J.Food Sci. Nutr., July, 52 (4), pp. 319-330.

9. Zelinski H., Frias J., Piskula M.K., Kozlowska H., Valverde-Vidal C. (2005) Vitamin B1 and B2, dietary fiber and mineral content of Cruciferae sprouts. European Food Research and Technology, Vol.221, pp. 78-83.

MINERALS IN OATS, BARLEY AND WHEAT GRAINS

Daina Rubene, Peteris Kuka
Latvia University of Agriculture
E-mail: dainaru@inbox.lv

Abstract

The mean content of minerals in grains varies significantly among different parts of the world as it depends on the type of grain growing conditions and fertilizer application. In this study, the content of minerals in the wheat, oat and barley grains of the crop of the year 2006 from different regions of Latvia were investigated. The grain samples were analysed for K, Mg, Ca, Na, Cu, Mn, Fe, and Zn using Atomic Absorbtion Spectrometer, and for P using spectrophotometer. Phosphorus content in different types of grains varied from 3.10 to 5.65 g kg^{-1}, potassium – from 4.37 to 6.10 g kg^{-1}, calcium – from 0.40 to 1.40 g kg^{-1}, magnesium - from 1.20 to 1.68 g kg^{-1}, manganese – from 14.50 to 55.54 g kg^{-1}, copper - from 3.35 to 6.01 g kg^{-1}, zinc - from 18.72 to 31.84 g kg^{-1}, iron – from 42.39 to 120.40 g kg^{-1}, and sodium - from 32.34 to 55.52 g kg^{-1}. The greatest difference was found between the content of manganese and iron in barley, wheat and oat grains, but small difference was between the mean content of P, K, Zn, Cu, Mg, and Na.

Keywords: minerals, grains, oats, barley, wheat.

Introduction

Cereal grains from the point of view of nutrition are considered the primary source of carbohydrates for humans and farm livestock, but they also contain other components such as protein, dietary fibre, fat, and minerals.

Minerals are inorganic elements found in small or insignificant amounts in various dietary constituents. Based on the amount present in the human body, minerals are classified as major or macro- and trace minerals. The major elements are those that are present in the body in amounts greater than 5 g. Trace minerals are those present in amounts less than 5 g (Kulp and Ponte, 2000).

Main and trace elements have varied functions: as electrolytes, as enzyme constituents, and as building materials in bones and teeth.

Calcium (Ca) is one of the most important minerals. Large amount of calcium is in the skeleton. Calcium is involved in the structure of the muscular system, it controls muscle contraction, blood clotting, activity of brain cells, and cell growth.

Phosphorus (P) plays an important role in metabolism. Magnesium (Mg) is a constituent and activator of many enzymes, stabilizer of plasma membranes, intracellular membranes, and nucleic acids. Potassium (K) is localized mostly within the cells. It regulates the osmotic pressure within the cell and is involved in cell membrane transport. Sodium (Na) is present mostly as an extracellular constituent and maintains the osmotic pressure of the extracellular fluid.

Trace elements are present in hormones, vitamins, enzymes, and proteins which have distinct biological roles. A deficiency in the trace elements results in metabolic disorders. Most of iron (Fe) is present in the hemoglobin and myoglobin pigments. Copper (Cu) is a component of a number of oxidoreductase enzymes. Zinc (Zn) is a component of a number of enzymes. Manganese (Mn) is the metal activator for various enzymes (Belitz et al., 2004; Ternes et al., 2005).

The average mineral content in grain varies significantly from one part of the world to another. This is a function of factors such as the type of grain, the variety, agricultural procedures, growing conditions, composition of the soil, and ripeness of the harvested crops, among other factors (Potter and Hotchkiss, 1995; Fennema, 1996; Kulp and Ponte, 2000; Ternes et al., 2005).

The importance of minerals as food ingredients depends not only on their nutritional and physiological roles. They contribute to food flavour and activate or inhibit enzyme-catalyzed and other reactions.

The aim of the investigation was to analyse the content of the minerals in oats, wheat and barley grains grown in the hot and dry summer of the year 2006.

Materials and Methods

Eight oat, eight wheat, and eight barley grain samples of the crop of the year 2006 from different regions of Latvia were investigated.

Table 1

Content of minerals in oat grains (average values in dry matter)

P, g kg^{-1}	Ca, g kg^{-1}	Mg, g kg^{-1}	K, g kg^{-1}	Mn, mg kg^{-1}	Cu, mg kg^{-1}	Zn, mg kg^{-1}	Fe, mg kg^{-1}	Na, mg kg^{-1}	Region
4.23	1.40	1.43	5.43	48.17	3.62	24.94	105.92	53.48	Saldus
4.24	1.20	1.38	5.64	48.06	4.34	18.88	104.19	52.48	Valmiera
4.04	1.16	1.28	5.30	43.15	4.54	18.74	97.29	54.34	Saldus
4.11	1.01	1.67	4.51	52.06	4.72	31.84	104.62	48.49	Daugavpils
3.90	1.03	1.52	5.26	36.20	4.09	22.00	120.40	55.52	Cesis
3.75	1.37	1.44	4.86	55.54	4.52	29.92	109.10	48.90	Ventspils
5.65*	0.87	1.61	4.80	51.07	3.67	26.12	58.38	48.47	Saldus
5.40*	0.74	1.68	4.77	41.30	3.35	24.66	70.37	47.26	Dobele

*- hulless oat grain

Phosphorus content was analyzed according to ISO 6491.

Sulphur content was analyzed using Carbon-Sulphur determinator ELTRA CS 530.

Calcium content was analyzed according to ISO 6490/2.

Ca, Mg, K, Na, Mn, Fe, Zn, and Cu were analysed according to ISO 6869 using Perkin Elmer Atomic Absorbtion Spectrometer A Analyst 700.

Dry matter content was determined according to LVS 272.

Microsoft Excel software was used to calculate the mean arithmetical values and standard deviations of the mathematical data used in the research.

Results and Discussion

Results of the investigation of the content of minerals in oat, wheat and barley grains are summarized in Tables 1-3.

Grains were analyzed also for sulphur content. On average in wheat grains, sulphur was 1.68 g kg^{-1} in dry matter, in barley grains – 1.70 g kg^{-1} in dry matter, in oat grains – 2.03 mg kg^{-1} in dry matter, and in hulless oat grains - 2.69 g kg^{-1} in dry matter.

The mean content of minerals in wheat, oat and barley grains is presented in Figs 1 and 2.

The mean content of calcium is lowest in wheat samples (0.48 g kg^{-1}) and highest in oat grains (1.20 g kg^{-1}) (Fig. 1).

Compared to other minerals, phosphorus is found in large quantities in cereal grains: 3.10 g kg^{-1} in wheat grains, and up to 5.65 g kg^{-1} in hulless oat grains (Tables 1-3). From a dietary point of view, moderately good sources of magnesium are barley, oat and wheat grains. Mean content of magnesium varies from 1.36 g kg^{-1} in barley to 1.50 g kg^{-1} in oat grains (Fig. 1).

Comparison of iron content in different types of grain (Tables 1-3), shows that the highest level is in covered oat grains (97.29 – 120.40 mg kg^{-1}), but the lowest level – in wheat grains (42.39 mg kg^{-1}- 52.81 mg kg^{-1}). Hulless oat grains contain

Table 2

Content of minerals in wheat grains (average values in dry matter)

P, g kg^{-1}	Ca, g kg^{-1}	Mg, g kg^{-1}	K, g kg^{-1}	Mn, mg kg^{-1}	Cu, mg kg^{-1}	Zn, mg kg^{-1}	Fe, mg kg^{-1}	Na, mg kg^{-1}	Region
3.75	0.40	1.5	4.37	24.66	4.66	21.92	47.58	46.59	Jekabpils
3.42	0.40	1.3	4.59	28.26	4.06	19.58	45.63	43.16	Jekabpils
4.10	0.52	1.5	4.42	24.98	5.30	25.84	52.75	48.62	Saldus
3.12	0.42	1.3	4.55	22.61	5.40	21.10	42.39	32.34	Tukums
3.30	0.56	1.5	4.97	19.25	5.25	28.15	49.73	38.50	Ogre
3.71	0.50	1.5	4.55	27.60	5.35	22.47	52.81	40.97	Bauska
3.50	0.50	1.5	4.50	23.50	5.30	24.50	44.20	42.20	Talsi
3.10	0.50	1.4	4.40	25.85	5.59	21.10	46.34	40.20	Jelgava

Table 3
Content of minerals in barley grains (average values in dry matter)

P, g kg^{-1}	Ca, g kg^{-1}	Mg, g kg^{-1}	K, g kg^{-1}	Mn, mg kg^{-1}	Cu, mg kg^{-1}	Zn, mg kg^{-1}	Fe, mg kg^{-1}	Na, mg kg^{-1}	Region
3.60	0.50	1.40	4.93	14.71	5.04	25.24	66.63	49.40	Jekabpils
3.80	0.62	1.20	6.08	16.46	4.66	18.72	88.90	48.11	Riga
4.10	0.54	1.30	6.10	15.52	5.06	19.74	90.88	43.50	Valmiera
3.60	0.55	1.40	4.91	16.00	5.22	19.87	79.28	46.41	Daugavpils
3.80	0.61	1.40	6.06	19.70	5.54	24.72	80.52	45.33	Valmiera
3.30	0.50	1.40	5.49	14.50	6.01	30.30	67.20	44.20	Talsi
3.80	0.56	1.35	5.30	15.42	5.30	22.40	70.55	45.30	Saldus
3.70	0.53	1.40	5.85	15.75	5.45	20.45	75.60	46.20	Cesis

lower iron content in comparison with covered oat grains.

There is no significant difference between the mean content of zinc in wheat, oat and barley grains, - it varies from 22.68 mg kg^{-1} to 24.63 mg kg^{-1} (Fig. 2).

From the dietary point of view, barley, oats and wheat are considered to be moderately good sources of copper. Oat grains have the lowest mean amount of copper – 4.03 mg kg^{-1}, while barley grains have 5.29 mg kg^{-1} of copper (Fig. 2). Sodium and potassium are the minerals of concern in health care. Potassium level is high in most cereal grains. Sodium level is the highest in oats and lowest in wheat grains.

A significant difference in manganese content of different types of grains was found. The highest average amount is in oat grains (47.20 mg kg^{-1}) but the lowest – in barley grains 16.01 mg kg^{-1} (Fig. 2).

As Tables 1-3 show, for some minerals there is a rather significant difference among one type of grains. It can be explained with different fertilization, different variety or different geographical conditions.

The average content of magnesium, potassium, phosphorus, copper, and sulphur in analysed wheat, oat and barley grain samples corresponds
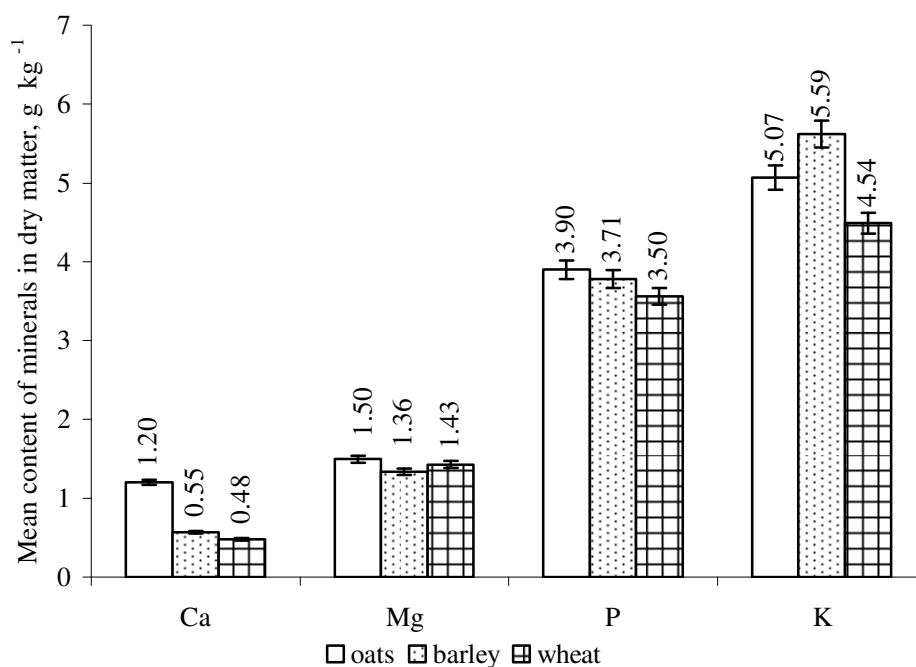

Figure 1. The mean content of Ca, Mg, P and K in wheat, barley and oat grains.
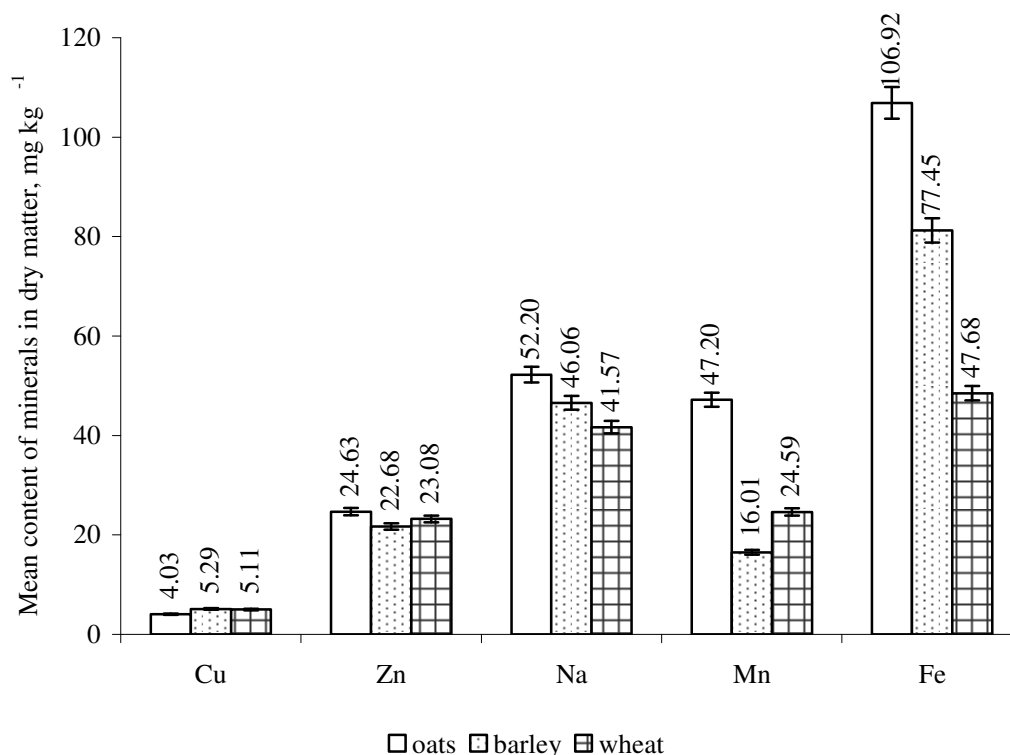
Figure 2. The mean content of Cu, Zn, Na, Mn and Fe in wheat, barley and oat grains.

(The data of analysed hulless oat grains were not included in calculation of the mean values of minerals in oat grains).

to the data given in the literature (Latvietis, 1996). The mean content of zinc, manganese and calcium is slightly lower in all analysed grains, but iron content is higher in oat grain and lower in barley grain samples if compared to the data given in the literature (Latvietis, 1996).

Conclusions

1. The results of this study indicate that the greatest difference is between the content of Mn and Fe in barley, wheat and oat grains.
2. There is almost no difference between the mean content of P, K, Zn, Cu, Mg, and Na in barley, oat and wheat grains.
3. The content of Ca and Fe is lower but content of P is higher in hulless oat grains in comparison with covered oat grains.
4. The highest sulphur content is in hulless oat grains but the lowest - in wheat grains.

Acknowledgement

References

1. Belitz H.D., Grosch W., Schieberle P. (2004) Food chemistry, Springer - Verlag: Berlin Heidelberg pp. 427 – 432.
2. Fennema O.R. (1996) Food chemistry, Marcel Dekker, Inc.: New York, pp. 642 – 643.
3. Kulp K., Ponte J.G. (2000) Handbook of cereal science and technology, Marcel Dekker, Inc.: New York, pp. 483 – 493.
4. Latvietis J. (1996) Lopbarības katalogs, (Catalogue of Feed) LLU, Jelgava, lpp. 53 – 54. (in Latvian).
5. Potter N.N., Hotchkiss J.H. (1995) Food science, Chapman Hall: New York etc., pp. 60 - 61.
6. Ternes W., Täufel A., Tunger L., Zobel M. (2005) Lexikon der Lebensmittel und der Lebensmittelchemie, (Dictionary of Food and Food Chemistry), Wissenschaftliche Verlagsgesellschaft: Stuttgart, S. 1201 – 1203. (in German).

POLYCYCLIC AROMATIC HYDROCARBONS IN SMOKED FOOD PRODUCTS

Ilze Stumpe-Vīksna[1], *Vadims Bartkevičs*[2], *Agnese Kukāre*[2], *Andris Morozovs*[1]
[1]Latvia University of Agriculture
E-mail: ilze_St@tvnet.lv, andrism@llu.lv
[2]National Diagnostic Centre
E-mail: vadims.bartkevics@ndc.gov.lv

Abstract

In presented study we have investigated an occurrence of 15 polycyclic aromatic hydrocarbons (PAH) in different smoked meat and fish samples. After clean up and extraction procedures, the samples were analyzed by gas chromatography-mass spectrometry (GC-MS). Large variability in PAH levels for samples of the same type was found, thus the contamination level is not strongly correlated with the type of product. In the smoked fish samples concentrations of total PAHs ranged from 0.26 to 104 μg kg^{-1}, and in smoked meat samples - from 1.7 to 197 μg kg^{-1}. In general, the predominating PAHs in all samples were benz(a)anthracene, crysene, and cyclopenta(c,d)pyrene. Also the elimination of PAHs in smoked fish by UV irradiation was investigated. Significant decrease in carcinogenic PAH content in smoked fish was found after a 15 min exposure.

Keywords: smoked fish, smoked meat, PAH, GC-MS.

Introduction

Polycyclic aromatic hydrocarbons (PAH) are a group of chemical compounds characterized by benzoic nucleus and resulting from the incomplete combustion or pyrolisis of organic materials. Some of these hydrocarbons are known to be carcinogenic (Howard and Fazio, 1980). Benzo(a)pyrene is the most well-known and studied member of these comounds because it is one of the most potent PAH animal carcinogens (Lijinsky, 1991). Some technological processes, such as cooking and smoking, can increase the PAH levels (Garcia-Falcon et al., 1999; Knize et al., 1999). In the literature, a lot of data are reported on the PAH contamination due to the smoking process of different food products (Anastasio et al., 2004; Jira, 2004; Moret et al., 1999).

It is well known that PAH are present in smoke, and that they are easy deposited on and can penetrate the food surface during traditional smoking. The actual level in smoked foods is dependent on several variables in the smoking process, including type of smoke generator, combustion temperature, and degree of smoking (Larsson, 1982).

The most famous and most studied PAH benzo(a)pyrene (BaP) historically has been used as a reference indicator compound for carcinogenic PAHs.

The European Commission has recently introduced maximum levels for PAHs in certain foodstuffs via Commission Regulation No. 1881/2006. The maximum level of benzo(a)pyrene 5 ng g^{-1} was set for the smoked meat and smoked fish products, serving as a marker for the presence of other PAHs in food. However, according to the Commission Recommendation 2005/108/EC, further analyses of the relative proportions of 15 PAHs (benz(a)anthracene, benzo(b)fluoranthene, benzo(j)fluoranthene, benzo(k)fluoranthene, benzo(g,h,i)perylene, benzo(a)pyrene, crysene, cyclopenta(c,d)pyrene, dibenz(a,h)anthracene, dibenzo(a,e)pyrene, dibenzo(a,h)pyrene, dibenzo(a,i)pyrene, dibenzo(a,l)pyrene, indeno(1,2,3-cd)pyrene, and 5-methylchrysene) in foods are necessary, to inform a future review of the suitability of maintaining benzo(a)pyrene as a marker, by 1 April 2007.

This study aims to fulfill the requirements of the Commission Recommendation 2005/108/EC by providing data on the occurrence of PAHs in relevant foodstuffs available on the Latvian market. Reduction of PAHs by exposure to UV radiation was also investigated.

Materials and Methods

Chemicals

For the sample preparation, cyclohexane (Electron Capture Detector tested), N,N-

dimethylformamide, methanol (High Performance Liquid Chromatography purity grade), and sodium chloride (American Chemical Society (ACS) purity grade) were purchased from Acros, ethanol - from J.T.Baker, sodium sulphate (ACS grade) - from Fluka, potassium hydroxide - from Avsista, and Silica solid phase extraction (SPE) tubes (500mg) - from Phenomenex. Ultra pure water was obtained with a MilliQ filter system. Mixture of 15 PAH standards: benz(a)anthracene (BaA), benzo(b)-fluoranthene (BbF), benzo(j)fluoranthene (BjF), benzo(k)fluoranthene (BkF), benzo(g,h,i)perylene (BghiP), benzo(a)pyrene (BaP), crysene (CHR), cyclopenta(c,d)pyrene (CPP), dibenz(a,h)-anthracene (DahA), dibenzo(a,e)pyrene (DaeP), dibenzo(a,h)pyrene (DahP), dibenzo(a,i)pyrene (DaiP), dibenzo(a,l)pyrene (DalP), indeno(1,2,3-cd)pyrene (IcdP), 5-methylchrysene (5MC), and deuterted standard benzo(a)pyrene-d_{12} were purchased from Dr. Ehrenstrofer. The standard mix of PAHs consisted of a solution in acetonitrile with concentration of 50 mg l^{-1}, and the concentration of deuterated benzo(a)pyrene-d_{12} dissolved in cyclohexane was 1000 ng μl^{-1}. Mixtures were stored at 4 C.

Preparation of samples

7 samples of smoked meat, 18 samples of smoked fish and 49 samples of canned fish were thoroughly homogenized. A totally of 25 g of samples were placed into a round bottomed flask, and 12 g of potassium hydroxide and 100 ml of ethanol were added. Then, 25 μl of internal standard benzo(a)pyrene-d_{12} solution with concentration of 10 ng μl^{-1} and 125 μl of PAH mix with concentration of 1 ng μl^{-1} were added, and the mixture was subjected to an alkaline treatment with potassium hydroxide and ethanol by heating for 2 h (40 °C) under reflux and filtered. After allowing the contents to cool to room temperature, the solution was transferred to a 500 ml separating funnel, and 100ml of water and 100ml of cyclohexane were added. The funnel was shaken and the layers were allowed to separate. The ethanol/water phase

was transferred into a 250 ml separating funnel and shaken with another 50 ml of cyclohexane. The ethanol/water phase was discarded and the cyclohexane phases were combined. The cyclohexane solution was washed successively with 50 ml × 2 of water, 50 ml of methanol/water (4:1) and 50 ml × 2 of water. The cyclohexane extract was shaken with 50 ml of N, N-dimethylformamide/water (9:1) solution. The layer of N, N-dimethylformamide/water solution was transferred into a 250 ml separating funnel; 50 ml of 1% NaCl solution were added, and PAHs were extracted with 75 ml of cyclohexane. The cyclohexane phase was dried over anhydrous sodium sulphate and concentrated by rotary evaporator under reduced pressure (40 C, 235 mbar). The extract (3 ml) was applied to a Silica SPE column previously conditioned with cyclohexane (5 ml). The flask was rinsed with cyclohexane (3 ml), and the PAHs were eluted with 6 ml (3 ml × 2) cyclohexane. The collected fraction was evaporated under a light stream of nitrogen at 40 C temperature, dissolved in 50 μl of cyclohexane and transferred into a GC vial.

Gas chromatography with mass selective detector (GC-MS)

A Hewlett Packard Model 6890 gas chromatograph equipped with a Model 5973 mass selective detector was employed for analysis. Operating conditions were as follows: Varian Factor Four capillary column - 30m × 0.25 mm with film thickness of 0.25 μm; helium carrier gas - 1 cm^3 min^{-1}; injector and detector temperature - 280 C; temperature program: 120 C (1 min), 120→ 250 C (15 C/min), 250 C (13 min), 250→ 280 C (20 C/min), 280C (1 min), 280→ 300 C (35 C), 300 C (20 min). Total run time was 45.74 min. The ionizing voltage was 1941 V. Then, 1μl of the sample solution was injected into gas chromatograph. The data were acquired operating the MS in selected ion monitoring mode. Peak spectra were compared to the mass spectra of PAH standards and library supplied with the instrument. The MS detector acquisition parameters are summarized in Table1.

Table 1

MS detector data acquisition parameters

Detection time, min	Ions monitored (m/z)
6.00 − 20.00	226, 228, 242
20.01 − 32.00	250, 252, 264, 276, 278
32.01 − 45.74	150, 302

It was not possible to separate BbF and BjF form using this methodology. These compounds were determined together as the sum.

UV irradiation of PAHs

The fish samples were placed in UV chamber (DRT 400, 400W) and irradiated at 254 nm (30 cm distance from a UV source) for 0-15min. The standard solution of BaP with concentration of 10 ng μl^{-1} was placed on glass Petri dish in UV chamber and irradiated for 0-30 min.

Results and Discussion

Levels of PAHs in smoked products

The smoked food products, including smoked fish, canned smoked fish and smoked meat, analysed in this survey were purchased from Latvian market. The levels of 15 polycyclic aromatic hydrocarbons were investigated. After clean up and extraction procedures, the samples were analyzed by gas chromatography-mass spectrometry. The limits of detection for all compounds were <0.1 μg kg^{-1}.

Table 2 shows the contamination of PAHs in canned fish products. Almost all 15 PAHs were quantified in the examined canned fish samples, except DahP. Minimum, maximum and median

Table 2

Polycyclic aromatic hydrocarbon (PAH) concentrations [a] in canned fish products (μg kg^{-1})

PAH	'Sprats' in oil ($n = 20$)		Pate of 'Sprats' ($n = 10$)		Fish noisette in tomato sauce ($n = 3$)		Baltic herring in tomato sauce ($n = 3$)		'Sprats' in tomato sauce ($n = 4$)		Baltic herring in oil ($n = 9$)	
CPP	0.24-20	(3.0)	ND-24	(2.3)	0.40-5.8	(3.1)	0.89-14.0	(5.5)	0.25-4.6	(1.1)	0.50-9.6	(0.88)
BaA	0.59-25	(2.8)	0.11-9.5	(1.7)	0.34-3.1	(1.6)	1.3-7.0	(3.1)	0.34-2.6	(1.1)	0.63-6.7	(1.5)
CHR	0.66-33	(2.7)	0.14-8.8	(1.7)	0.35-2.4	(1.4)	1.2-6.3	(2.8)	0.36-2.3	(1.0)	0.70-6.7	(1.5)
5MC	ND-2.3	(0.39)	ND-1.6	(0.20)	0.07-0.50	(0.25)	0.21-0.89	(0.31)	0.12-0.68	(0.26)	0.11-1.2	(0.41)
BbF + BjF	ND[b]-12.1	(1.8)	ND-7.8	(1.1)	0.75-2.7	(1.7)	0.57-5.7	(1.1)	ND-1.7	(0.71)	0.51-3.9	(0.59)
BkF	0.64-5.2	(1.7)	0.18-6.1	(1.1)	1.2-4.4	(1.8)	0.93-3.4	(1.2)	1.1-2.8	(1.9)	0.31-2.7	(0.98)
BaP	0.85-13.8	(2.4)	ND-14	(1.6)	0.59-3.0	(1.8)	0.79-9.6	(3.2)	0.94-2.3	(1.3)	0.68-8.0	(0.74)
IcdP	ND-3.6	(0.67)	ND-4.8	(0.37)	ND-0.33	(0.17)	ND-1.9	(0.57)	ND-0.43	(0.11)	0.13-2.0	(0.22)
DahA	ND-0.54	(ND)	ND-0.55	(ND)	ND	(ND)	ND	(ND)	ND	(ND)	ND-0.28	(ND)
BghiP	ND-5.1	(0.77)	ND-5.9	(0.51)	ND-0.71	(0.25)	ND-3.5	(1.5)	ND-0.80	(0.21)	0.18-2.2	(0.29)
DalP	ND-0.48	(ND)	ND-2.9	(ND)	ND	(ND)	ND	(ND)	ND	(ND)	ND-0.49	(ND)
DaeP	ND-0.10	(ND)	ND-0.29	(ND)	ND	(ND)	ND	(ND)	ND	(ND)	ND-0.06	(ND)
DaiP	ND-0.10	(ND)	ND-0.14	(ND)	ND	(ND)	ND	(ND)	ND	(ND)	ND	(ND)
DahP	ND	(ND)	ND	(ND)	ND	(ND)	ND	(ND)	ND	(ND)	ND	(ND)
Σ_{PAH}	4.6-104	(17)	0.68-78	(10.6)	3.7-22.9	(12.1)	5.9-52	(19)	3.8-18	(7.3)	4.8-44	(6.6)

[a] Min.-max. (median).

[b] ND, below detection limit (0.1 μg kg^{-1}).

values of individual compounds and of the sums of 15 PAHs are given for each set of samples.

As shown, the concentrations of BaP and total PAHs in the canned fish samples ranged between not detectable and 14 μg kg^{-1} and 0.68-104 μg kg^{-1}, respectively, with CPP, BaA and CHR consistently being the most abundant compounds. DahA, DalP, DaeP, DaiP, and DahP were not found in canned fish samples in tomato sauce.

However, as we can see from Table 2, there is a large variability in PAH levels for samples of the same type, thus the contamination level is not strongly correlated with the type of product.

The smoked fish samples contained no detectable up to 13 μg kg^{-1} amounts of BaP and 0.26-94 μg kg^{-1} of total PAHs. Samples of smoked 'Sprats' and Baltic herring showed the highest PAH levels in this study (see Fig. 1). The somewhat higher levels for hot smoked 'Sprats' and Baltic herring could be explained by its large surface to weight ratio. The higher PAH concentrations in smoked tench in comparison to smoked perch could be because tenches are more fatty fishes, and PAHs trend to form in products with higher content of fat.

In general, the predominating PAHs in smoked fish were compounds with lower molecular-weight (BaA, CHR, and CPP). In cold smoked mackerel we found very low content of PAHs

and determined only BaA, CHR, and BkF, with concentrations close to the detection limit. However in hot smoked fish products concentrations of CPP, BaA and CHR mainly were higher than concentrations of other PAHs, in hot smoked perch these PAHs were below detection limit and only BbF+BjF, BkF and BaP were found close to the detection limit.

DahP and DaiP were not found in any of smoked fish samples, but DalP, DaeP and DahA were found in samples of smoked 'Sprats' and Baltic herring in very low levels.

The PAH levels found in smoked meat products from Latvian market are listed in Table 3. Minimum, maximum, mean and median values of individual compounds and total PAH are given for each species. The concentration of BaP and total PAH varied between 0.26-25 μg kg^{-1}and 1.7-197 μg kg^{-1}, respectively. Results of analysis show the great differences in PAHs concentrations in samples of the same type. Probably, the effect is due to differences in smoking technology.

To verify whether there are significant statistical correlation between BaP concentration and total PAHs concentration, all the data from the smoked fish and meat samples were submitted to linear regression analysis. Fig. 2 shows the regression lines obtained by plotting BaP concentrations against total PAH concentrations.
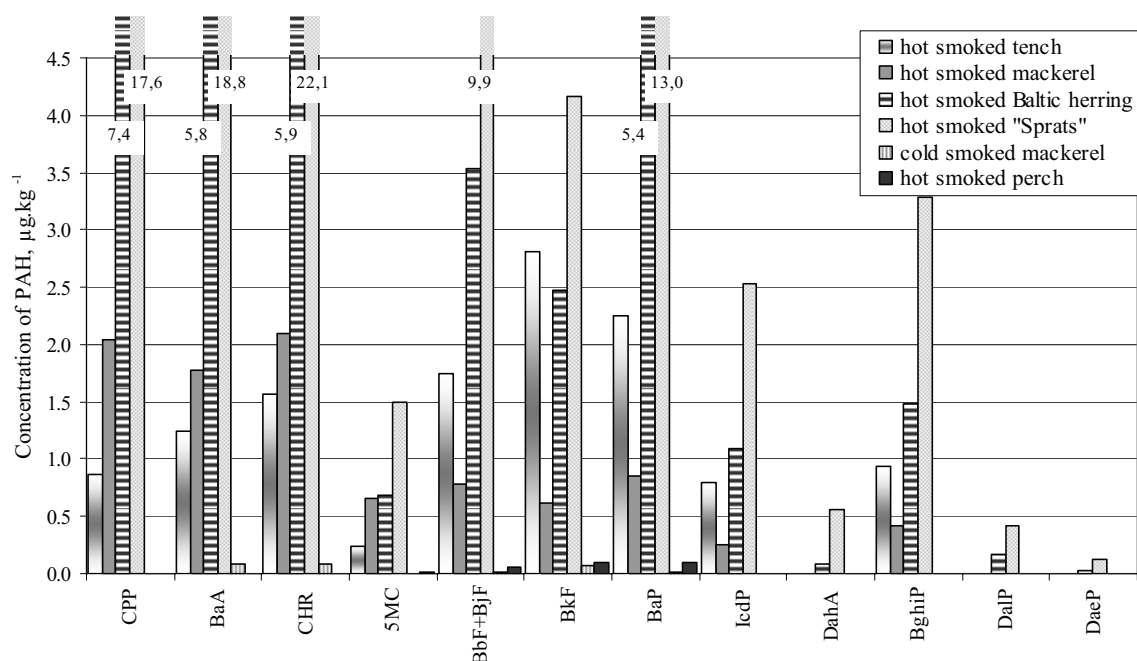

Figure 1. Mean concentrations of PAH in smoked fish products.

Table 3

Polycyclic aromatic hydrocarbon (PAH) concentrations in smoked meat products (μg kg^{-1})

PAH	Smoked chicken products ($n = 3$)			Smoked pork products ($n = 4$)		
	Min.-max.	Mean	Median	Min.-max.	Mean	Median
CPP	0.97-43	16	4.3	0.33-11.7	3.3	0.62
BaA	1.1-38	15	7.1	0.29-5.3	1.8	0.75
CHR	1.5-40	17	9.3	0.27-6.7	2.3	1.1
5MC	0.13-0.65	0.30	0.13	ND-0.76	0.20	ND
BbF+BjF	3.3-22	9.7	4.4	0.21-3.8	1.2	0.35
BkF	2.0-9.4	4.6	2.5	0.34-1.4	0.71	0.56
BaP	4.2-25	11.9	6.2	0.26-3.4	1.1	0.39
IcdP	1.4-9.1	4.5	3.0	ND-1.5	0.41	0.09
DahA	ND-1.3	0.60	0.50	ND-0.26	0.07	ND
BghiP	1.7-10.2	5.0	3.0	ND-1.6	0.55	0.28
DalP	ND-1.2	0.43	0.06	ND	ND	ND
DaeP	ND-0.29	0.10	ND	ND	0.10	ND
DaiP	ND-0.26	0.09	ND	ND	0.09	ND
DahP	ND	ND	ND	ND	ND	ND
ΣPAH	16-197	85	43	1.7-36	11.6	4.5

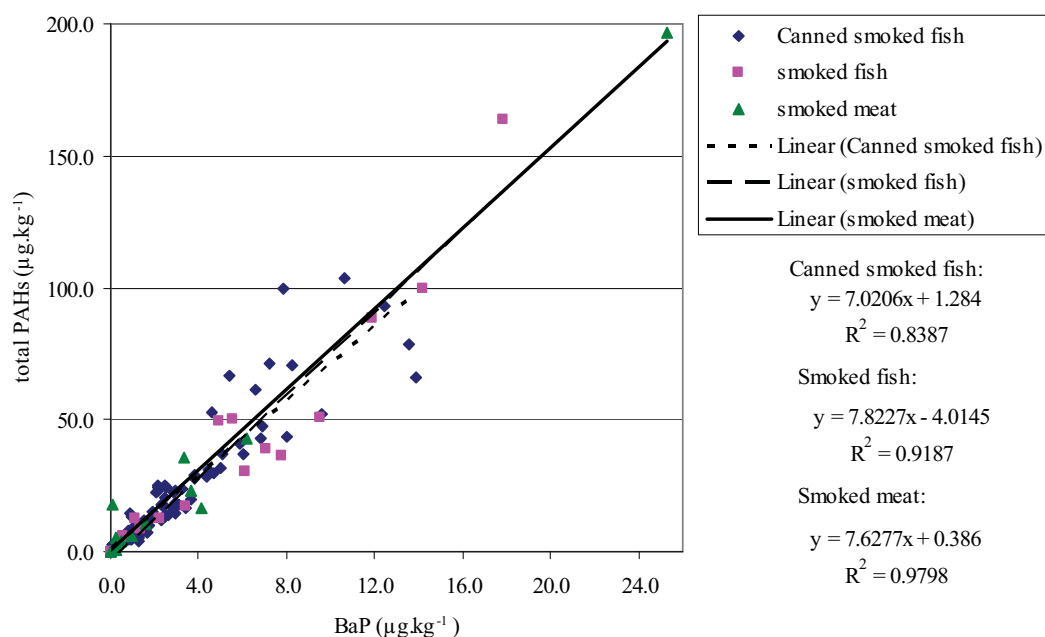[a] ND, below detection limit (0.1 μg kg^{-1}).

Figure 2. Correlation between BaP and total PAH concentration (linear regression analysis).
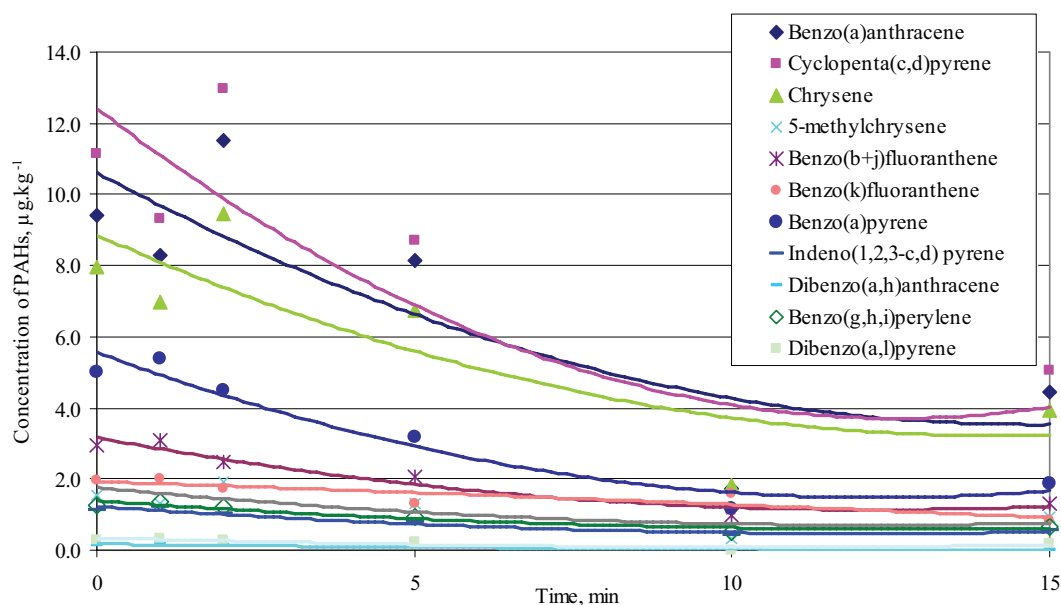
Figure 3. The dependence between the decrease in PAHs concentration in smoked fish and the exposure time under UV lamp.

There was strong correlation for smoked meat products and also significant for smoked fish products, however the R^2 value for canned smoked fish products was 0.84. In general, to simplify analytical control ensuring adequate consumer protection, using of BaP as a marker for the determination of total genotoxic PAH seams to be a good solution, however in some cases the deviations are high.

Though, the European Food Safety Authority (EFSA) in recent findings on PAHs in food reported that crysene was the most problematic compound with 22% of positives in samples negative for benzo(a)pyrene and the assumption that benzo(a)pyrene is a good indicator of any PAH contamination was proved dubious. EFSA found also that benzo(c)fluorene had the second highest maximum of almost 27 μg kg^{-1} in a sample testing negative for banzo(a)pyrene (EFSA, 2007). We found 3 positive samples of crysene with highest concentration 0.28 μg kg^{-1} in samples negative for benzo(a)pyrene, but also 3 positives samples of benzo(a)pyrene with highest concentration 0.21 μg kg^{-1} in samples negative for crysene. However the total PAH concentrations in all these samples were low.

In general, in about 2-20% of the smoked products, the content of BaP was below detection limit and 60-85% of samples contained less than 5.0 μg kg^{-1} BaP, which is maximum permitted level in EU. Though, 12-33% of samples exceeded the legal limit. This suggests that companies producing these types of products should regulary control the levels of PAHs in their production. Thus, action on the part of the producers as well as of the authorities is still needed to monitor this situation.

Effect of UV irradiation on PAHs in smoked fish

PAHs are mostly concentrated on the skin of smoked fish products (Larsson, 1982) and it is an effective barrier against PAH penetration in the inner tissue (Moret et al., 1999). As well sometimes after smoking process smoked fish products have been hanged in sun, thus we checked sensitivity of PAHs to the photochemical effects of UV irradiation and decrease of PAHs in smoked fish.

Photolysis and microbial degradation are the main processes for eliminating PAHs (Miller et al., 1988; Sabate et al., 2001). According to their chemical structures, PAHs readily absorb sunlight and ultraviolet radiation (Chen et al., 2001; Nico et al., 1987). PAHs with a high molecular weight tend to photolysis faster, but chemically derivatized samples are more resistant to photolysis (Chen et al., 2001; Sabate et al., 2001). Bernstein et al. (1999) demonstrated that PAHs are converted to alcohols, ketones and ethers by oxidation of peripheral carbon atoms
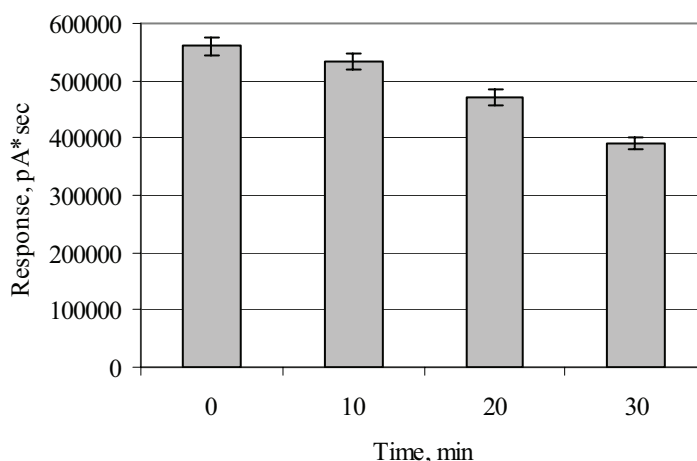
Figure 4. The dependence between the decrease in BaP concentration in standard solution and the exposure time under UV lamp.

when they are exposed to UV radiation in ice. These compounds are also constituents of smoke (Toth and Potthast, 1984).

In our study smoked fish samples were placed under UV lamp and exposed to UV irradiation 0-15 min. PAH contents in the smoked fish were measured after 1, 2, 5, 10, and 15 min. Significant decrease in carcinogenic PAH content in smoked fish was found (see Fig. 3). After 2 min the decrease of BaP content was already 10%, but residual PAHs in smoked fish samples were 37-64% after a 15 min treatment. Among the 11 selected PAHs, BaP was found to be the most sensitive to UV radiation.

However, by UV irradiation of BaP standard solution, the decrease in BaP concentration was not so quick (see Fig. 4). After 30 min treatment, the concentration of BaP has dropped by 30%. Apparently, degree of decrease of PAHs depends not only on the duration of exposure, but also on other factors, which can be type and concentration of sample and diffusion of PAHs, that occur not only during the smoking time, but also after finishing of smoking procedure. However, the specific mechanism that controls this process will require further investigation.

Conclusions

The PAH content in smoked fish and meat products was found to be at very different levels, thus the contamination level is not strongly correlated with the type of product. The analyzed samples contained BaP levels ranging from <0.1 to 25 μg kg^{-1} and total PAH varied between 0.26 and 197 μg kg^{-1}. The CPP was the most represented among PAH, followed by BaA, and CHR in all samples.

PAHs in smoked fish products may be eliminated by UV radiation, but further investigations are necessary to avoid possible toxicity of oxidized compounds.

References

1. Anastasio A., Mercogliano R., Vollano L., Pepe T., Cortesi M.L. (2004) Levels of Benzo(a)pyrene (BaP) in 'Mozzarella di Bufala Campana' cheese smoked according to different procedures. Journal of agricultural and food chemistry, 52, pp. 4452-4455.
2. Chen B.H., Chen Y.C. (2001) Formation of polycyclic aromatic hydrocarbons in the smoke from heated model lipids and food lipids. Journal of agriculture and food chemistry, 49, pp. 5238-5243.
3. Commission Recommendation 2005/108/EC of 4 February 2005 on the further investigation into levels of polycyclic aromatic hydrocarbons in certain foods, Official Journal of European Union (2005), L 34, 43.
4. Commission Regulation (EC) No. 1881/2006 of 19 December 2006 setting maximum levels for certain contaminants in foodstuffs, Official Journal of European Union, L 364/5.
5. European Food Safety Authority (2007) Findings of the EFSA Data Collection on Polycyclic aromatic Hydrocarbons in Food, A report from the Union of Data Collection and Exposure on a request from European Commission.

6. Garcia-Falcon M.S., Gonzalez Amigo S., Lage Yusty M.A., Simal Lozano J. (1999) Determination of benzo(a)pyrene in some Spanish commercial smoked products by HPLC-FL. Food Additives and Contaminants, 16, pp. 9-14.

7. Howard J.W., Fazio T. (1980) Polycyclic aromatic hydrocarbons in foods. Journal of the Association of Official Analytical Chemists, 63, pp. 1077-1104.

8. Jira W. (2004) A GC/MS method for the determination of carcinogenic polycyclic aromatic hydrocarbons (PAH) in smoked meat products and liquid smokes. European Food Research Technologies, 218, pp. 208-212.

9. Knize M.G., Salmon C.P., Pais P., Felton J.S. (1999) Food heating and the formation of heterocyclic aromatic amine and polycyclic aromatic hydrocarbon mutagens/carcinogens. Advances in experimental medicine and biology, 459, pp. 179-193.

10. Larsson B.K. (1982) Polycyclic aromatic hydrocarbons in smoked fish. Zeitschrift für Lebensmittel-Untersuchung und Forschung, 174, pp. 101-107.

11. Lijinsky W. (1991) The formation and occurrence of polynuclear aromatic hydrocarbons associated with food. Mutation Research, 259, pp. 251-261.

12. Miller R.M., Singer G.M., Rosen J.D., Bartha R. (1988) Photolysis primes biodegradation of benzo(a)pyrene. Applied Environmental Microbiology, 54, pp. 1724-1730.

13. Moret S., Conte L., Dean D. (1999) Assessment of polycyclic aromatic hydrocarbon content of smoked fish by means of fast HPLC/HPLC method. Journal of agricultural and food chemistry, 47, pp. 1367-1371.

14. Nico D.K., Schouten T., Gerrit H.D., Van Der Stegen A. (1987) Rapid determination of benzo(a)pyrene in rosted coffee and coffee brew by high-performance liquid chromatography with fluoriscence detection. Journal of agricultural and food chemistry, 35, pp. 545-549.

15. Sabate J., Bayona J. M., Solanas A.M. (2001) Photolysis of PAHs in aqueous phase by UV irradiation. Chemosphere, 44, pp. 119-124.

16. Toth L., Potthast K. (1984) Chemical aspects of the smoking of meat and meat products. Advances in food research, 29, pp. 87-158.

ASSESSMENT OF FOOD SAFETY RISKS IN CATERING ESTABLISHMENTS

Aija Melngaile, Daina Karklina
Latvia University of Agriculture
E-mail: aija.melngaile@pvd.gov.lv
E-mail: daina.karklina@llu.lv

Abstract

The aim of the research was to assess food safety risks in catering establishments. To analyse food safety risks during production and distribution of ready-to-eat food in catering establishments, internal database of the Food and Veterinary service of the Republic of Latvia was used. Catering establishments, food items, technological processing methods, as well as environmental objects were encoded to perform mathematical analyses of state's monitoring and surveillance data. The probability of the microbiological risk factors coliforms and *S.aureus* in food and environmental samples as well as the total plate count in ready-to-eat food was assessed to forecast common risks in catering establishments and to set hygiene management priorities in frame of HACCP procedures. For estimation of individual risk factors, results were statistically analysed using SPSS statistical package and a $p < 0.05$ was considered to be statistically significant. The significant differences were established between certain bacteria presence in food and such factors as food group, method of technological processing, and type of catering establishment. The results on bacterial contamination of food correlate with the results on contamination of environmental objects. The research suggests that control of food safety risks that is built on testing of pathogenic bacteria is not effective enough to evaluate actual level of implementation of hygiene measures in catering establishments. Risk assessment during routine monitoring both in state's official control level and catering establishments' self-control level should be concentrated on testing of hygiene indicator microorganisms rather than pathogenic microorganisms to establish and prevent food safety risks.

Keywords: risk assessment, catering, HACCP, microbiological criteria.

Introduction

Emergence of food-borne infection outbreaks is characterized as a mutual interaction of three principal factors – pathogenic organism, host, and environment. In spite of development of food science and food production technology, food-borne illnesses cause public health problems even in developed countries. Results of the research on food-borne infection prevalence suggest that on average 10 – 15% of population suffer from food-borne infections in developed countries each year (Luning et al., 2006). According to statistical data, food poisonings are mainly caused by pathogenic bacteria (Luning et al., 2002; Sprenger, 2004).

In view of periodical outbreaks of food-borne infections, significance of preventive food safety assurance strategies has greatly increased during last decades. Hazard identification is required in EU food legislative acts as the first step in application of HACCP principles to prevent or eliminate hazards, or to reduce them to acceptable levels (Meulen and Velde, 2004). Considering implementation of HACCP procedures, risk-based approach is generally advised to establish specific procedures for effective management of food safety hazards (Luning et al., 2006; Rico et al., 2005).

When pathogenic microorganisms enter food, food products can become unsafe without any sign of spoilage or change of sensory properties. To control food safety hazards, new technological and/or process management approaches are developed and applied in food establishments (Luning et al., 2002; Luning et al., 2006). System approach for assurance of microbiological safety of ready-to-eat food including hygiene monitoring tests and food safety surveillance tests is recommended also in catering area.

In opposition to food manufacturing enterprises, the large majority of catering establishments can be characterized as small, dynamic and changeable business companies. It is believed that introduction of HACCP approach is more difficult in catering establishments in comparison with food manufacturing enterprises because many simultaneous processes occur together in kitchen area during a working day. It is commonly considered that the effective food quality assurance system should concentrate on providing of correct working procedures to ensure end products of high quality and safety level. To establish and evaluate both technological procedures and hygiene procedures in catering

establishments, hazard identification and risk assessment should be taken into account. It is generally recommended to make sure about characteristic risks in frame of specific business, including consideration of risks, implementation of procedures to control risks, and obtaining necessary evidences to demonstrate the control of identified risks (Airey and Greaves, 2005).

Materials and Methods

The probability of the individual risk factors coliforms and *S.aureus* in food and environmental samples as well as the total plate count in ready-to-eat food was assessed to forecast common risks in catering establishments and to set hygiene management priorities in frame of HACCP procedures. To analyse food safety risks during production and distribution of ready-to-eat food in catering establishments, internal database of the Food and Veterinary service of the Republic of Latvia was used.

During the time period of 2002–2004, in total 17 192 food samples were taken in catering establishments in the frame of state's monitoring and surveillance program to control presence of certain bacteria in food, including 3152 food samples were taken and analysed to assess the total plate count in ready to eat foods, 4481 food samples were taken and analysed to detect the presence of coliforms, 2138 food samples were taken and analysed to detect the presence of *S.aureus,* and 5283 food samples were taken and analysed to detect the presence of *Salmonella* spp. in food.

During the time period of 2002–2004, in total 17604 swab samples were taken in catering establishments in the frame of state's monitoring and surveillance program to control the presence of certain bacteria on environmental surfaces, including 8934 swab samples were taken and analysed for presence of coliforms, 5113 swab samples were taken and analysed for presence of *S.aureus,* and 3385 swab samples were taken and analysed for presence of *Salmonella* spp.

Food and swab sample microbiological testing was done in laboratories of the National Diagnostic Centre according to accredited methods: aerobic plate count in food was detected according to the standard method LVS EN ISO 4833:2003, coliforms in food were detected according to the standard method ГОСТ Р50474-93, coagulase-positive *S.aureus* in food and swab samples were detected according to the standard method LVS EN ISO 6888-1:1999/A1:2003, *Salmonella* spp. in food and swab samples were

detected according to the standard method LVS EN ISO 6579:2003, and coliforms in swab samples were detected according to the method VVMDC-T-012-010.2-2000.

During the research done by the authors, catering establishments, food items, technological processing methods, as well as environmental objects were encoded to perform mathematical analyses of state's monitoring and surveillance data. For estimation of individual risk factors, results were statistically analysed using SPSS statistical package and a $p < 0.05$ was considered to be statistically significant. The Chi-square tests were used to determine association between coliforms and *S.aureus* presence in food samples and various factors, including such factors as the food group, the method of food technological processing, and the type of catering establishment. Chi-square tests were also used to determine association between coliforms and *S.aureus* presence in swab samples and various factors, including the type of catering establishment and the type of environmental surface. The Post Hoc Tests were performed to establish relationship between the total plate count in certain food samples and the food group, as well as relationship between the total plate count in food samples and the method of technological processing of food. The Chi-square Tests and the Post Hoc Tests were used to conclude about the repeatability of the bacteria testing results taking into account the probability of bacterial contamination.

Results and Discussion

Mathematic Analyses of Food Testing Results

The results of the Multivariate analyses suggest that the total plate count in ready-to-eat food is dependent on the interaction of two factors – the group of food and the year of taking food samples ($p = 0.000$). During research, significant differences were established between the total plate count of bacterial cells and the food group but no difference was established between the total plate count and the year of taking food samples ($p = 0.416$). The results suggest that the total plate count is a rather constant parameter that is specific for each identified food group and has not changed significantly during the time period of 2002-2004. The highest deviations for the total plate count were observed in such food groups as pork food, cold meat refreshments, pasta food with meat components, farinaceous food with meat components and soups with meat components, grouts food with meat components

or without meat, pastry, cold curd dishes, egg dishes, and milk products. The highest values of the total plate count were observed both for salads made with products of animal origin and salads made from products of plant origin, pastry, cold curd dishes, but the lowest values of the total plate count were established for beef dishes, vegetable dishes, and vegetarian soups (Figure 1).

The results of the research suggest that there is a significant difference between different food groups and presence of coliforms in food samples ($p = 0.000$) and between food groups and presence of *S.aureus* in food samples ($p = 0.000$). The results indicate that in the case of coliforms the high proportion of positive food samples was established for both salad types – salads that were made with products of animal origin and salads made from products of plant

origin. Presence of coliforms in food samples was often detected for pastry, chilled meat and fish refreshments, pasta food with meat component, desert food, and chilled curd foods. It should be mentioned that coliforms were detected in many thermally processed foods that suggests about cross-contamination of ready-to-eat food due to unhygienic storage conditions and/or time/temperature abuse during storage. In case of pasta food, vegetable food, farinaceous food and soups, the highest proportion of coliforms positive food samples was established for food that was made with meat components. The highest proportion for *S.aureus* positive food samples was established for pasta food made with addition of meat component. High and equivalent *S.aureus* contamination risk was observed in case of salads made both with products of animal
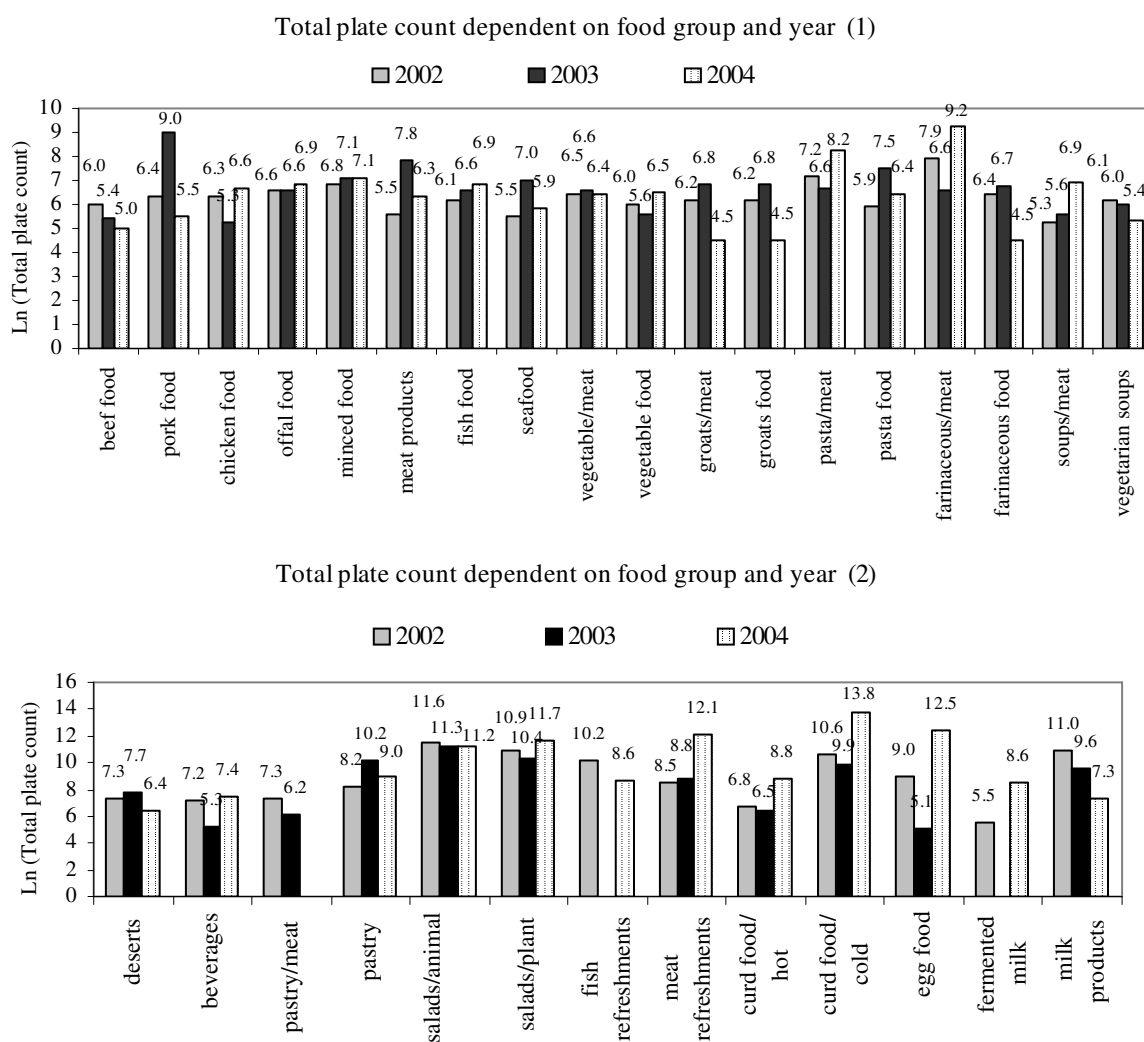

Figure 1. Interconnection between total plate count, food group and year.

origin and with products of plant origin (Figure 2).

The results of the research indicate that in most food groups where coliforms were found, *S.aureus* also was detected. The results suggest that the main food safety risks in catering establishments arise due to both inadequate cleaning of food contact surfaces and poor personnel hygiene.

The results of the Multivariate analyses suggest that the total plate count is not dependent on the interaction of two factors – the method

of food technological processing and the year of taking food samples ($p = 0.075$). At the same time the results of the research suggest that there is a significant difference between the total plate count and method of technological processing ($p = 0.000$) as well as there is a significant difference between the total plate count and the year of taking samples ($p = 0.003$). The results demonstrate that the method of thermal processing has a significant impact on the total plate count; nevertheless, this impact is not related to the year of taking of samples. The total
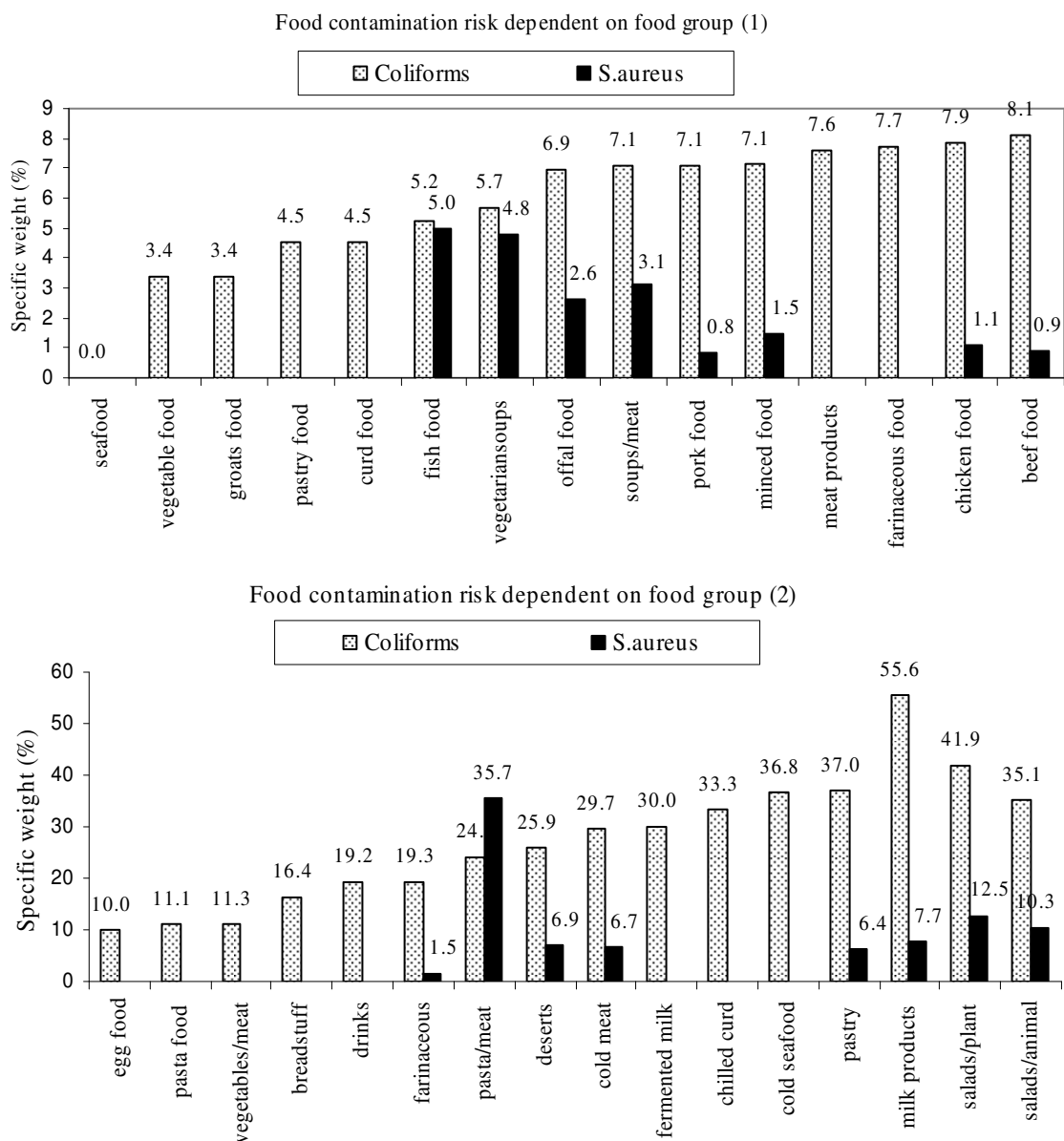

Figure 2. Presence of coliforms and *S.aureus* in food dependent on the group of food.

plate count is rather dependent on technological and organizational aspects of food preparation and distribution in catering establishments (for example, establishment and adequate application of food processing methods, adequate functioning of technological equipment, adequate knowledge of food service personnel or adequate setting and control of process parameters), and for that reason no significant difference was observed during a three years period (Figure 3).

When different methods of technological processing were compared, highest values of the total plate count were observed for multistage technological processing methods, including technological chain that consists of thermal processing (boiling), mechanical processing, repeated thermal processing (boiling) and chilling of food, technological chain that consists of thermal processing (boiling), mechanical processing, thermal processing (frying), and baking of food, as well as in case of frying of food in the deep fat.

The highest values of the total plate count were established for salads, which components were mechanically processed after thermal processing and chilling, and salads that were prepared in a cold manner without thermal processing of components. Inconsistent values of total plate count were observed for raw meat products and pasteurised milk products. It should be mentioned that values of the total plate count for raw meat food often were comparable with values of the total plate count in salads that were mechanically processed after thermal processing and chilling. The results indicate that hygiene situation and time/temperature settings and control during food preparation processes do not eliminate both cross-contamination of food and multiplication of bacteria cells during food processing stages in catering establishments.

The results of the research suggest that there is also a significant difference between the method of technological processing and presence of coliforms in food samples ($p = 0.000$) and a significant difference between the method of technological processing and presence of *S.aureus* in food samples ($p = 0.000$). Similarly, as it was observed in case of the total plate count, the highest proportion of both coliforms positive food samples and *S.aureus* positive food samples was established for foods that should undergo multistage technological processing. Comparatively low coliforms and *S.aureus* contamination risk was established for the traditional basic cooking methods – boiling, frying, and braising. Both technological methods for salad preparation comprised a significant food contamination level regarding coliforms and *S.aureus* presence in food (Figure 4).
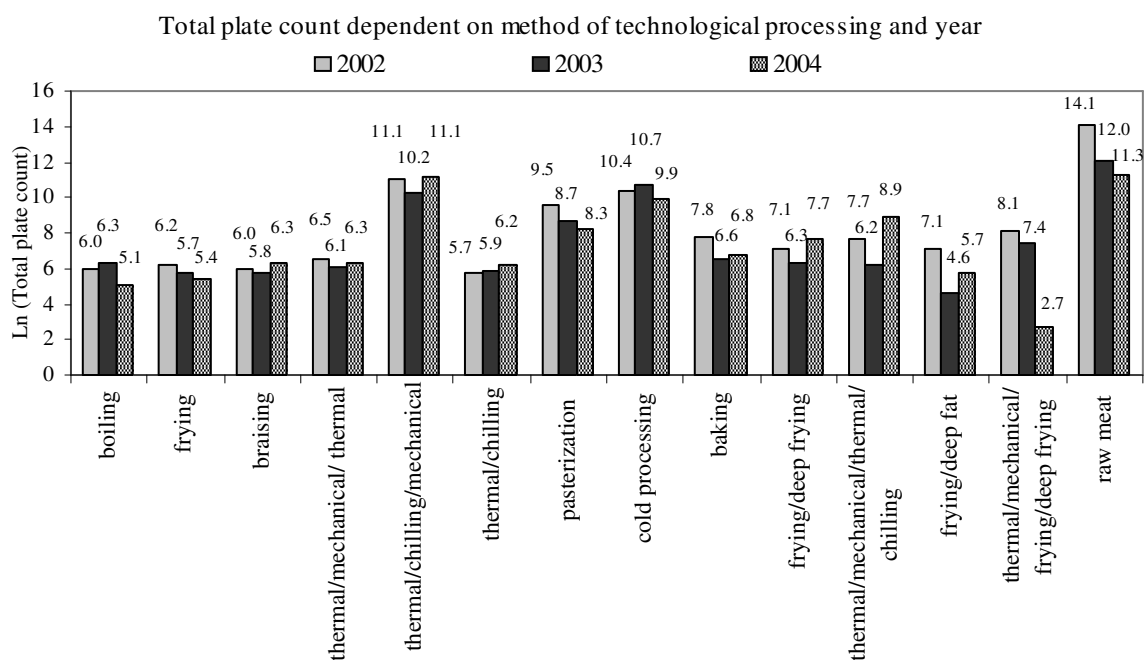

Figure 3. Interconnection between the total plate count, method of technological processing and year.
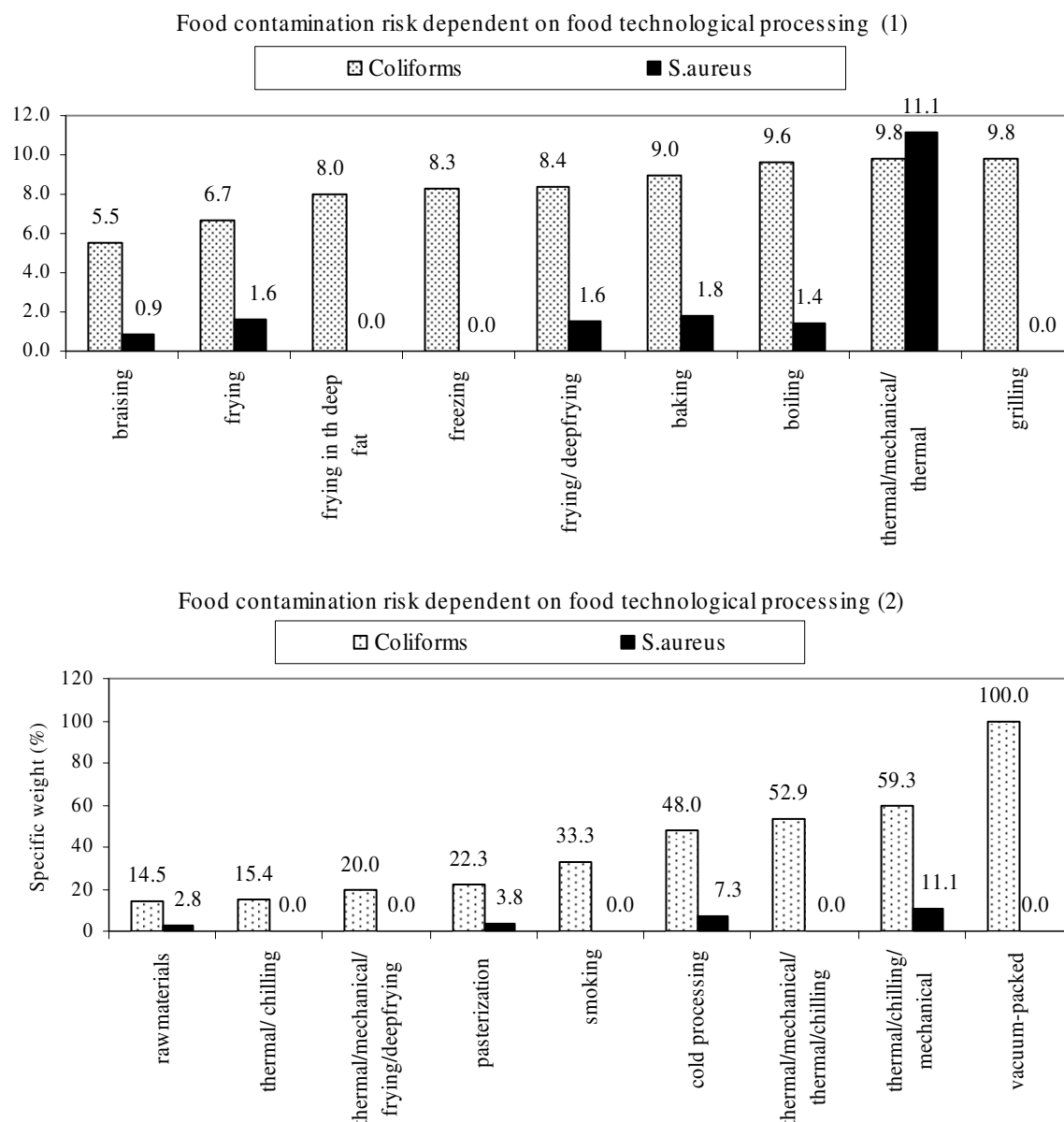
Food contamination risk dependent on food technological processing (1)

Food contamination risk dependent on food technological processing (2)

Figure 4. Presence of coliforms and *S.aureus* in food dependent on the method of technological processing.

Mathematic Analyses of Swab Testing Results

The results of the research suggest that there are significant differences with probability rate of 95% between 16 identified tips of environmental objects and coliforms or *S.aureus* presence on surfaces ($p = 0.000$). The rating of different surfaces suggests that coliforms most often are found on washing basin surfaces, but *S.aureus* – on surface of human hands. The greatest contamination risk due to transfer bacterial contamination to food and food contact surfaces must be associated with human hands (29.4%

positive samples in coliforms tests and 12.9% positive samples in *S.aureus* tests). It should be mentioned that all surfaces that come into contact with food – surfaces of cooling and processing equipment, as well as working surfaces of tables, surfaces of food primary processing inventory, and also surfaces of dishware drying and storage surfaces and cloth inventory – show positive testing results regarding coliforms in 20%-25% swab samples. Coliforms are found also on surface of food display inventory, on surface of different pots and food storage inventory. The results suggest that there is a great possibility for food

Contamination density of environmental objects
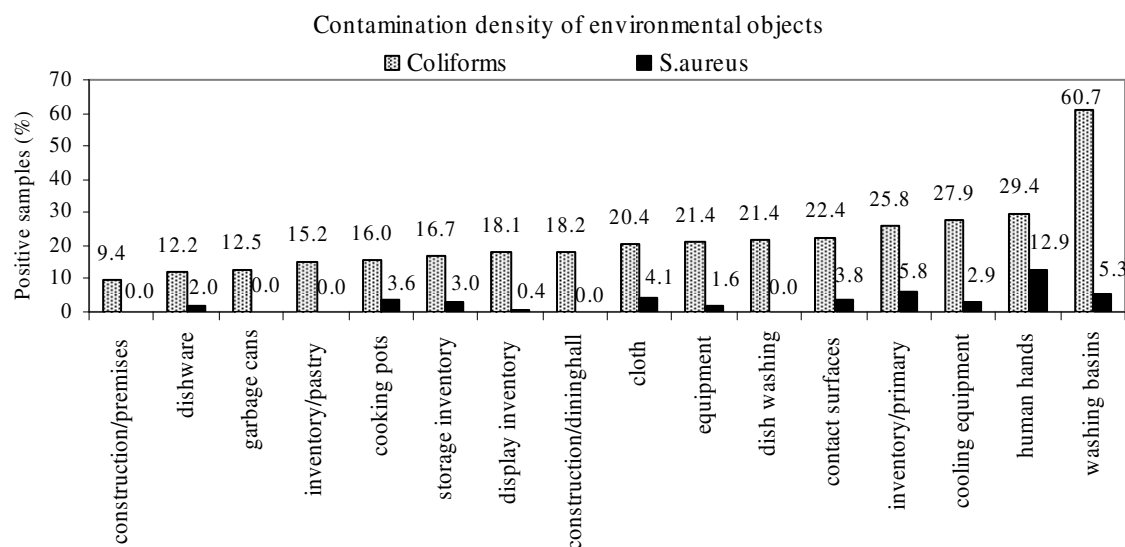
Figure 5. Contamination of environmental objects with coliforms and *S.aureus*.

contamination during food preparation, storage and display processes (Figure 5).

When environmental surfaces were divided into 187 different environmental objects, the significant differences with probability rate of 95% were found between surfaces and presence of coliforms in swab samples ($p = 0.000$) but significant differences were not found between objects and *S.aureus* bacteria presence in swab samples ($p = 0.150$). According to the classification done by the authors, positive results for testing of *E.coli* group bacteria were established in swab samples taken from 118 different environmental objects. The highest surface contamination rate concerning *E.coli* group bacteria was stated for surface of table in salad preparation area (74.1% positive samples), surface of knife for cutting raw vegetables (54.0% positive samples), surface of cutting board for cutting raw vegetables (46.1% positive samples), surface of glass for juice (44.8% positive samples), and surface of table in chilled food preparation

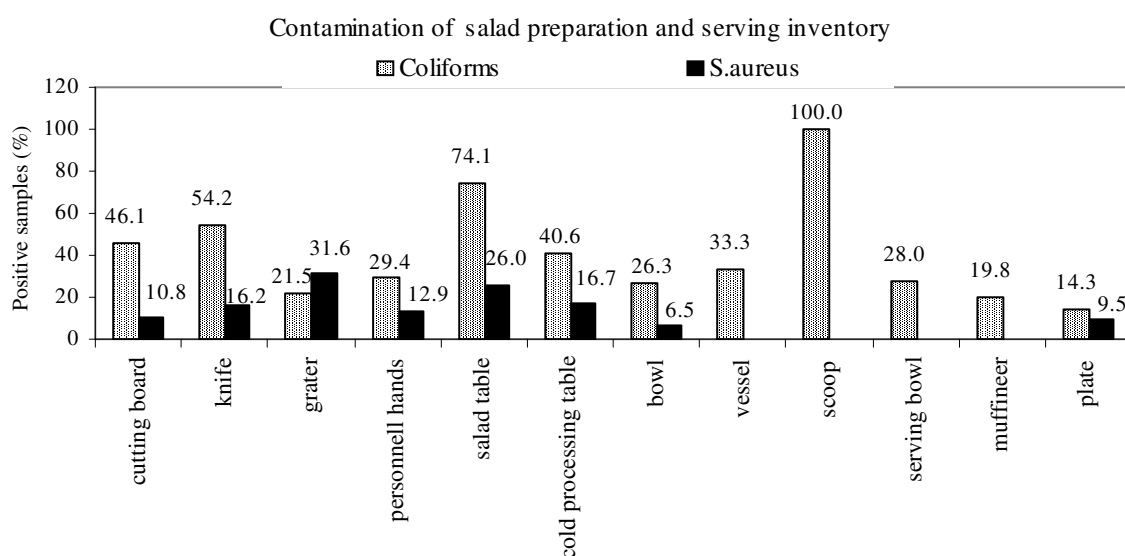Contamination of salad preparation and serving inventory

Figure 6. Potential spread of contamination during raw vegetable salad preparation chain.

zone (40.6% positive samples).

Positive results for testing of *S. aureus* were established in swab samples taken from 34 different environmental objects. The results of the mathematical analyses suggest that more often *S. aureus* were detected on surface of table in salad preparation area (26.0% positive samples), surface of table in chilled food preparation zone (16.7% positive samples), surface of glass for bear (16.7% positive samples), surface of knife for cutting raw vegetables (16.2% positive samples), and surface of glass for juice (14.3% positive samples). Nevertheless, the results indicate that *S. aureus* contamination can be also associated with other surfaces.

To characterize potential risk of contamination of raw vegetable salads during preparation, storage and presentation environmental risks were summarized and compared with specific risks in meat food preparation chain (Figures 6 and 7). The results indicate that contamination potential of food contact surfaces in raw vegetable salad chain is higher than in meat preparation chain and consequently the possible risk during salad technological processing is elevated. Results on investigation of surface contamination correlate with high-level bacterial contamination observed in ready-to-eat vegetable salads.

It should be emphasized that microbiological contamination, which enters into food from contact surfaces during cold processing stage, can not be eliminated during subsequent processing because no thermal processing is being to applied. Pure personnel hygiene presents additional food safety risk during food technological processes,

particularly during preparation of food that is not thermally processed.

In frame of the research significant difference with probability rate of 95% was found between the type of catering establishments and the presence of coliforms in swab samples ($p = 0.000$), but no difference was found between the type of catering establishments and the presence of *S. aureus* in swab samples ($p = 0.191$). When open-type public catering establishments were compared, rare occurance of coliforms was found for swab samples from buffets and restaurants, but high contamination risk was noticed for swab samples from catering establishments where ready-to-serve food was prepared and sold, as well as for fast food restaurants. The highest *S. aureus* presence risk in swab samples was observed for restaurants, cafes and bars; *S. aureus* was not detected in swab samples from buffets, fast food restaurants and catering establishments where ready-to-serve food was distributed (Figure 8).

Comparatively high risk of presence of coliforms and *S. aureus* on kitchen surfaces was observed in closed type catering establishments in health care institutions and social care institutions. The highest rate of presence of coliforms was detected in swabs from surfaces of catering establishments in health care institutions, but the highest rate of *S. aureus* contamination – in social care institutions. High-level presence of coliforms on kitchen surfaces was also detected in catering establishments inside structures of National Army Force, Ministry of Internal Affairs and Ministry of Justice (Figure 9).
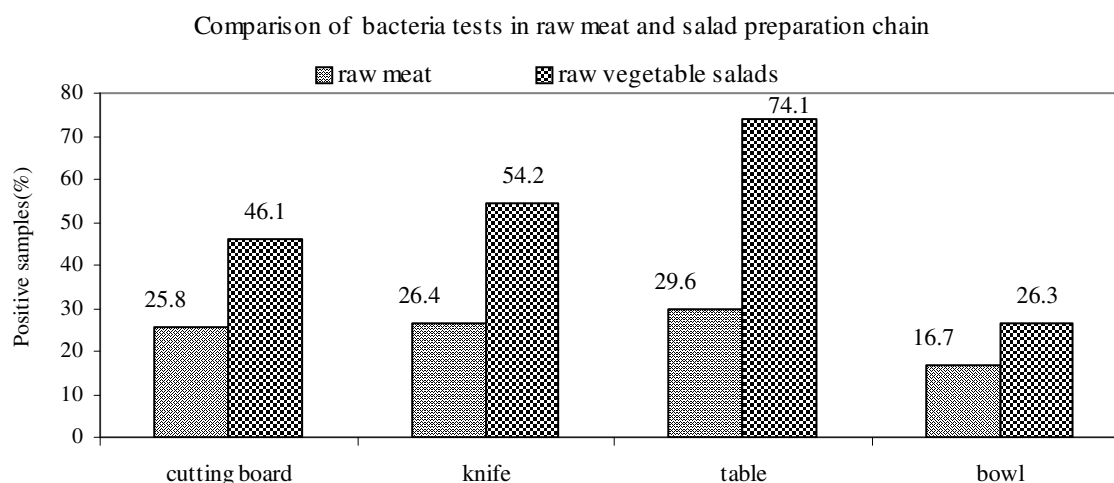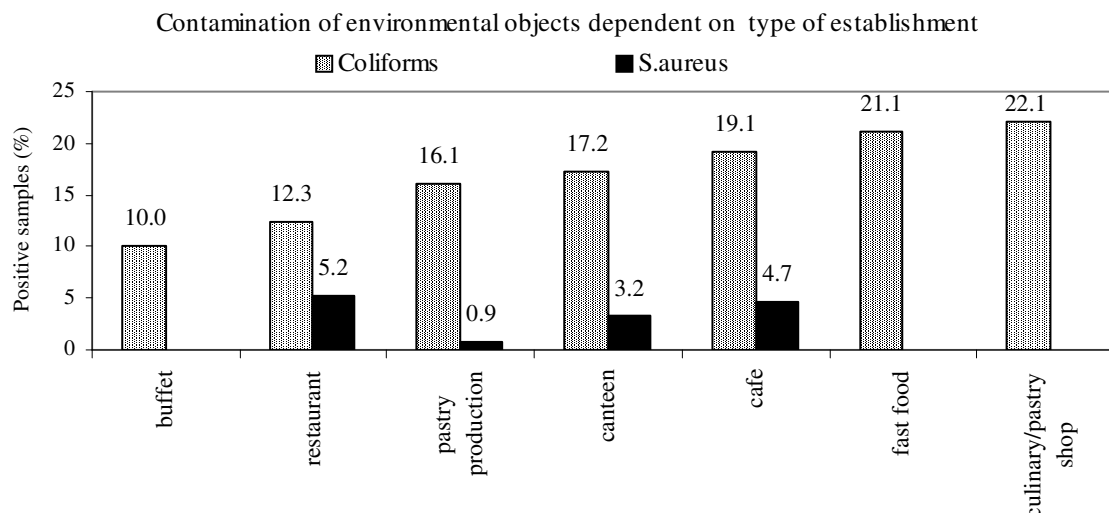

Figure 7. Comparison of coliforms contamination of inventory.

Contamination of environmental objects dependent on type of establishment

Figure 8. Presence of coliforms and *S.aureus* in swabs from open-type institutions.

When catering establishments of different children educational institutions were compared to assess presence of coliforms in swab samples, the lower contamination risk with coliforms was observed for surfaces in catering establishments of boarding-schools, but the highest – in catering establishments of children creative centres and in catering establishments of vocational education institutions. *S.aureus* were detected in swab samples from all types of children educational institutions with exception of catering establishments of children creative centres. The results suggest that the contamination of surfaces with *S.aureus* was almost equal in all catering establishments of children educational establishments (Figure 10).

The presence of *Salmonella* spp. was detected only in one ready-to-eat minced meat food sample that was taken in café. All results on testing *Salmonella* spp. swab samples were negative.

The results of the research on the food safety risks in catering establishments suggest that there are common food safety risks dependent on food group and food technological processing therefore adequate cleaning–disinfection measures and temperature control should be focused to

Contamination of environmental objects dependent on type of establishment
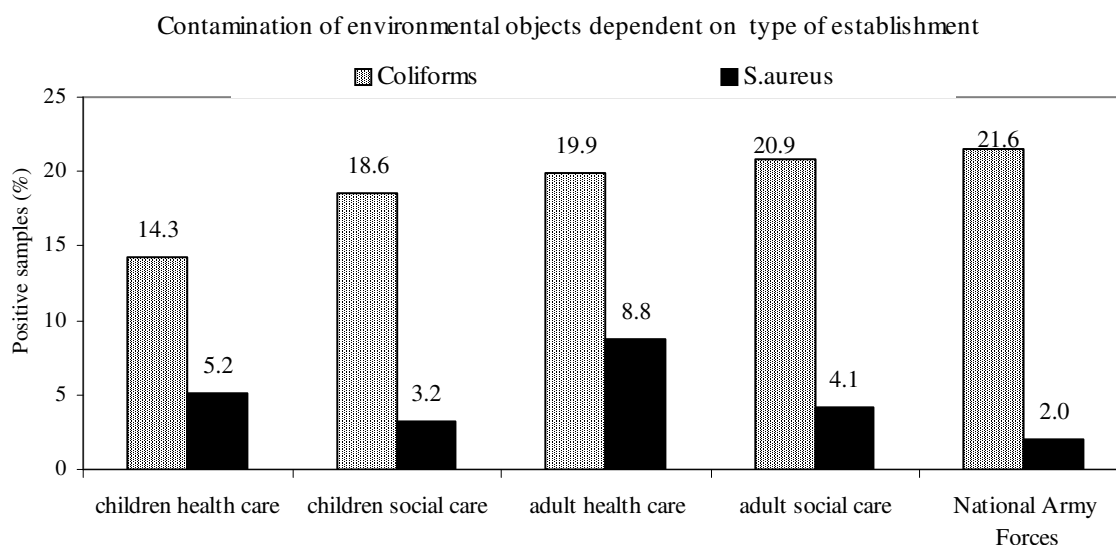
Figure 9. Presence of coliforms and *S.aureus* in swabs from closed-type institutions.

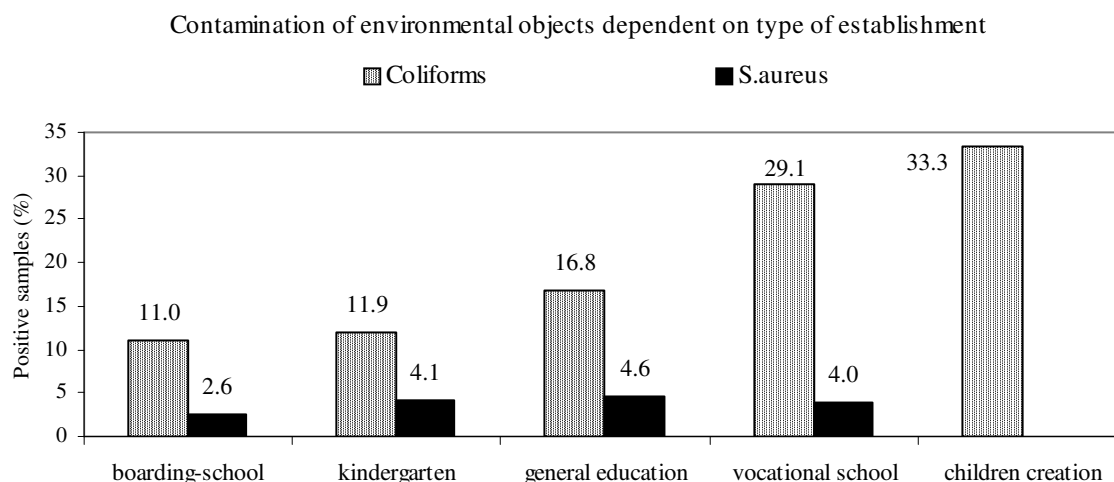Contamination of environmental objects dependent on type of establishment

Figure 10. Presence of coliforms and *S.aureus* in swabs from educational institutions.

avoid critical hygiene problems. Control of food safety risks, which is built on testing of pathogenic bacteria, is not effective enough to evaluate both the actual level of implementation of hygiene measures and the level of food contamination rate in catering establishments. Tests of pathogenic bacteria should be rather recommended during epidemiological investigation to obtain evidence about infection source and/or distribution routes. The results of the research indicate that risk assessment during routine monitoring both in state's official control level and catering establishments' self-control level should be based on testing of hygiene indicator microorganisms rather than pathogenic microorganisms to establish and prevent hygiene problems in frame of HACCP procedures.

Conclusions

The results of the research on the food safety risks in catering establishments indicate that monitoring of food safety risks in catering establishments should concentrate on potential threats during food handling processes:

1. the total plate count in ready-to-eat food is dependent on technological and organizational aspects of food preparation and distribution in catering establishments. In general, highest values of the total plate count are observed for multistage technological processing methods. The highest absolute values of the total plate count are established for salads consisting of components that are mechanically processed after thermal processing and chilling, and

salads that are prepared in a cold manner without thermal processing of components;

2. coliforms and *S.aureus* are common for foods that should undergo multistage technological processing. Both technological methods for salad preparation comprise a significant food contamination level regarding coliforms and *S.aureus* presence;

3. the total plate count is a rather constant parameter that is specific for each identified food group and does not change significantly during years. The highest values of the total plate count are observed both for salads with products of animal origin and salads with products of plant origin, as well as for pastry and cold curd dishes;

4. coliforms most often are found in salads; high *S.aureus* contamination risk also is associated with salads. In general, most food groups where coliforms are found *S.aureus* also are detected;

5. the presence of coliforms is established on surface of 118 environmental objects, but the presence of *S.aureus* – on surface of 34 different environmental objects. In general, the greatest food and surface contamination risk is associated with human hands. Most surfaces that come into contact with food show positive testing results regarding coliforms in 20%-25% cases;

6. results on certain surface contamination with coliforms and *S.aureus* correlate with high-level of bacterial contamination observed in ready-to-eat vegetable salads. Microbiological contamination, which enters into food from contact surfaces during cold

processing stage, can not be eliminated if thermal processing is not applied;

7. the level of contamination of environmental surfaces with coliforms is dependent on type of catering establishments, but presence of *S.aureus* is detected on surfaces in almost all catering establishments and is not related with certain type of establishment. Nevertheless, it can not be concluded that presence of coliforms on surfaces is dependent on establishment group:

open-type, closed-type or educational establishment group. The research suggests that inadequate hygiene situation can arise without reference to catering establishment type.

Acknowledgements

References

1. Luning P.A., Devlieghere F., Verhe R. (2006) Safety in the Agri–Food Chain. Wageningen Academic Publishers, the Netherlands, 684 p.
2. Luning P.A., Marcelis W.J., Jongen W.M.F. (2002) Food Quality Management: a Techno-Managerial Approach. Wageningen Academic Publishers, the Netherlands, 323 p.
3. Sprenger R.A. (2004) Hygiene for Management. Highfield limited, UK, 416 p.
4. Meulen B., Velde M. (2004) Food Safety Law in the European Union. Wageningen Academic Publishers, the Netherlands, 272 p.
5. Rico H., Soriano J.M., Molto J.C., Mane J. (2005) Effect of Introduction of HACCP in Spanish University Restaurants. In: Maunsell B., Bolton D.J. (eds) Restaurant and Catering Food Safety: Putting HACCP on the Menu. EU Risk Analysis Network, Teagasc – Ashtown Food Research Centre, Dublin, Ireland, pp. 113-138.
6. Airey S., Greaves A. (2005) HACCP for small businesses in UK. In: Maunsell B., Bolton D.J. (eds) Restaurant and Catering Food Safety: Putting HACCP on the Menu. EU Risk Analysis Network, Teagasc – Ashtown Food Research Centre, Dublin, Ireland, pp. 138-158.

MICROBIOLOGICAL QUALITY ASPECTS OF READY-TO-EAT FOODS FROM CATERING ESTABLISHMENTS

Tatjana Marcenkova, Martins Rucins
Latvia University of Agriculture
E-mail: tatjana.marcenkova@pvd.gov.lv; marty@delfi.lv

Abstract

A total of 120 food samples from 6 traditional and 3 non-traditional (Oriental) public catering establishments in Latvia were taken. Preliminary all food samples were divided in three food groups (categories) depending on the components of the products and processing methods. Ready-to-eat foods (RTE) with high level of total amount of microorganisms (aerobic colony count-ACC) and total coliforms (TC), as well as appropriate infringements of hygienic requirements in public catering establishments which had an impact on microbial contamination were clarified. The reasons for microbiological contamination of RTE and the growth of the microorganisms were analyzed in dependence on food category group, the activity of hydrogen ions (pH) in food, food temperature at the sampling point, their processing mode and composition. Different indicator microorganisms including *Staphylococcus, Enterobacter, Escherichia, Bacillus*, yeasts, moulds and etc. were identified. The comparison between the temperature and pH and the level of microbiological contamination of the samples of food and hygienic practice in the catering establishments were clarified.

Keywords: catering, ready-to-eat foods (RTE), food safety, microbiological investigations, food hygiene requirements, colony forming units (CFU).

Introduction

The role of catering establishments, offered services and amount of the products produced there has substantially increased during the past few years. The food processing technologies are improving. The attention of food operators and customers on the nutrition value of RTE, their composition, visual decoration, and also on quality of raw materials, safety of used processing methods and other specific aspects has been paid considerably more and more.

The state monitoring of microbiological investigation samples of RTE is additional mechanism for realization of food safety surveillance functions. Actually this is one of the risk assessment's components – risk analysis. The quality and safety norms for RTE prepared in catering establishments are not regulated at present in Latvia and consequently there are not precisely required quality and safety criteria which are much to be compared with appropriate and non-appropriate microbiological quality of RTE (PVD, 2006).

Directives and Regulations of the European Community require quality and safety food circulation politics, based on the latest scientific achievements and risk analysis which include risk assessment, risk communication, and risk management (CAC/GL-21, 1997; CAC/GL-30, 1999; CAC/RCP39, 1993; Luning et al., 2004).

The new European Union hygiene regulation state mandatory microbiological safety criteria for the end products and separate voluntary quality criteria for products processed during the stages of the technological process. Microbiological criteria can be used to design products and processes and to indicate the required microbiological status of the raw materials, ingredients or end-products at any stage of the food stage of the food chain, as appropriate (Brown and Springer, 2002). Unfortunately, these norms are appropriate mostly for industrially processed products and not for RTE that are prepared in catering establishments.

Indicator groups of bacteria are widely used as measure of the hygienic characteristics of food and beverage. They have the advantage of being enumerated inexpensively and easily for quantifying the performance of a production process, when particular pathogens or spoilage organisms might be difficult to detect. Total *Enterobacteriacae* are used as measure or faecal contamination during meat production in Europe, although coliforms are also encountered in research (Jordan et al., 2006).

However, RTE pretty often are potentially hazardous for human health. Despite the positive dynamics of the past few years, the outbreaks of foodborne diseases, that were caused by foods prepared in these establishments, are registered

relatively often in Latvia (SVA, 2003-2006).

The information provided by Public Health Agency of Latvia concluded that greatest amount of incidents of outbreaks of foodborne diseases during the last 5 years was identified in particular at closed-type catering establishments, including school and kindergarten canteens, health care institutions, National Forces etc. Thus, 41.7% of registered outbreaks in 2003 were related to catering establishments and children care institutions, in 2004–50%, in 2005–38.5%, and 60% in 2006 (with 5 and more illness cases). In 2005, the disease agent was not found in 17% cases of outbreaks. As a result of epidemiological investigation, different food pathogens were identified in 83% of cases. In 2005, 39% of outbreaks had viral etiology, in 22% salmonella, in 11% *Shigellae*, and in 11% of cases other bacterial agents were identified. During the year 2006, the prevalent agent was salmonella – in 69% cases of outbreaks. Viral agents and non-identified agents were identified only in 8% of cases, and other bacterial agents in 15% of cases (SVA, 2003-2006).

Only because of active and focused preventive activities performed by Food and Veterinary service (FVS) since the year 2002, the number of total outbreaks has diminished substantially (see Figure 1).

Therefore the main task of this study was to clarify the microbiological contamination of some RTE.

Materials and Methods

A totally 120 samples of RTE from public catering establishments as a result of first stage of investigations (March–December, 2005) were investigated, including identification of total

amount of microorganisms – aerobic colony count (ACC), indicator microorganisms – total coliforms (TC), genera determination of separate isolated cultures, determination of total amount of isolated pathogens or spoilage microorganisms, determination of hydrogen ion concentration (pH), and identification and validation of other necessary characterization parameters. Part of the 120 samples at the same time were investigated on ACC (90 samples) and on TC (90 samples).

Nine public catering establishments from Riga city (capital of Latvia) with comparative similar hygienic situation were selected for sampling. The names of these establishments were specially coded with number code that is shown in Table 1, which helps ensure confidentiality of the information.

All samples were divided in to three food categories, depending on the components of the products and used processing methods (see Table 3). First category of RTE ($n = 80$) included hot meals, soups, hot main courses, dressings, porridges, puddings etc. All components of food were heat treated and ready for use. The second category ($n = 20$) included cold meals, salads without sour cream and mayonnaise, cold soups, non-alcoholic beverages and pastry without cream. Separate components were heat treated and intended for further storage. Third category ($n = 20$) included mixed salads without sour cream and mayonnaise (where separate components were heat treated), and salad with sour cream and mayonnaise, cold soups, meals that consisted of fermented products, and meals with naturally high level of microorganisms and that were intended for use without extra heat
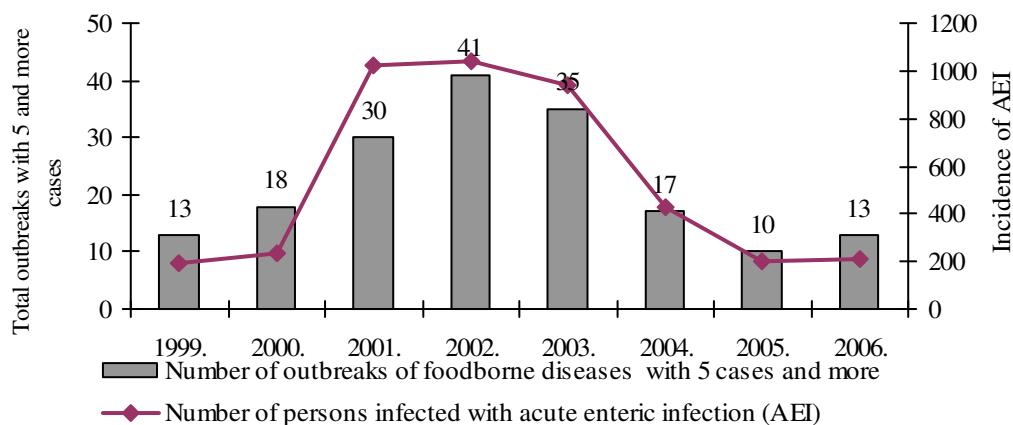

Figure 1. Number of outbreaks of foodborne diseases and number of infected persons related to food establishments and children care institutions in Latvia during 1999-2006.

Table 1

Hygienic evaluation of catering establishments during the sampling

Number /code of an establishment	Amount of taken samples	Samples having nonconformities with stated criteria	Hygienic evaluation of establishments			Notes
			good	medium	bad	
1(LN)	11	8 (74.6%)		X		Damaged floor covering in dishwashing room,nonconformities on food chilling processes
2(IL)	10	0	X			-
3(ED)	10	1(10.0%)		X		Nonconformities in food cross contamination
4(IE)	9	6(66.6%)		X		Nonconformities in food defrosting and chilling processes
5(JM)	10	0		X		Nonconformities of contact surfaces intended for contact with food
6(JU)	10	6(60.0%)		X		Nonconformities in food chilling processes
7 (H)	20	0		X		Nonconformities of contact surfaces intended for contact with food
8 (S)	23	0		X		Nonconformities in personal hygiene and cleaning procedures
9 (SA)	17	0		X		Nonconformities in personal hygiene, cleaning and food chilling processes
Total	**120**	**21 (17.5%)**	**1**	**8**	**-**	

processing (see Tables 2 and 3).

The horizontal method of microorganism counting and colony counting method under $30\,^\circ$C was used for determination of ACC (standard – LVS EN ISO 4833:2003). The Plate count agar (PCA) was used. The method LVS ISO 4832:2003 'General directions for counting of coliform bacteria. Colony counting method' was

Table 2

Categories of foods and total number of investigations

Category group of RTE	Total number of food samples	Total number of investigations		
		number of samples investigated on ACC	number of samples investigated on TC	number of investigations with genera determination
1st category	80	69	71	28
2 nd category	20	10	10	17
3rd category	20	11	9	23
Total food samples of1st–3rd category	**120**	**90**	**90**	**68**

used for determination of total coliforms (TC), in which Crystal violet red bile lactose agar was used.

For genera determination of separate isolated cultures and for determination of total amount of isolated pathogens or spoilage microorganisms, the method of culture isolation on non-selective agar media was used, including the methods of visual evaluation of isolated culture, inoculation of isolated culture to the agarisated media, and identifying morphology of determined culture and its microscopy, and in the final stage – identification of biochemical parameters of isolated cultures (API biochemical test systems – API 20E, API STREP, API Staph, API A etc.).

The verified pH meter and the method – ГОСТ 26188-84 'Processing products of fruits and vegetables, meat and meat with non-animal canned products. Methods of pH determination' was used for determination of pH in the samples.

Sampling was carried out according the quality management procedures of Food and Veterinary Service (FVS), samples were taken by trained persons – food inspectors. Investigations of the samples were carried out in accredited laboratory – National Diagnostic Centre of FVS.

For the evaluation of the results guidelines of the Irish Food Safety Agency and the Australia New Zealand Food Authority, and internal guidelines of the Latvia FVS on evaluation of the results of microbiological investigation of samples of some RTE taken in catering establishments were used (ANZFA, 2001; FSAIE, 2001).

Results and Discussion

From total investigated samples ($n = 120$) non-conformities with stated criteria concerning ACC and TC 21 samples (17.5%), were identified.

Comparatively more often nonconformities with stated criteria were recognised in 20 (22.2%) samples investigated on TC. In the first category food group, the biggest number of nonconformities was found – in 6 (7.5%) samples from 80 investigated. Concerning traditional meals, the biggest number of nonconformities was identified in meals that contained boiled rice ($n = 9$) – in 4 samples (1 on ACC and 3 on TC). Only in one (1.1%) of the 90 samples investigated for ACC whereas nonconformities with stated criteria were found (see Tables 2 and 3).

Table 3

Categories of foods and total number of nonconformities with stated criteria

Category group of RTE	Food name and/or short description of its composition	Investigated samples		
		total number	samples, where nonconformities with stated criteria were detected	
			ACC	TC
	Traditional meals			
Category 1 FSAIE, 2001. *Guidance Note on the interpretation of results of microbiological analysis of some ready-to-eat foods sampled at point of sale.* ACC ($N =< 10^4$ CFU per gram) TC ($N =< 10^2$ CFU per gram)	Cabbage with meat and rice	1	0	**1**
	Boiled rise	8	1	**2**
	Roasted pork	2	0	**1**
	Boiled potatoes	3	0	**0**
	Boiled buckwheat	2	0	**0**
	Pork with bitter sauce	1	0	**0**
	Pork meatballs	2	0	**0**
	Beef liver fritters	1	0	**0**
	Non-traditional meals			
	Chicken meat 'Torino'	7	0	**0**
	Vegetable meal 'Tempura jače'	7	0	**0**
	Vegetable stew	6	0	**0**
	Chicken meat with vegetables 'Torino terijaki'	6	0	**0**
	Pork in sweet sour soy source	7	0	**0**
	Vegetable dish	7	0	**0**
	Spicy beef with vegetables	6	0	**0**
	Pork ribs	7	0	**0**
	Beef stew of Thailand's kind	7	0	**0**

Table 3
continued

Category group of RTE	Food name and/or short description of its composition	Investigated samples		
		total number	samples, where nonconformities with stated criteria were detected	
			ACC	TC
	Total 1st category	80	1(1.25%)	**5(6.25%)**
Category 2. FSAIE, 2001. *Guidance Note on the interpretation of results of microbiological analysis of some ready-to-eat foods sampled at point of sale.* ACC ($N =< 10^6$ CFU per gram) TC ($N =< 10^2$ CFU per gram)	**Traditional meals**			
	Fresh cabbage salad with vegetable oil	8	0	**6**
	Fresh vegetable salad (fresh tomatoes, cucumbers,paprika, Chinese cabbage, and vegetable oil)	2	0	**1**
	Salad 'Rozmarija' (fresh cauliflower, tomatoes,cucumbers, paprika, canned corn, vegetable oil, and vinegar)	1	0	**0**
	Boiled red beet salad	3	0	**2**
	Apple juice gelatine drink	2	0	**0**
	Apple pie	1	0	**0**
	Beef meat jelly	1	0	**0**
	Total 2nd category	20	0	**9 (45%)**
Category 3. FSAIE, 2001. *Guidance Note on the interpretation of results of microbiological analysis of some ready-to-eat foods sampled at point of sale.* ACC ($N =$ not applicable) TC ($N =< 10^2$ CFU per gram)	**Traditional meals**			
	Freshly made carrot juice	5	0	**1**
	Meat salad (sausage, potatoes, fresh cucumbers, eggs, mayonnaise, mustard, and horseradish)	1	0	**1**
	Celery salad	1	0	**1**
	Vinaigrette	1	0	**0**
	Vegetable salads	4	0	**2**
	Salad 'Rasols' (pickled cucumbers, canned green beans, sausage, eggs, carrots, potatoes, and mayonnaise)	2	0	**0**
	Salad with 'crab meat' steaks	1	0	**0**
Category group of RTE	Food name and/or short description of its composition	Investigated samples		
		total investigated samples	samples, where nonconformities with stated criteria were detected	
			ACC	TC
	Chocolate cream	1	0	**0**
	Milk cocktail (ice-cream with apple juice)	2	0	**1**
	Mushroom salad	1	0	**1**
	Salad with lightly salted herring	1	0	**1**
	Total 3rd category	20	0	**7 (35%)**
Total food samples of 1st-3rd categories		**120**	**1(0.83%)**	**20(16.7%)**

During the investigation, different nonconformities in food processing, chilling, and storage stages were identified. Regarding traditional meals nonconformities in food internal temperatures were detected. In few cases, the temperature was much higher than the permissible critical limits; however the storage and delivery time of these products did not exceed the permissible critical time limits.

In total of 18 samples, mostly in chilled meals, including salads, and fresh-made juice – in 15 cases, were identified problems with temperature requirements. Only in one of the nonraditional meal samples, nonconformities with temperature requirements were identified. Received results were probably related to nonconformities in food processing, chilling, and storage stages. The lowest amount of TC (lg 10 CFU per gram) – below 3.0 lg 10 or 1000 CFU per gram in 76 (84.4%) of samples was found. The lowest CFU amount was 10, but the highest 580 000 CFU per gram (in celery salad). In 12 cases (15.6 %) of the total of 90 investigated samples, nonconformities in temperature criteria were discovered (see Figure 2 and 3).

The lowest amount of ACC (lg 10 CFU per gram) was found in 59 (65.6%) samples –below 3.0 lg 10 or 1000 CFU per gram. The lowest amount of ACC was 10, but the highest – 6 600 000 CFU per gram (in fresh extracted carrot juice).

The level of microbiological contamination is very closely connected with food processing methods, as well as with pH of foods, etc. In general, bacteria grow fastest within the range of pH from 6.0 to 8.0, yeasts within the range of pH from 4.5 to 6.0, and filamentous fungi within the range of pH from 3.5-4.0. Bacteria grow slower in pH below 4.6 and higher than 7.5. The pH lower than 4.6 is considered as a limit of safe food, in its turn pH limit that is higher than 4.6 up to 7.5 is considered as unsafe food zone. The acidity of a product can have important implications for its microbial ecology and the rate and character of its spoilage. In fruits, however, a lower pH prevents bacterial growth, and spoilage is dominated by yeasts and moulds (Adams and Moss, 2006).

Compliance with hygiene requirements in 9 catering establishments was evaluated during the sampling. Self-control system (based on HACCP principles) procedures were evaluated in these establishments as well. As a result of this evaluation it was detected that worst microbiological samples were taken from establishments with lowest hygiene level (PVD, 2004-2006) (see Table 1). In 55.5% of total investigated samples (n = 90) were found 68 different genera of separate isolated cultures. Among 19.1% of isolated cultures, *Bacillus*, *Enterobacter* and *Staphylococcus* genera were isolated, 13.2% were *Klebsiella* genus, 5.8% – *Citrobacter* genus, and 2.9% were *Escherichia* genus (see Figure 4). Identificated *Bacillus* genus normally include three species, of which two – *Bacillus subtilis* and *Bacillus licheniformis* – have
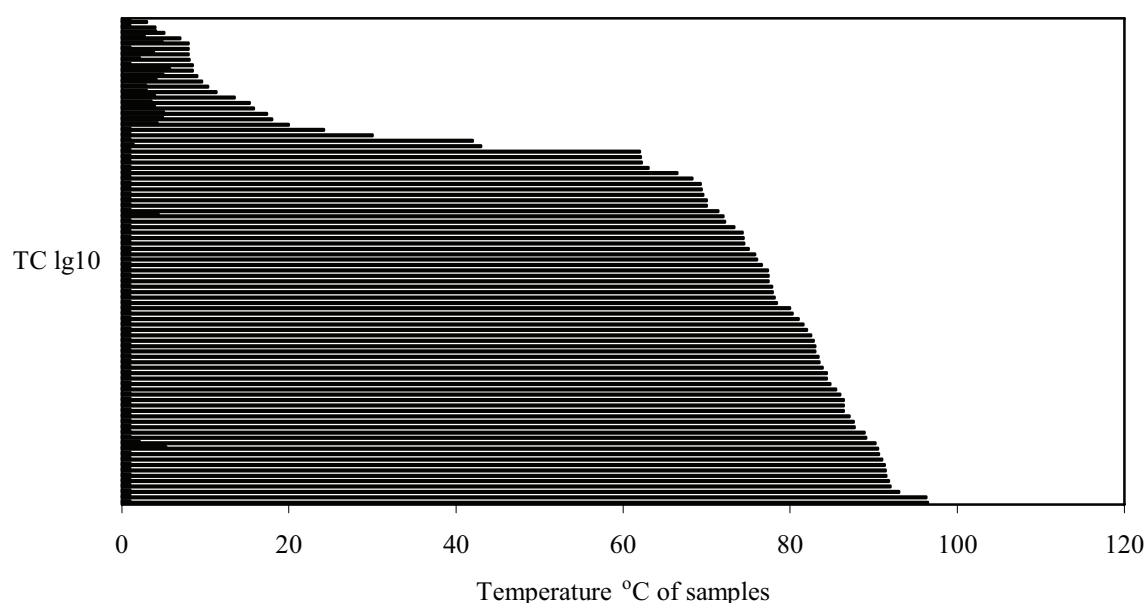

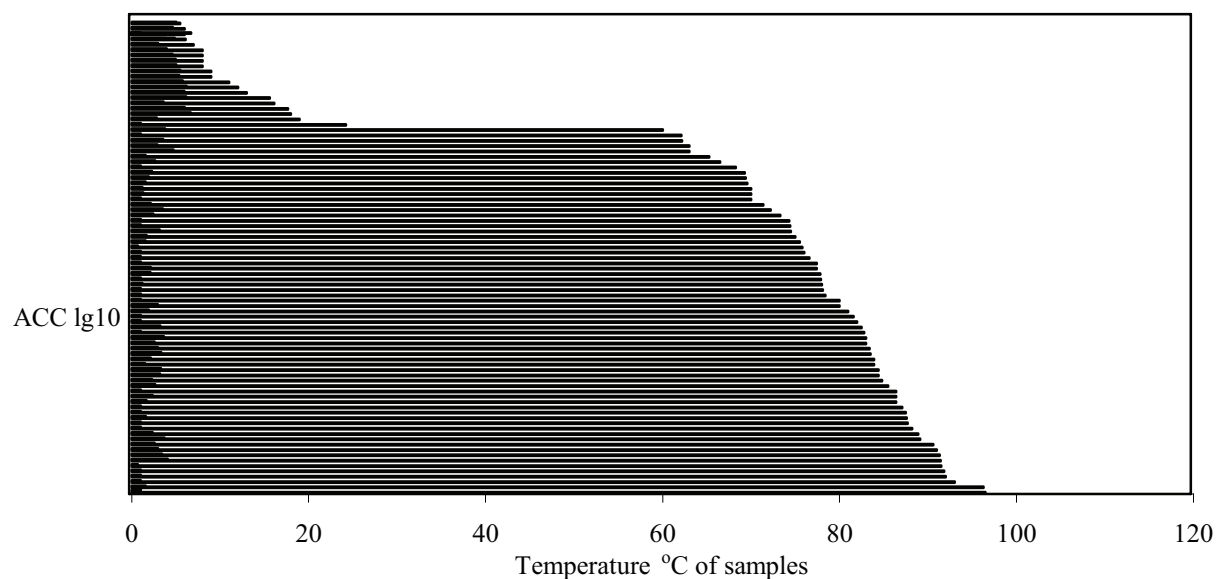Figure 2. Total coliforms depending on the temperature of food samples.

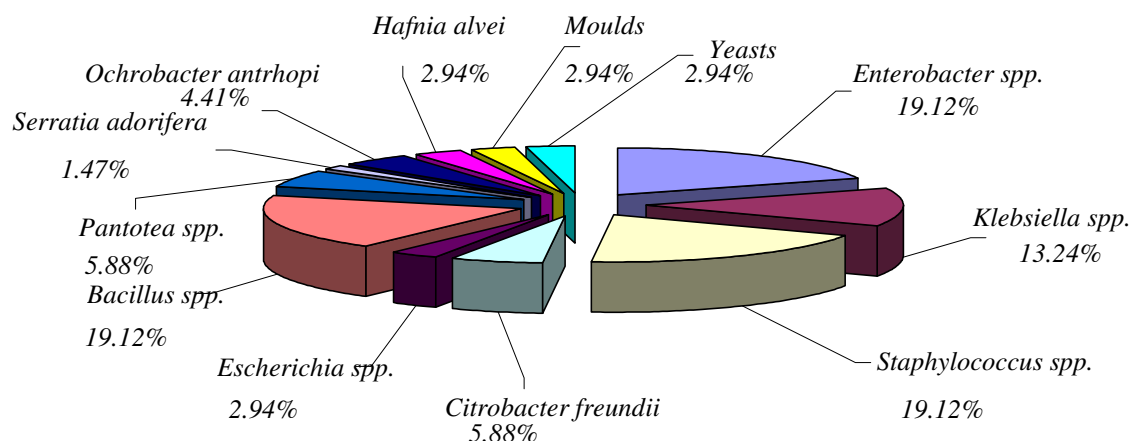Figure 3. Aerobic colony count depending on the temperature of food samples.

Figure 4. Percentage of detected microorganisms genera in RTE samples ($n = 90$).

occasionally shown to be responsible for incidents of food-poisoning resembling one or other of the syndromes typical of *Bacillus cereus*, which are well-known foodborne pathogen (Blackburn, McClure, 2002).

Conclusions

1. In RTE samples, which components were not heat processed, highest microbiological contamination was found: aerobic colony count there varied between 4200 CFU per gram up to 6 600 000 CFU per gram and total coliforms varied between smaller than 10 up to 5 800 000 CFU per gram. 20 of 90 (22.2%) samples however, were not in compliance with the stated criteria;

2. Research suggests a connection between processing and storage temperature, and level of microbiological contamination of samples. In establishments, where nonconformities in chilling, storage requirements and cross-contamination risk were observed (in 4 from the 9 establishments – 44.4%), there were found more often RTE samples which did not meet the stated criteria;

3. 68 different genera of separate isolated cultures in 50 samples (55.5% – from 90 investigated samples) were identified. The main isolated cultures were of *Bacillus, Enterobacter, Staphylococcus,* and *Klebsiella* genera. Some of these microorganisms are well-known food pathogens;

4. The total amount of detected microorganisms was depended on the category of the products, processing methods, hygienic situation in food establishments, and other microbial growth influencing factors.

References

1. Adams M.R., Moss M.O. (2006) Food microbiology, RSC, second edition, pp. 479.
2. Australia New Zealand Food Authority - ANZFA (2001) Guidelines for the microbiological examination of ready-to-eat foods. Available at: http://www.foodstandards.gov.au/newsroom/publications/guidelinesformicrobi1306.cfm, 06.10.2007.
3. Dr. Blaithin Maunsell, Prof. Jim Sheridan & Dr.Declan J.Bolton (2004) Food Pathogen Epidemiology: Microbes, Maladies and Methods. Proceedings of an International EU-RAIN conference hosted by the Instituto Zoooprofilattico Sperimentale delle Venezie, Padua, Italy. December 2nd-3rd 2004. Teagasc – The National Food Centre, Ireland, pp. 156.
4. Clive de W. Blackburn and Peter J. McClure (eds.) (2002) Foodborne pathogens. Hazard risk analysis and control. Woodhead publishing LTD, CRC press, Cambridge, England, pp. 521.
5. Codex Alimentarius Commission. Guidelines. Principles for the establishment and application of microbiological criteria for foods. CAC/GL - 21 (1997) Available at: http://www.codexalimentarius.net/web/standard_list.do?lang=en, 06.10.2007.
6. Codex Alimentarius Commission. Guidelines. Principles and guidelines for the conduct of microbiological risk assessment. CAC/GL - 30 (1999) Available at: http://www.codexalimentarius.net/web/standard_list.do?lang=en, 06.10.2007.
7. Codex Alimentarius Commission. Code of Hygienic Practice for Precooked and Cooked Foods in Mass Catering. CAC/RCP 39-1993 (1993) Available at: http://www.codexalimentarius.net/web/standard_list.do?lang=en, 01.10.2007.
8. Declan J. Bolton, Blaithin Maunsell (2004) Guidelines for Food Safety Control in European Restaurants. Teagasc – The National Food Centre, Ireland. Available at: http://www.eu-rain.com/publications/docs/Retail%20HACCP.pdf , 06.10.2007.
9. Jordan D., Philips D., Summer J., Moris S. and Jenson I. (2006) Relationships between the density of different indicator organisms on sheep and beef carcases and in frozen beef and sheep meat. Journal of Applied Microbiology, Volume No102, pp. 57-64.
10. Food Safety Agency of Ireland (2001) - FSAIE. Guidance Note on the interpretation of results of microbiological analysis of some ready-to-eat foods sampled at point of sale. Available at: http://www.fsai.ie/publications/index.asp, 06.10.2007.
11. Food and Drug Administration (2000) Foodborne Pathogenic Microorganisms & Natural Toxins. Handbook. The centre for Food Safety and Applied Nutrition (CFSAN), pp. 163.
12. Gilbert R.J, J de Louvois, Donovan T., Little C., Nye K., Ribeiro C.D., Richards J., Roberts D., Bolton F.J., (2000) Guidelines for the microbiological quality of some ready-to-eat foods sampled at the point of sale. Journal of Communicable diseases and public health, Volume No 3, pp. 163-167.
13. Luning P.A., Marcelis W.J., Jongen W.M.F., (eds.) (2004) Food quality management a techno-managerial approach. Wageningen Pers, pp. 323.
14. Martin Brown, Mike Stringer (2002) Microbiological risk assessment in food processing. Woodhead publishing LTD, CRC press, Cambridge, England. In: Microbial criteria and microbial risk assessment. T.Ross and C.Chan, Safe Food Production NSW, Sydney, pp. 214-247.
15. Pārtikas un veterinārā dienesta uzraudzības programma (2006) - PVD. (Food and veterinary service food surveillance programme of 2006) Available at: http://www.pvd.gov.lv/?sadala=557&id=2981, 19.07.2006 (in Latvian).
16. Richard A. Sprenger (2004) Hygiene for management. A text for food safety courses. Highfield.Co.UK Limited (Eleventh edition), pp. 415.

17. Sabiedrības veselības aģentūras (SVA) statistiskie biļeteni, informācija par epidemioloģisko situāciju valstī ar pārtikas izraisītām saslimšanām (2003-2006) (Statistic overviews on epidemiologic information on foodborne diseases). Available at http://www.sva.lv/epidemiologija/statistika/, 06.10.2007 (in Latvian).

18. Карцев В.В., Белова Л.В., Иванов В.П. (2002) Санитарная микробиология пищевых продуктов. (Food sanitary microbiology). Санкт-Петербургская государственная медицинская академия им. Мечникова, 312 стр. (in Russian).

ELABORATION OF SOLID PHASE EXTRACTION METHOD FOR ANALYSIS OF STERIGMATOCYSTIN

Aleksandrs Veršilovskis, Velga Miķelsone
Latvia University of Agriculture
E-mail: alex.vers@inbox.lv; velgamik@inbox.lv

Abstract

Sterigmatocystin is a mycotoxin produced by fungi of many *Aspergillus* species and it is a biogenic precursor of aflatoxin B_1. For analysis of various mycotoxins to clean up sample extracts, mainly solid phase extraction (SPE) is used. An elution of sterigmatocystin from Strata X and Strata C18 SPE columns by different acetonitrile-water and methanole-water solutions were cheked in this paper.

Acquired results showed a possible suitability of both columns for the analysis of sterigmatocystin.

Keywords: Sterigmatocystin, mycotoxin, solid phase extraction, C18 columns, Strata X.

Introduction

Sterigmatocystin (STC) is a mycotoxin produced by fungi of many *Aspergillus* species. Sterigmatocystin is a biogenic precursor of aflatoxin B_1 (Hsieh et al., 1975; Betina, 1998) (Fig.1.) and is known to be produced by isolates of *Aspergillus versicolors, Aspergillus nidulans* (Atalla et al., 2003), and *Bipolaris sorokiniana.* Schroeder and Kelton (1975) reported that a large number of isolates of *Aspergillus parasiticus* and *Aspergillus flav*us produce STC, and they also added *Aspergillus chevalieri, Aspergillus ruber,* and *Aspergillus stelodami* to the list of known STC producers.

Since mycotoxins are normally present in food and food products at very low levels, a strong concentration of the extract is necessary to make detection possible. The frequent presence of lipids and other substances that may interfere in the final detection makes it necessary to clean up the extract prior to concentration by column clean up and/or precipitation of impurities. Several chromatographic clean up steps are possible with materials such as silica gel, modified silica gel, aluminium oxide, polyamide, Florisil®, and Sephadex®. Silica gel is most frequently used sorbent. Prepacked columns are now commercially available. Many recently published analytical methods for mycotoxins use these columns. The advantages of such prepacked columns, e.g. Sep-pak® and Baker®, are obvious. Time, needed to prepare the columns is saved, and variations in preparation of columns between analyses are less. On the other hand, variations between lots of prepacked columns have been reported (Van Egmont et al., 1986), and they do not offer the possibility of easily introducing slight variations in the column composition (for instance, adjustment of the water content or column size). The sample extract is usually added to the column in an appropriate solvent, after which the column is washed with one or more solvents in which the toxins are insoluble or less
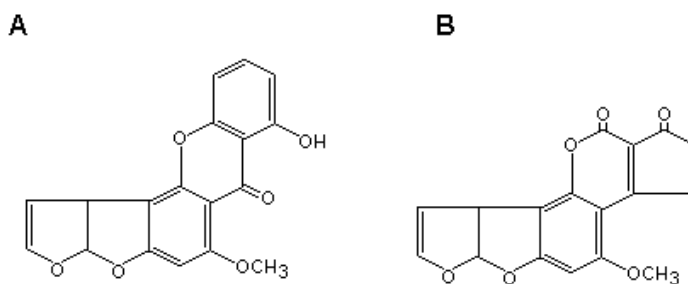

Figure 1. Chemical structures of (A) sterigmatocystin and (B) aflatoxin B_1.

soluble than the impurities. Then the solvent composition is changed in such a way that the toxins are selectively eluted from the column and the eluate is collected.

Today the most popular clean up SPE columns for mycotoxins are based on normal and reversed phase chromatography, as well as ion-exchange (Jestoi et al., 2004; Uhlig et al., 2004; Vesonder et al., 1985).

For analysis of STC by thin layer chromatography (TLC), sample extracts basicaly are purified by Florisil (Vesonder et al., 1985) and phenyl-bonded SPE columns (Stroka et al., 2004).

Strata X SPE column contains a new polymeric sorbent – styrene divinylbenzene. It is developed for the reversed phase (RP) SPE of polar and non-polar molecules.

Strata C18 SPE column contains a classic C18 sorbent for SPE .

During this study, Strata X and Strata C18 SPE columns for the first time were applied for the analysis of STC.

The aim of this study is to compare two different STC eluting procedures (using acetonitrile-water solutions and methanol-water solutions) with two different SPE columns Strata C18 and Strata X.

Materials and Methods

Strata C18 (500 mg) SPE column (Phenomenex Co., Torrance, USA) and Strata X (500 mg) SPE column (Phenomenex Co., Torrance, USA) were used for the experiments.

Chemicals and reagents

Methanol (HPLC-grade) and acetonitrile (HPLC-grade) were purchased from 'Merck' (Darmstadt, Germany). Deionized water was purified with Millipore Milli-Q Plus system (Millipore, Molsheim, France). Sterigmatocystin (STC) standard was purchased from 'Sigma' (St Louis, USA). Argon (AGA, Latvia) was used as a collision gas in the mass spectrometry.

Preparation of standard solutions

Stock solution A (500 μg ml^{-1}) preparation: 5 mg of solid STC standard was dissolved in 10 ml of acetonitrile.

Working standard solution B (10 μg ml^{-1}) preparation: 200 μ l^{-1} of stock solution A was dissolved in 20% water solution in acetonitrile.

Working standard solution C (10 μg ml^{-1}) preparation: 200 μ l^{-1} of stock solution A was dissolved in 20% water solution in methanol.

Experiment

During the experiment, possibilities of STC holding and eluting options from the Strata X and Strata C18 SPE columns were checked.

Column conditioning procedure: column was conditioned with 6 ml of methanol, followed by 6 ml of water prior to use.

STC loading into the column and eluting from the column was done using acetonitrile-water system:

5 ml of working standard solution B were loaded in Strata X SPE column. The outgoing eluate was the first control fraction, then the column was progressively washed with 5 ml portions of pure eluting solution which consisted of different composition of acetonitrile-water. Eluting solutions composition was (% volume/volume): 25/75, 30/70, 35/65, 40/60, 45/55, 50/50, 55/45, 60/40, 70/30 and as the final eluting solution – pure acetonitrile.

The second control fraction was outgoing eluting solution 25/75, the third fraction was outgoing eluting solution 30/70 until the last 11th fraction which consisted from a pure acetonitrile.

The collected eluting solutions fractions were analyzed for content of STC by Liquid Chromatography – tandem Masspectrometry (LC – MS/MS).

STC loading in the column and eluting from the column was performed using methanol-water system:

Column conditioning procedure was the same as described above.

5 ml of working standard solution C were loaded in Strata X SPE column. The outgoing eluate was the first control fraction, then the column was progressively washed with 5 ml portions of pure eluting solution which consisted of different composition of methanol-water. Eluting solutions composition was (% v/v): 25/75, 30/70, 35/65, 40/60, 45/55, 50/50, 55/45, 60/40, 70/30, and as the final eluting solution – pure methanol.

The second control fraction was outgoing eluting solution 25/75, third fraction was outgoing eluting solution 30/70 until the last 11th fraction which consisted from a pure methanol.

The collected eluting solutions fractions were analyzed for content of STC by LC – MS/MS.

The experiments on Strata C18 columns were followed by the same procedure.

LC-MS/MS – analysis

A Waters Alliance 2695 liquid chromatograph (Waters Co., Milford, MA, USA) was connected to a MicroMass Quattro LC triple-quadrupole

mass spectrometer (Micromass Ltd., Manchester, UK). An electrospray ionization (ESI) probe in the positive mode was used in the analysis of sterigmatocystin. The mobile phase consisted of 0.01% formic acid in acetonitrile and 0.01% formic acid in water (75:25) used in isocratic regime. The column used was a Phenomenex Luna $C_{18}(2)$ (5 μm), 3.0 x 150 mm (Phenomenex Co., Torrance, USA). The flow rate was 0.3 (ml min^{-1}) and the injection volume was 50 μl. The parameters of the mass spectrometer were optimized using the sterigmatocystin standard. The best response was recorded with the following parameters: cone voltage – 30 V, capillary voltage – 3.5 kV, extractor – 2 V, RF lens – 0.2 V, source temperature – 120 °C and desolvation temperature – 350 °C, cone gas flow – 63 (l h^{-1}), desolvation gas flow – 553 (l h^{-1}), and collision energy 30 eV.

For the structural identification in MRM mode, the molecular ion [M^{+}-H] ($mw = 325$) was fragmented within the MS to its daughter-ions (325 > 310 and 325 > 281) with the cone voltage – 30 V, collision energy – 30 eV, and dwell – 0.2 sec. Argon was used as a collision gas. The daughter-ion ($mw = 281$) was used for the quantification of sterigmatocystin.

Results comparing method

For comparing of the acquired study results, Microsoft office Excel 2003 statistical functions ('t-test: Paired two sample for means' and 't-test: Two-Sample Assuming Equal Variances') were applied.

Results and Discussion

Elution of STC from two columns starts already at 45% of acetonitrile and completely elutes from the column with pure acetonitrile.

Summary results for STC eluting from the Strata X and Strata C18 SPE columns using acetonitrile and acetonitrile-water solutions are shown in Figure 2.

Using methanol-water solutions, STC elution from the column starts at 45% of methanol content in eluting solution and completely elutes from the column with pure methanol.

The results for STC elution from the Strata X and Strata C18 SPE columns using methanol and methanol-water solutions are shown in Figure 3. For comparing of STC elution procedure efficiency from Strata C18 SPE column, the 't-test: Paired two sample for means' was applied. Test results showed there were no differences between using acetonitrile and acetonitrile-water solutions and between using methanol and methanol-water solutions for elution of STC from Strata C18 column.

For comparing of STC elution procedure efficiency from Strata X SPE column, the 't-test: Paired two sample for means' was applied. Test
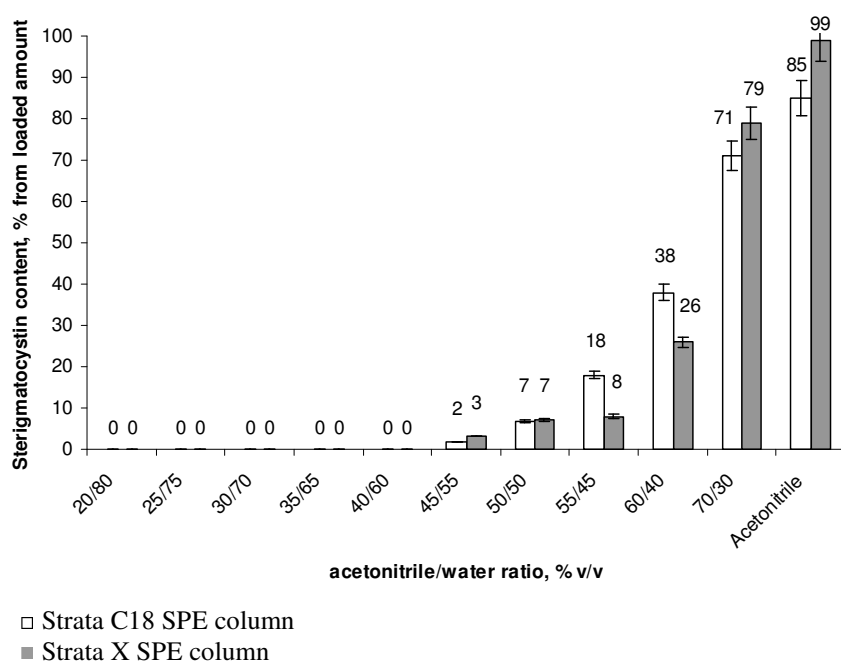

Figure 2. STC content in different acetonitrile-water fractions on Strata X and C18 SPE columns.
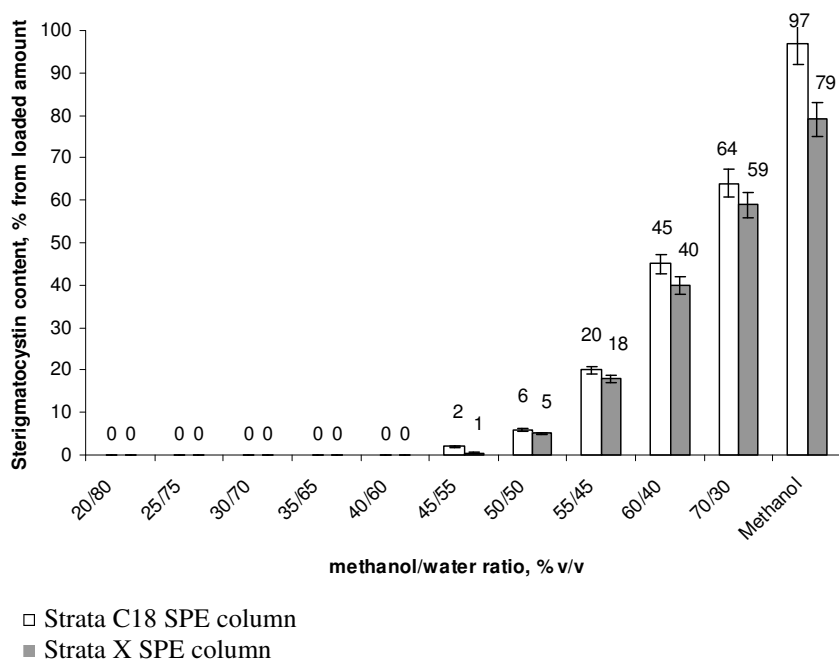
Figure 3. STC content in different methanol-water fractions on Strata X and C18 SPE columns.

results showed there were no differences between using acetonitrile and acetonitrile-water solutions and between using methanol and methanol-water solutions for elution of STC from Strata X SPE column.

For comparing of STC elution procedure efficiency from Strata C18 SPE column and from Strata X SPE column using acetonitrile and acetonitrile-water solutions the 't-test: Paired two sample for means' was applied. Test results showed there were no differences between Strata C18 SPE column and Strata X SPE column using acetonitrile and acetonitrile-water solutions.

For comparing of STC elution procedure efficiency from Strata C18 SPE column and from Strata X SPE column using methanol and methanol-water solutions, the 't-test: Paired two sample for means' was applied. Test results showed there were no differences between Strata C18 SPE column and Strata X SPE column using methanol and methanol-water solutions.

For comparing of STC elution procedures efficiency from two different SPE columns (Strata C18 SPE column and Strata X SPE column) using two different procedures (elution by acetonitrile and acetonitrile-water solutions from Strata C18 SPE column and elution by methanol and methanol-water solutions from Strata X SPE column), the 't-test: Two-Sample Assuming Equal Variances' was applied. Test results showed that

there are no differences between Strata C18 SPE column and Strata X SPE column using two different elution procedures.

For comparing of STC elution procedures efficiency from two different SPE columns (Strata X SPE column and Strata C18 SPE column) using two different procedures (elution by acetonitrile and acetonitrile-water solutions from Strata X SPE column and elution by methanol and methanol-water solutions from Strata C18 SPE column), the 't-test: Two-Sample Assuming Equal Variances' was applied. Test results showed there were no differences between Strata X SPE column and Strata C18 SPE column using two different elution procedures.

Conclusions

Acetonitrile and acetonitrile-water solutions and methanol and methanol-water solutions can be applied for elution of STC from Strata X SPE column as well as from Strata C18 SPE column.

Acknowledgements

References

1. Atalla M.M., Hassanein N.M., El-Beih A.A., Youssef Y.A. (2003) Mycotoxin production in wheat grains by different Aspergilli in relation to different relative humidities and storage periods. Nahrung, 47, pp. 16-10.
2. Betina V. (1989) Mycotoxins: Chemical, Biological, and Environmental Aspects. Elsevier: Amsterdam, The Netherlands, Bioactive Molecules, 9, 438 p.
3. Hsieh D.P.H., Yang S.L. (1975) Preparation of '4C-labeled sterigmatocystin in liquid media. Applied Microbiology, 29, pp. 17-20.
4. Jestoi M., Rokka M., Yli-Matilla T., Parikka P., Rizzo A., Peltonen K. (2004) Presence and concentrations of the fusarium – related mycotoxins beauvericin, enniatins and moniliformin in Finnish grain samples. Food Additives and Contaminants, 21 (8), pp. 794-802.
5. Schroeder H.W., Kelton W.H. (1975) Production of sterigmatocystin by some species of the genus Aspergillus and its toxicity to chicken embryos. Applied and Environmental Microbiology, 30, pp. 589-591.
6. Stroka J., Dasko L., Spangenberg B., Anklam E. (2004) Determination of the mycotoxin sterigmatocystin by thin-layer chromatography and reagent free derivatization. Journal of liquid chromatography and related technologies, 27(13), pp. 2101-2111.
7. Uhligh S., Torp M., Jarp J., Parich A., Gotleb A.C., Krska R. (2004) Moniliformin in Norwegian grain. Food Additives and Contaminants, 21 (6), pp. 598-606.
8. Van Egmond H.P., Walter H. Paulsch (1986) Determination of mycotoxins. Pure and Applied Chemistry, 58 pp. 315-326.
9. Vesonnder R.F., Horn B. (1985) Sterigmatocystin in Dairy Cattle Feed Contaminated with Aspergillus versicolor. Applied and Environmental Microbiology 49, pp. 234-235.

CHANGES IN COLD PRESSED RAPESEED OIL QUALITY IN DIFFERENT PACKAGING MATERIALS DURING STORAGE

Aldona Bluka, Ilze Cakste
Latvia University of Agriculture
E-mail: Aldona.Bluka@llu.lv

Abstract

The dynamic of rapeseed oil oxidizing processes under the influence of light in brown glass, colourless glass, and colourless PET bottles during storage at 18 ± 2 °C were investigated. The changes in A and E vitamins content in rapeseed oil packed in colourless PET packaging materials were determined after 4 months storage at 18 ± 2 °C at daylight. The connection between different packaging materials' transparency and oxidizing of oil were observed.

Keywords: rapeseed oil, packaging, light transparency, oxidizing.

Introduction

Packaging is not only important component in food products realization, but also indicator of society development. The importance of packaging is very high for preservation of nutrients' quality and for decreasing of their losses. Good packaging materials not only preserve food products during transportation and storage, but also allow to forward food products with good quality to the consumer. The barrier properties of packaging depend on the packaging material. Many factors connected with properties of the food product influence the choice of suitable packaging materials.

Because of food production development and improvement PET (polyethylenetherephtalat) increasingly more often is used for vegetable oils packaging and, due to its relatively small weight often serves as replacement of glass packaging materials.

Glass materials are high-quality packaging materials due to their design, variety of colours, and simple processing. The transparency of colourless glass and dark glass materials is different. Different food products have a different wave range critical for their quality changes. UV radiation usually has a powerful influence. Therefore, for some food products, colourless glass packaging materials can be used, but for other food products, more coloured glass materials are needed.

The most popular packaging materials for vegetable oils are different colour glass materials and PET. However, oxidization of oils damages them. Therefore packaging material of oils has been the barrier not only for air oxygen, but also for oxidizing reactions promotes by light irradiance. For that reason, the transparency of the packaging material is a very important parameter. The influence of light on food product quality is complex, which causes and accelerates different undesirable processes, for example, oxidizing processes. Under the influence of light, the processes going on in food products are:

- changes in color;
- losses of vitamins;
- forming of unpleasant odour;
- changes in structure.

During oxidizing of oils, changes in oils structure occur: products of secondary oxidizing are formed. These products undesirably influence the processes in the human body.

Vegetable oils produced in Latvia contain polyunsaturated fatty acids which play important role in the human body. During storage, light and temperature promote oils oxidizing.

Oxygen influences oxidizing of oils during storage, and oxidizing reaction is very important between polyunsaturated fatty acids and oxygen (Gunstone, 1996). Many factors ions of metals, in particular copper, iron, manganese, cobalt, and nickel, temperature and ultraviolet rays - promote this process. The rate of oxidizing reaction is greater if more double bonds are in a fatty acid molecule (Encyclopedia of Food, 2003).

Rapeseed oil contains fat-soluble vitamins A, E, and D.

Carotenes are the provitamin of vitamin A and also work as antioxidants, but vitamin E (tocopherols) prevents oxidizing of

polyunsaturated fatty acids. The highest activity of vitamin E and the lowest antioxidative activity have α-tocopherol, but upside down these connections is regarding γ-tocopherol (Deshpande, 2002).

The aim of this work was to investigate the influence of packaging material transparency on oxidizing processes of cold pressed rapeseed oil produced in Latvia, during storage.

Materials and Methods

Fresh, unrefined rapeseed oils obtained by cold pressing in stock company 'Iecavnieks' were used in the experiments. Brown glass, colourless glass, and colourless PET bottles with 0.40±0.01 mm walls were used for packaging. Peroxide value of cold pressed rapeseed oil was determined after 1, 2, 3, and 4 months of storage using chemical method volumetrically (ISO 3960:2001). Light absorption of packaging materials (brown and colourless glass, and colourless PET) was determined with JENWAY 6485 UV/VIS spectrophotometer. Transparency was calculated according to equation:

$$A = -\lg T, \tag{1}$$

where A – absorption,

T - transparency, %.

The amounts of A and E vitamins in cold pressed rapeseed oil after 4-month storage were determined by standard methods – AOAC Official Standard Method 974.29 and AOAC Official Standard Method 971.30.

Results and Discussion

Oils for marketing and using in housekeeping mainly are kept at ambient temperature and under light. In these conditions light promotes the oxidizing processes of oils. Therefore the dynamic of rapeseed oil oxidizing processes under the influence of light in brown, colourless glass, and colourless PET packaging materials were investigated. The peroxide value was determined as indicator of oxidizing rate.

Obtained results showed that packaging materials have significant influence on oils providing quality. Figure 1 demonstrates that peroxide value still increases after 1 month of storage, but after 4 months it increases 1.6-14.5 times in rapeseed oil in different packaging materials compared with peroxide value in fresh pressed rapeseed oil. The European Council Regulation No.178/2002 of 28.01.2002 prescribes that permissible amount of peroxide value in cold pressed rapeseed oils is up to 10 meq kg^{-1}.
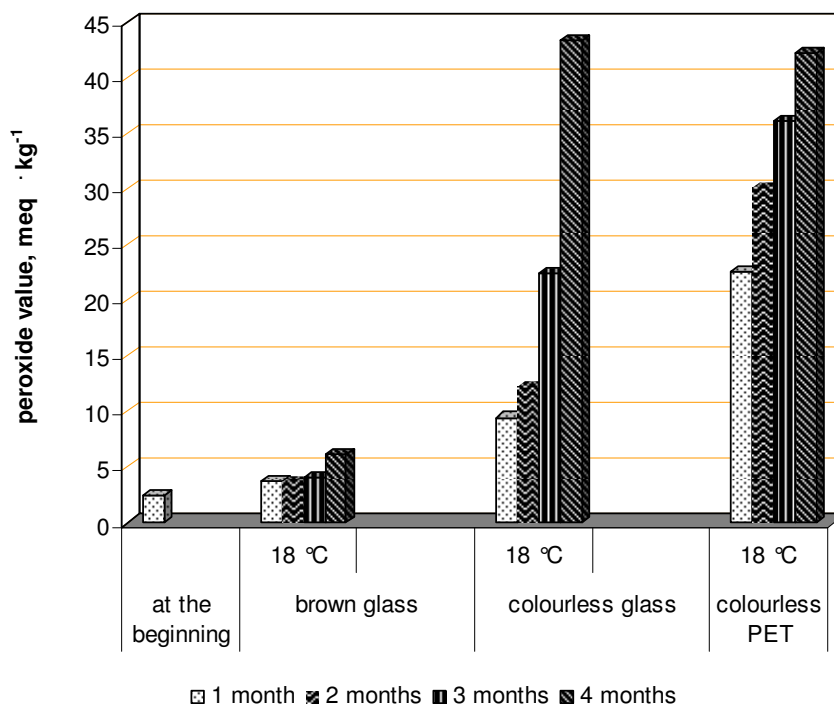
Figure 1. The changes in peroxide value of cold pressed rapeseed oils in different packaging materials during storage.

colourless glass ——— colourless PET ——— brown glass
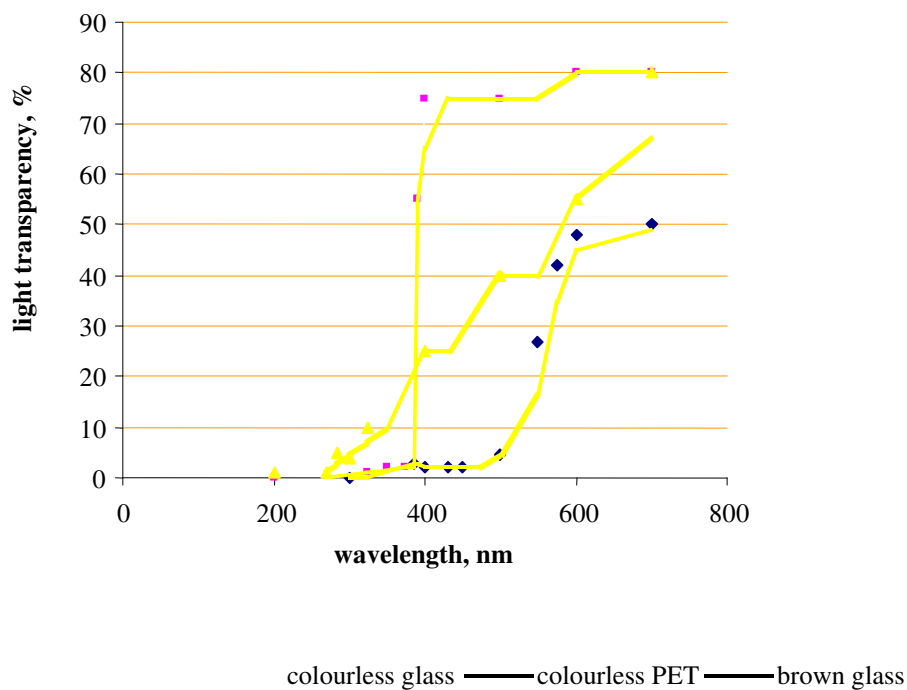
Figure 2. Light transparency of rapeseed oil packaging materials.

Therefore it can be concludd that most suitable material for oils packaging and storage is brown glass bottles, because oils packaged in this material oxidize less than oils packaged in uncoloured glass bottles. Ansuitable packaging material for oils storage proved to be colourless PET.

It is known that light promotes oxidizing
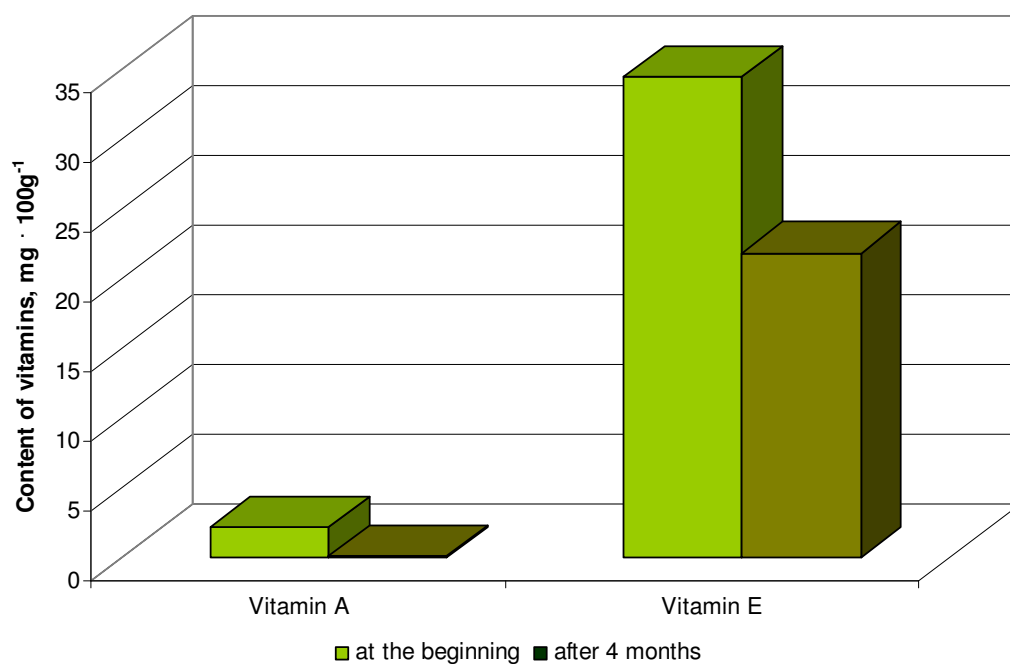
Figure 3. The content of vitamins A and E in rapeseed oil 18 ± 2 °C, colourless PET material.

processes in oils and ultra-violet light transparency decreases as follows: PET → colourless glass → brown glass (Robertson, 1993; Ханлон, 2004). PET films have not absolute oxygen barrier properties. With the increasing of PET films' density the penetrability of oxygen decreases.

Figure shows that a greater light transparency was determined for uncoloured glass material, but less - for brown glass packaging material.

When analyzing the obtained results we found connection between transparency of different packaging materials and oxidizing of rapeseed oil. Colourless glass material has the highest transparency, and after a 4 month storage the highest oxidizing of rapeseed oil in this packaging material was determined. Accordingly, brown glass material had the lowest transparency, and also oxidizing of rapeseed oil in this packaging material was lower (Figures 1 and 2).

The greatest part of cold pressed rapeseed oil produced in Latvia are packed in colourless PET material, therefore the changes in A and E vitamins content were investigated only in cold pressed rapeseed oil packed in colourless PET materials during storage at 18 ± 2 °C.

The results suggest that the content of vitamins A and E decreases after 4 months of storage.

Vitamins A and E are natural antioxidants therefore changes in the content of these vitamins can be explain by oxidizing processes of rapeseed oil packed in colourless PET material, caused by light.

Conclusions

1. The most suitable material for packaging and storage of cold pressed rapeseed oils is brown glass bottles.
2. Connections between transparency of packaging materials and oxidizing of rapeseed oil were observed during storage at 18 ± 2 °C under the influence of light: the oxidizing is higher in materials with higher transparency.
3. Decreasing in A and E vitamins content in rapeseed oil packed in colourless PET material during storage can be connected with oxidizing processes caused by light.

Acknowledgements

References

1. Deshpande S.S. (2002) Handbook of food toxicology - New York: Marcel Dekker, p. 25.
2. Encyclopedia of food sciences and nutrion (2003) /Edited by Caballero B.,Trugo L., Finglos P., vol. 4.,- Elsevier science Ltd, pp. 2301-2311.
3. Gunstone F. (1996) Fatty acid and lipid chemistry - London: Chapman Hall, pp. 35-39, 67-71, 162-183.
4. Robertson G.L. (1993) Food packaging: Principles and practice - New York: Marcel Dekker Inc 293 p.
5. Ханлон Дж.Ф., Келси Р.Дж., Форсино Х.Е. (2004) Упаковка и тара. Проектирование, технологии, применение (Packaging and tare. Designing, technology, applying). Санкт–Петербург: Профессия, 280 с. (in Russian).

INVESTIGATION OF THE QUALITY OF VEGETABLE OILS

Sanita Vucāne, Māra Kūka
Latvia University of Agriculture
E-mail: sanitavucane@inbox.lv

Abstract

Vegetable oils are essential providers of energy to a human body; they play important role as a foodstuff. During processing and storage of vegetable oils, they may undergo molecular changes adverse to the human organism affecting the quality of the oils.

The content of fatty acids of fresh rapseed, linseed and hemp oils and of the mixture of rapeseed (800 g kg^{-1}) and linseed (200 g kg^{-1}) oils was determined by the method of gas chromatography (GH).

α -, δ - and γ - tocopherols was analyzed in the vegetable oils by the methods of the highly effective liquid chromatography (HPLC).

The hemp oils contain the indispensable polyunsaturated fat acids: linoleic acid – 53.0%, and linolenic acid – 23.2%. Such proportion of the fatty acids (3:1) is considered optimal in the nutrition.

When using both hot and cold pressure technology for the obtaining of oil it is possible that the polycyclical aromatic hydrocarbon – Benzo[a]pyrene – may be created and influenc the quality of the oil.

The environment also affects the content of the lead in the oils.

The density of the various vegetable oils at the temperature of 20 °C proved to be within the limits of 0.917 and 0.942 kg dm^{-3}.

Keywords: vegetable oil, fatty acids, α -, δ - γ, tocopherol, benzo(a)pyrene, density, lead.

Introduction

Over the last few years, a lot of attention has been paid to the plants that are most suitable to the Latvia climate and has-been cultivated from the ancient times, yielding oil, like rape, hemp, and flax. The oil processed through the technology of cold press, not exceeding the temperature of +50 °C, without purifying is considered to be a natural vegetable oil.

The oil of linseed and hemp is a really valuable resource of the natural products. It used to be the first curative accessible to our grandparents for the treatment of various diseases.

Linoleic and linolenic acids are called the vitamin F which has rich reserves of the flax and hemp oils. Those compounds are called indispensable fatty acids; they are necessary to the organism, though they cannot be synthesized and must be taken in with the food. Nature holds just a few products like oils of blackcurrant and grape seeds which are particularly rich in this vitamin and which directly stimulate the work and renewal of cells and normal functioning of metabolism processes (Mustard, 2005).

Tocopherols (vitamin E) naturally save the polyunsaturated fatty acids from being oxidized by default. Particularly large amounts of vitamin E are to be found in the oils of sunflower seeds, flax seeds and sprouts of wheat. During the process of refinement, some part of vitamin E is being lost, and the oil contains some remaining 75% of this vitamin, which is enough to save this oil from oxidation for some time (Dutta et al., 2003; Kulas et al., 2002; Farag et al., 1989). Anti radical characteristics within the cell membranes are displayed by vitamin E. Oxidation inhibitor soluble in the lipids reacting with the ROO$^-$ of the lipid - peroxiradically (Tang et al., 2005; Goffman et al., 2001).

One of the most important role in the quality of oils plays the Benzo[a]pyrene.This is a polycyclic aromatic hydrocarbon with the cancerous cell development characteristics. Benzo[a]pyrene may be included into the oil through the seeds if they have been dried and ignoring the technology.

When using the food containing lead, it is absorbed in the small intestines. The lead accumulates in the liver, the kidneys, the bones, the pancreas, sometimes in the spleen and the brain. It may lay inactive for many years, and the human being feels healthy. The period of saving of the lead in the bones is approximately 20 years, in the blood – 35 days. The knowledge about the processes of the discharge of lead out of the body is very scarce. With the lowering of the organism's immunity (due to an increased intake of alcohol or smoking) and as the result of infectious diseases, physical or psychic trauma,

the lead may enter the blood vessels causing the poisoning. Entering the blood the lead links itself with hemoglobin and plasma proteins, which may lead to erythrocythemia and disorders of the cell oxidation. Therefore, control over the contents of lead is so important (Belitz et al., 2004).

Various oils have different densities inherent just to them. They depend upon the contents of oil fatty acids.

The task of the investigation is:

- to determine and compare the contents and density of the fatty acids, tocopherols, Benzo[a]pyrene and lead for the rapseed oil, linseed oil and hemp oil produced in Latvia;
- to create the mix of rapeseed oil and linseed oil, 80 % and 20 % correspondingly.

Materials and Methods

Materials

Fresh, cold pressed and unrefined vegetable oil (rapseed, linseed and hemp oils), as well as the mix of rapseed and linseed (80% and 20% correspondingly) from 'Naukšēni' Ltd and 'Iecavnieks' Ltd were determined.

Methods

The content of vegetable oils was determined using the gas chromatography (GH). The content of fatty acids was analyzed with the Shimadzu GC 2010 (detector – flame ionization, column – AT-Wax length 50 m, internal diameter – 0.25 mm, thickness of immobile phase – 0.2 μm) (LVS EN ISO 5508:1995, LVS EN ISO 661:2005, LVS EN ISO 5509:2001).

Huge resolution of the highly effective liquid chromatography (HPLC) methods allows separating the classes of the matter of a wide range; it is used as the method for separation of the hardly evanescent or thermally unstable compounds.

The content of tocopherols in the vegetable oils was established with the HP HPLC 1110 (ELSD detector, column – Pronto SIL C 30 5μm, length – 250 mm x 4.6 mm, mobile phase 96% of methanol : 4% of water, thermostat temperature – 25 °C, 0.9 mL min) (LVS EN ISO 9936:2001).

The content of Benzo[a]pyrene was set by the HP HPLC 1110 (ELSD detector, column: C 18, 5 μm, length 250mm x 4,6mm, mobile phase: 40% acetonitrile: 60% water, thermostat temperature – 25 °C, 1.0 mL min) (LVS EN ISO 15302:2001).

Table 1

The Content of fatty acids in the oils of linseed, rapseed and hemp

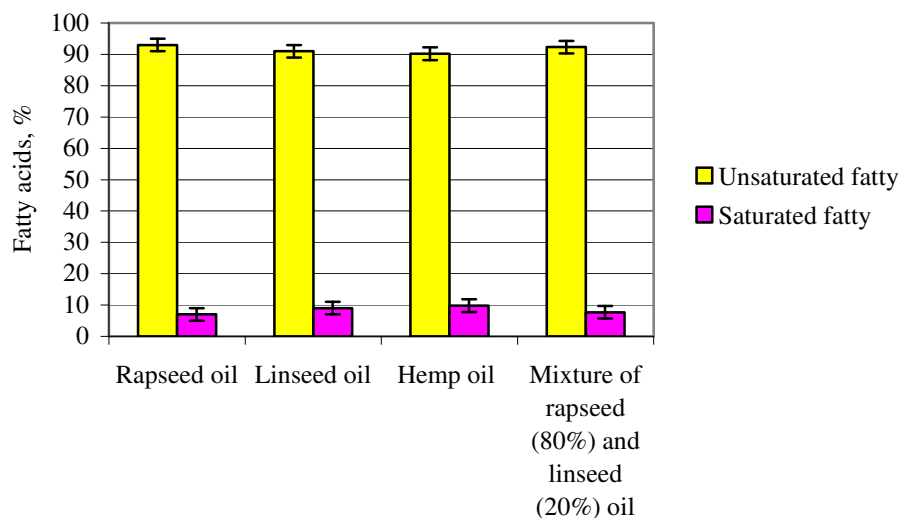| Fatty acids	Rapseed oil, % ±2.0	Linseed oil, % ±2.0	Hemp oil, % ±2.0	The mix of the rapseed and linseed oil, % ±2.0
14:0	0.1	0.1	0.1	0.1
16:0	4.1	4.9	5.8	4.4
16:1	0.2	0.2	0.1	0.2
17:0	0.1	0.1	0.1	0.1
17:1	0.1	-	-	-
18:0	1.7	3.4	2.4	2.3
18:1 cis 9	58.0	19.3	10.5	48.0
18:1 cis 11	3.0	0.8	0.9	2.8
18:2	19.5	14.7	53.0	17.0
18:3 gamma	**-**	**-**	**4.3**	**-**
18:3 alpha	10.3	55.8	18.9	22.9
18:4	-	-	1.5	-
20:0	0.6	0.2	0.9	0.5
20:1	1.4	0.2	0.5	1.2
20:2	0.1	-	0.1	-
22:0	0.3	0.2	0.4	0.2
22:1	0.2	-	0.3	0.1
24:0	0.1	0.1	0.1	0.1
24:1	0.2	-	0.1	0.1

Figure 1. The content of saturated and unsaturated fatty acids in the vegetable oils.

The content of lead in the vegetable oils was established by the x–ray fluorescence method with the Oxford Instruments EDXRF spectrophotometer Lab-X 3500.

The density of vegetable oils was established by means of the Anton Paar digital density measurer (DMA 48) (LVS EN ISO 3656:2003). The densities of vegetable oils was established electronically by measuring the oscillation of the vibration of the U–tube.

Each measuring was carried out several times and then the simple average was calculated.

The data were analyzed statistically by using SPSS for Windows, MS Excel.

Results and Discussion

The content of linseed, rapseed and hemp oils was determined using the gas chromatography method (Table 1).

It should be emphasized that the content of γ-linolenic within the hemp oil constitutes 4.3%. The physiological characteristics of this acid has been examined just recently. However, it plays an important role in the prevention of the immunological disturbances. The author may mention the few oils containing the γ-linolenic, for example, the black currant and grape seed oil (Belitz et al., 2004).

By the use of the chromatography data, a comparison between the contents of saturated and unsaturated fats in the oils of rapseed, linseed and hemp was made (Figure 1).

The common content of unsaturated fatty acids in rapseed oil was 93.0%, in linseed oil –

91.0% and in hemp oil – 90.2%, but the content of polyunsaturated fatty acids in rapseed oil was 29.8%, in linseed oil – 70.5% and in hemp oil – 77.7%. In the mixture of rapseed and linseed oils, the content of unsaturated fatty acids was 92.3% and of polyunsaturated fatty acids – 39.9%.

Due to the influence of the indispensable fatty acids ω-6 and ω-3, that is, linoleic and linolenic, the level of the triglycerides and the low density lipoproteins lowers, and the level of the high density lipoproteins increases, which helps protect against the heart diseases, cancer and atherosclerosis, and slightly increases the blood vessels. Therefore the author investigated the fatty acids content in linseed, hemp and rapseed oils (Figure 2). The hemp oil contains indispensable polyunsaturated fat acids: linoleic – 53.0%, and linolenic – 23.2 %. Such proportion of the fatty acids, 3:1, is considered to be the optimal in the human nutrition thereby hemp oil is considered to be unique among the other vegetable oils under the research.

Linseed oil is rich in linolenic acid (55.8%) which is an essential fatty acid for the human being. The unsaturated fatty acids are very important for our immune system and help us regulate our blood pressure.

With the HPLC method of the liquid in determining the tocopherol content it was found that the predominant ingredient in the linseed, hemp and rapseed oils was the α-tocopherol. The highest content of tocopherols was found in the hemp oil (Figure 3).

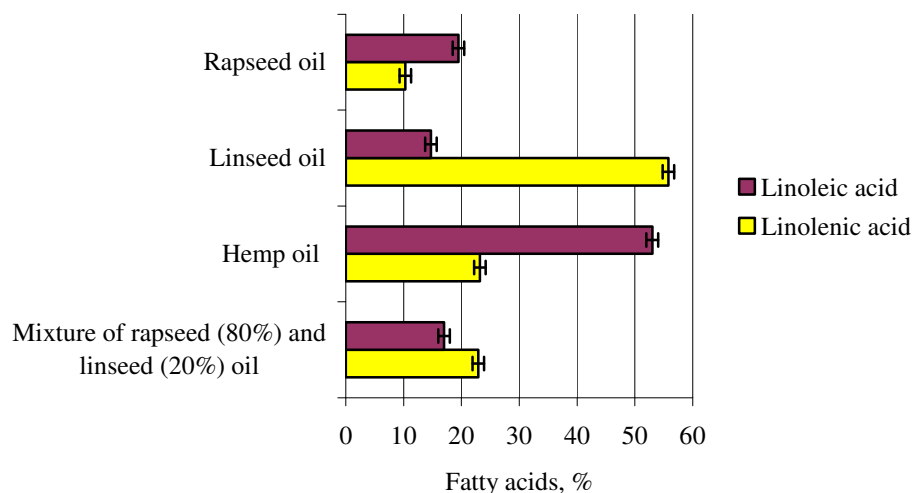The content of α-tocopherols in rapseed oil was 95.8 mg kg^{-1}, in linseed oil – 25.3 mg kg^{-1},

Figure 2. The ratio between linolenic acids and linoleic acids in the vegetable oils.

and in hemp oil – 32.4 mg kg^{-1}. In the mixture of rapseed and linseed oils, the content of α-tocopherols was 88.1 mg kg^{-1}.

It is well known that the α-tocopherols take an active part in the work of ductless glands and fat metabolism, as well as participates in the process of transforming the carotene into vitamin A. Its work is associated with the processes of fat metabolism.

The content of Benzo[a]pyrene was established using the highly effective liquid chromatography (Figure 4). In the oils under the research, the content of Benzo[a] pyrene did not exceed the permissible level of 2 μg kg^{-1}. Benzo[a] pyrene, having carcinogenic qualities, may serve both as quality and quantity indicator in relation to the multiring aromatic hydrocarbon content within the product (Commission Regulation 2005/208/EC).

The results of obtained vegetable oils density are shown in Figure 5. The results show that density of the various oils differs in a wide range. The volume of the density was observed depending the type of the oils, and this also affects the changes in those oils.

With the use of the x–ray fluorescence spectrometer, the content of lead was established in various vegetable oils. An increased lead
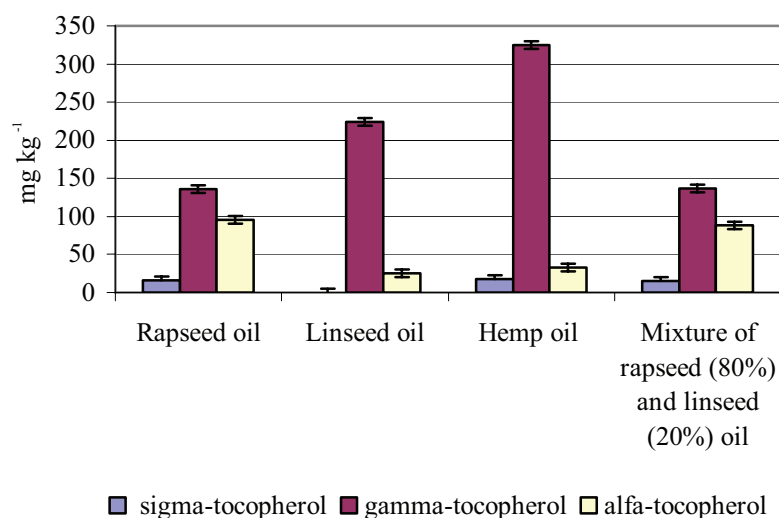
Figure 3. Tocopherols content in the vegetable oils, mg kg^{-1}.
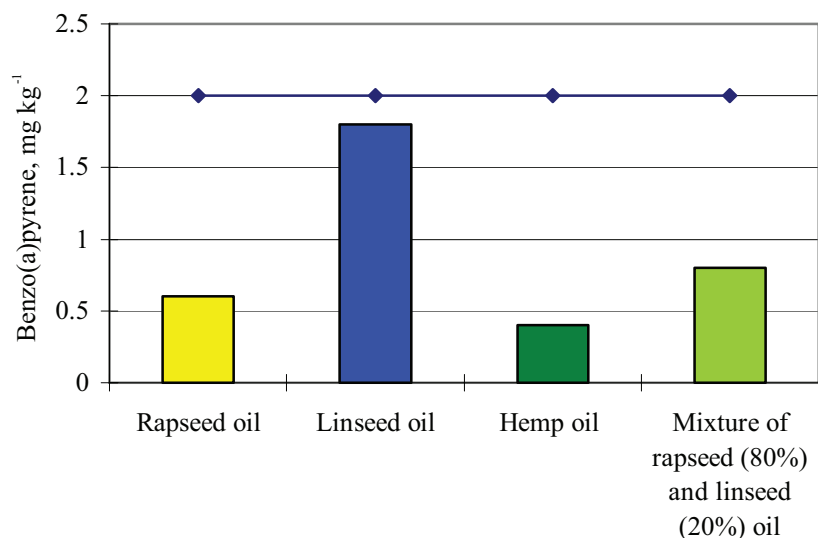
Figure 4. Benzo[a]pyrene content in fresh vegetable oils, μg kg^{-1}.

intake through foods and vegetable oils may cause illnesses of various origin, as well as disorders of the nervous system, therefore control of the lead content is so important (Commission Regulation 2005/78/EC).

The lead content in the vegetable oils was established in all the oils ranging from 0.02 to 0.05 mg L^{-1}. In accordance with the data from FAO, the human daily intake of lead may reach 0.2 – 0.3 mg L^{-1} (Codex STAN 33-1981).

Conclusions

- The content of fatty acids in the vegetable oils under the research was established as follows:

  - total content of unsaturated fats in linseed oil amounted to 91.0 %, including irreplaceable fat acids – 70.5%; in hemp oil – correspondingly 90.2% and 77.7%, and in rapseed oil – 93.0% and 29.8%;
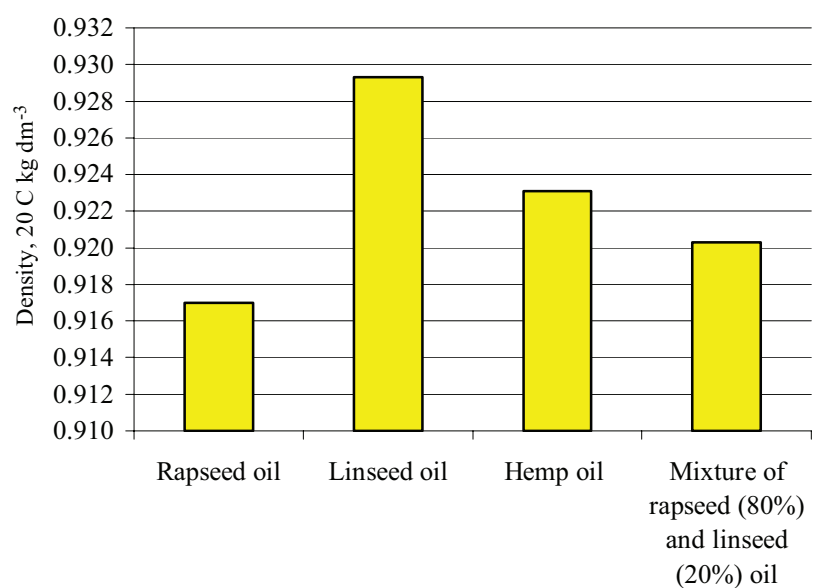
Figure 5. Density of the vegetable oils.

- in the mixture of rapseed and linseed oils, the content of unsaturated fatty acids was 92.3%, and that of polyunsaturated fatty acids – 39.9%;
- the hemp oil is the only oil under the research containing the flex acid γ-linolenic (4.3%). The ratio between linoleic and α-linolenic is 3:1 for the demands of the optimal human organism. Thus, hemp oil may be considered as unique among other vegetable oils under the research.

- While examining the contents of tocopherols it was established that linseed oil, hemp oil and rapseed oil predominantly contain α-tocopherols that are followed by α-tocopherols and smaller amount of α-tocopherols. The highest content of tocopherols was found in hemp oil. The content of α-tocopherols in rapseed oil was 95.8 mg kg^{-1}, in linseed oil – 25.3 mg kg^{-1}, and in hemp oil – 32.4 mg kg^{-1}. In the mixture of rapseed and linseed oils the content of α-tocopherols was 88.1 mg kg^{-1}.

- Benzo[a]pyrene was found in all of the oils under the research, and its content did not exceed 2 μg kg^{-1}.
- The density of vegetable oils at the temperature of 20 °C remained within the range of 0.917 – 0.942 kg dm^{-3}.
- As one of the indicators of the pollution, was determined the content of lead in the oils under the research. In all the oils the lead content was established 0.02 – 0.05 mg L^{-1}. The level of lead in the vegetable oils is not a reason for alarm, though it is necessary to take sustained measures to continue to decrease the average level of the lead content in the foodstuffs.

References

1. Belitz H.D., Grosch W. (2004) Food Chemistry. Berlin etc. Springer Verlag, 774 p.
2. Codex Standart (2003) Codex Standart for Olive oils and Olive pomace oils, Codex STAN 33-1981 (Rev. 2-2003)[1] 6 p.
3. Commission Regulation 2005/208/EC of 4 February 2005 as regards polycyclic aromatic hydrocarbons. Official Journal of the European Communities, 2005, pp. 34/3 – 34/5.
4. Commission Regulation 2005/78/EC of 19 January 2005 as regards heavy metals. Official Journal of the European Communities, 2005, pp. 16/43 – 16/45.
5. Dutta A., Dutta S.K. (2003) Vitamin E and its role in the prevention of atherosclerosis and carcinogenesis. Journal of the American College Nutrition 22, pp. 258-268.
6. Farag R.S., El-Baroty G.S. (2003) Basunu A.M. Safety evaluation of olive phenilic compounds as natural antioxidants. International Journal of food sciences and nutrition, Vol. 54, Nr. 3 May pp. 159-174.
7. Goffman, F.D., Becker H.C. (2001) Diallel analysis for tocopherol contents in seeds of rapeseed. Crop Science 41, pp. 1072-1079.
8. Kulas E., Olsen E., Ackman R.G. (2002) Effect of α-, γ-, δ-tocopherol on the distribution of volatile secondary oxidation products in fish oil. European Journal of Lipid Science and Technology, 104(8), pp. 520-529.
9. Latvian State Standard (2005) LVS EN ISO 661:2005, Animal and vegetable fats and oils – Preparation of the sample to be analyzed, pp. 2-4.
10. Latvian State Standard (2003) LVS EN ISO 3656:2003, Animal and vegetable fats and oils – determination of the ultraviolet optical density in accordance with the UV radiation special weakening pp. 1-4.
11. Latvian State Standard (1995) LVS EN ISO 5508:1995, Animal and vegetable fats and oils – Analysis of the fat acids methyl esters with the gas chromatography, pp. 4-6.
12. Latvian State Standard (2001) LVS EN ISO 5509:2001, Animal and vegetable fats and oils – Preparation of the fat acids methyl esters, pp. 2-5.
13. Latvian State Standard (2001) LVS EN ISO 15302:2001, Animal and vegetable fats and oils analysis of Benzo[a]pyrene with a highly effective liquid chromatography, pp. 2-3.
14. Latvian State Standard (2001) LVS EN ISO 9936:2001, Animal and vegetable fats and oils. Analysis of the tocopherols with a highly effective liquid chromatography, pp. 6-8.
15. Mustard V.A., Demichele S., Zinker B.A., Huang Y. (2005) Lipid system and methods of use containing omega fatty acids. U.S. Pat. Appl. Publ. US 54,724 10 mart 2005, Appl. 656,662, 5 sept 2003, pp. 20.

16. Tang J.L., Faustman C., Hoagland T.A., Mancini R.A., Seyfert M., Hunt M.C. (2005) Interactions between mitochondrial lipid oxidation and oxymyoglobin oxidation and the effects of vitamin E. Journal of Agricultural and Food Chemistry. American Chemical Society, Washington, USA: 53: 15, pp. 6073-6079.

THE STUDY OF RHEOLOGICAL PROPERTY OF FUNCTIONAL FERMENTED MILK

Ilze Beitane, Inga Ciproviča
Latvia University of Agriculture
E-mail: Inga.Ciprovica@llu.lv

Abstract

The role of *Bifidobacterium lactis* and the effect of the addition of inulin and lactulose on the viscosity of a functional fermented milk product have been investigated.

The effect of chosen starter and prebiotics on the properties of the functional fermented milk was significant for the apparent viscosity. Generally the viscosity of analyzed products was lower than the viscosity of classical fermented milk products, such as yoghurt, kephir or others. The viscosity was strongly affected by the content of total solids of the analyzed products: with an increase in the total solids there was increase in the viscosity. Among analyzed fermented milk samples, sample with 5% of lactulose had the highest viscosity. In general, inulin did not seem to have an effect on the viscosity of the analyzed product samples compared with the control sample. *Bifidobacterium lactis* has a weak proteolytic activity, therefore the structure and consistency of functional fermented milk product were characterized as weak, too. It is known that inulin is not only dietary fibre or prebiotic, it has the functions of food additives, too. Inulin is added to food formulations to modify products' texture or viscosity and sweetness of products. Comparison of the obtained results shows that the viscosity of the functional fermented milk product with various concentrations of lactulose or inulin is different. This suggests that the role of inulin in a food matrix is bi-functional. Inulin does not increase the viscosity of a milk product but gives a richer texture to liquid products and spreads.

Keywords: viscosity, shear rate, functional fermented milk, *Bifidobacterium spp.*

Introduction

Continuously increasing consumer health consciousness is responsible for the expanding worldwide interest in functional foods. Fermented dairy products, such as yoghurt, have been known for their use in managing intestinal disorders such as lactose intolerance or acute gastroenteritis. There are different approaches in the dairy industry, which are aimed at modifying the intestinal microflora and thereby beneficially influencing the health of the host. These include the fermentation of milk with probiotics, such as various strains of *Lactococcus, Lactobacillus* and *Bifidobacterium spp.* which inhabit the human gut. The addition of prebiotics is supposed to stimulate the growth of various health-promoting bacteria in the human colon. The application of each treatment potentially influences the rheology property, as different starter cultures are used, or conventional starter cultures show other modified fermentation patterns (Torre et al., 2003). Therefore the task of current study was to investigate the influence of *Bifidobacterium lactis* and the different concentrations of prebiotics on the rheological property of a functional fermented milk product.

Materials and Methods

The research was performed at the laboratory of the investigations of the properties of packaging materials at the Department of Food Technology of Latvia University of Agriculture.

The strain of *Bifidobacterium lactis* (BB-12, Chr.Hansen, Denmark) was used for experiments. During the experiments, the culture was maintained at -18 °C. The lactulose syrup (Duphalac®, Netherland) was used for growing of bifidobacteria in milk. The composition of the syrup of lactulose was as follows (%): lactulose – 67, lactose – less than 6, galactose – less than 10. The inulin Raftiline®HP (ORAFI Active Food Ingredients, Belgium) was used for growing of bifidobacteria in milk. The composition of inulin was (%): inulin – more than 99.5, glucose, fructose and sucrose – less than 0.5.

Bifidobacterium lactis was incubated in milk. Different lactulose and inulin concentrations (1, 2, 3, 4, and 5%) were added individually to 100 g of milk. *Bifidobacterium lactis* was inoculated with 2 ml of milk suspension (10^6 cfu ml^{-1}) and cultured at 36 °C for 16 hours. The control sample was prepared without the prebiotics for comparing with the obtained results.

The rheological property was examined with the *DV-III Ultra Rheometer BROOKFIELD*

equipped with TC-102 water bath for keeping temperature at 20.0±0.3 °C. All measurements were carried out by BROOKFIELD standard methods in three independent repeats on 1st, 2nd, 5th, 6th, and 7th day of fermented product storage with a controlled shear rate using a spindle SC4-16.

Results and Discussions

The effect of starter and prebiotics on the properties of the functional fermented milk was significant to the viscosity. Quantity of added oligosaccharides is one of the significant factors which have an influence on the fermentation process and the consistency of product. Some authors suggest that lesser than 5% addition of oligosaccharides would improve the growing of *Bifidobacterium lactis* in milk during fermentation and the products' consistency, too (Palframan et al., 2002). The data of viscosity of the analyzed functional fermented milk samples is shown in Figure 1.

Generally, the viscosity of analyzed products was lower than the apparent viscosity of classical fermented milk products, such as yoghurt and others. Yoghurt produced using the starter culture YC-180 (*Lactobacillus delbrueckii subsp. bulgaricus, Streptococcus thermophilus*)

was characterized by the following apparent viscosity from 4506 till 4764 mPa s (Benezech et al., 1993). The viscosity was strongly affected by the content of total solids of the analyzed products: with an increase in the total solids there was increase in the apparent viscosity (Penna et al., 2006). Among analyzed fermented milk samples, sample with 5% of lactulose had the highest viscosity. In general, additional inulin did not seem to have an effect on the viscosity compared with the control sample. According to Tamine and Marstall, the fast development of acidity in fermented milk, for example, yoghurt, is necessary for making of a stable product with desirable rheological parameters (Tamine et al., 1997). Although, the development of acidity of *Bifidobacterium* species compared with *Lactococcus spp.* and *Lactobacillus spp.* is weak. The differences in acidic abilities of bacteria, which are included in cultures used for functional products production, mainly *Bifidobacterium spp.*, were probably main reason for differences in rheological properties of the investigated product samples.

Also, for the analyzed product, stated the lowest viscosity and the lowest shear stress at maximum shear rate were stated. The data regarding the influence of shear rate on the
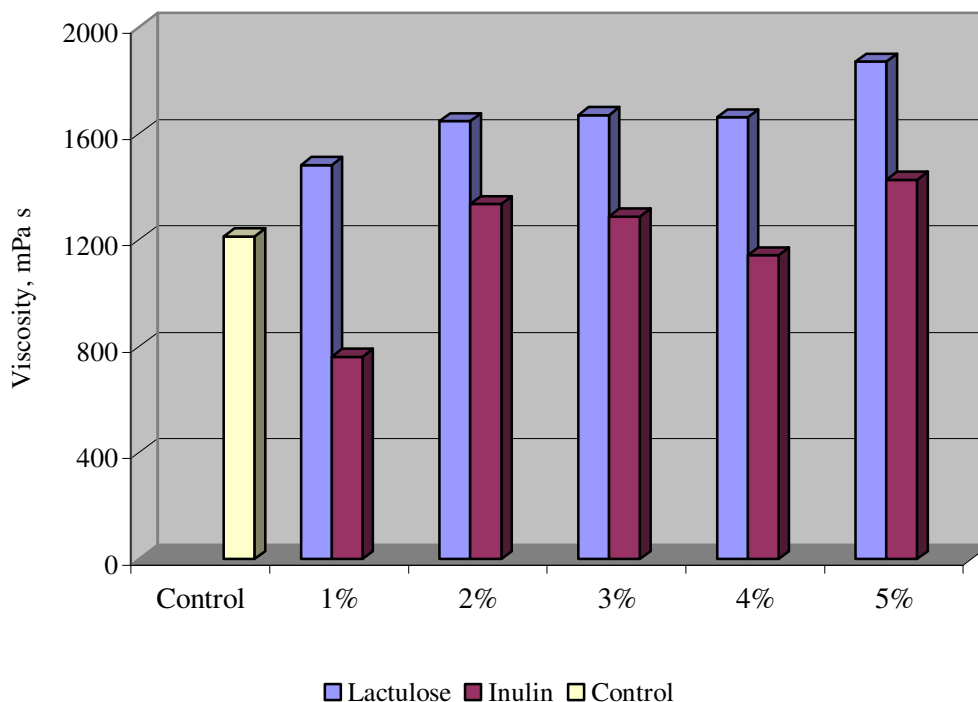

Figure 1. Viscosity of functional fermented milk with different concentration of lactulose and inulin is measured at shear rate of 3 s^{-1}.
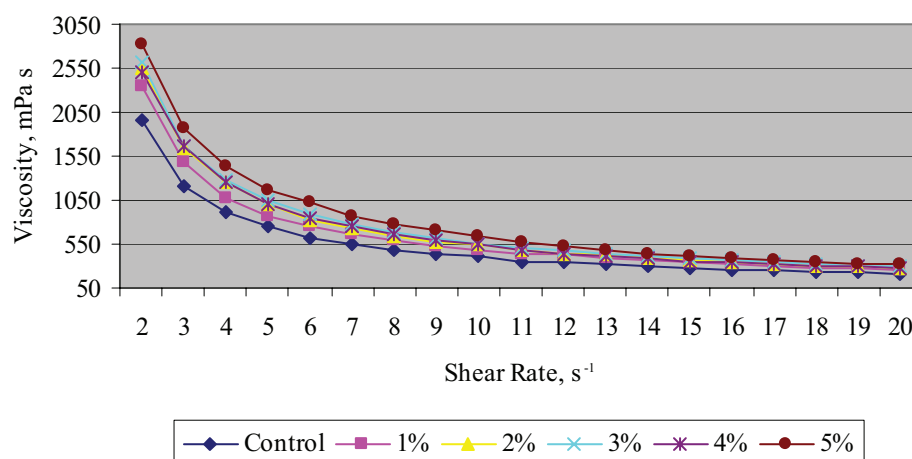
Figure 2. The influence of shear rate on the viscosity of functional fermented milk with lactulose.

viscosity of analyzed products is shown in Figures 2 and 3.

These results have been obtained during the tests where the samples structure was disrupted or weakly disrupted. The rheological behavior of functional fermented milk samples makes the comparison of data from shearing tests, where the samples structure was disturbed, possible.

In practice, among all fermented milk products obtained using classical starter cultures from the genera *Lactococcus* and *Lactobacillus* was characterized by the hysteresis loop area (Domaga et al., 2004). The hysteresis loop area can be interpreted as measure of fermented milk structure breakdown during shear rate, and a slant of curve can testify to resistence of fermented milk gel to action of shear forces (Benezech et

al., 1993). Functional fermented milk obtained using *Bifidobacterium lactis* (Bb 12, Chr.Hansen, Denmark) was not characterized by the hysteresis loop. As described above, *Bifidobacterium lactis* has a weak proteolytic activity therefore the structure and consistency of functional fermented milk product were characterized as weak, too. It is known that inulin is not only dietary fibre or prebiotic, supposed to stimulate the growth of lactic acid bacteria during the fermentation process of milk or other substrates and also various health-promoting bacteria in the human colon, inulin has the functions of food additives, too. Inulin is added to food formulations to increase products' texture or viscosity and sweetness of products (Kip et al., 2006). If we compare the obtained results we can see that

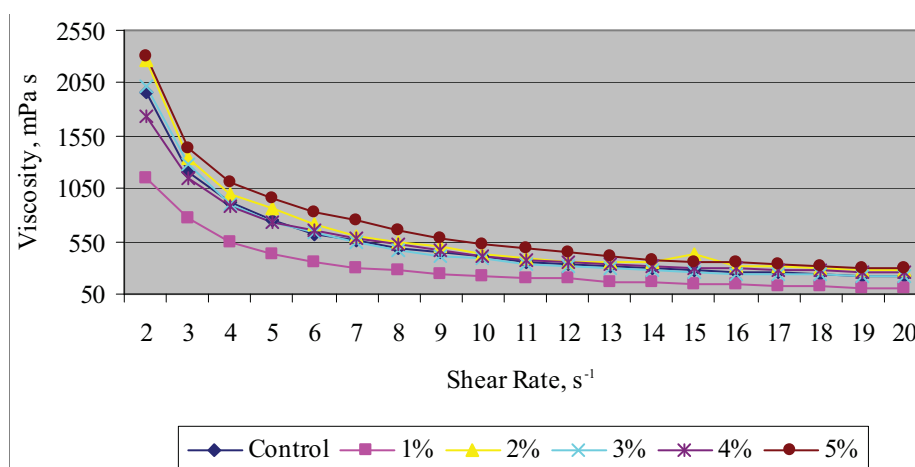
Figure 3. The influence of shear rate on the viscosity of functional fermented milk with inulin.

the apparent viscosity of the functional fermented milk product with various concentrations of lactulose or inulin is different. This suggests that the role of inulin in a food matrix is bi-functional. Inulin does not increase the viscosity of a milk product but gives a richer texture to liquid products and spreads (Leporanta, 2001).

Also some extracellular polysaccharides produced by lactic acid bacteria are known to cause an increase in viscosity, thus leading to improved physical stability of a fermented product. Due to the lack of the weak proteolytic or other technological properties, *Bifidobacterium lactis* could not be able to synthese extracellular polysaccharides. Abovementioned information

would be a possible explanation for these results.

Conclusions

1. The differences in rheological property of functional fermented milk with different prebiotic (oligosaccharides) concentrations were ascertained.
2. The investigated functional fermented milk samples were characterized by lower viscosity than other fermented milk products.
3. The viscosity was strongly affected by the content of total solids of the analyzed products, with an increase in the total solids there was increase in the viscosity.

References

1. Benezech T., Maingonnat J.F. (1993) Flow properties of stirred yoghurt: structural parameter approach in describing time-dependency. J.Texture Studies 24: pp. 455-473.
2. Kip P., Meyer D., Jellema R.H. (2006) Inulin improves sensoric and textural properties of low-fat yoghurts. International Dairy Journal 16: pp. 1098-1103.
3. Domaga J., Juszczak L. (2004) Flow behaviour of goat's milk yoghurts and bioyoghurts. Food Science and Technology 7, Issue 2.
4. Leporanta K. (2001) Developing fermented milks into functional foods. Innovation Food Technology 10: pp. 46-47.
5. Penna A.L.B., Converti A., de Oliveira M.N. (2006) Simultaneous Effects of Total Solids Content, Milk Base, Heat Treatment Temperature and Sample Temperature on the Rheological Properties of Plain Stirred Yoghurt. Food Technol.Biotechnol. 44: pp. 515-518.
6. Tamine A.I., Marshall V.M.E. (1997) Microbiology and Biochemistry of Cheese and Fermented Milk. London, Chapmann & Hall, pp. 52-152.
7. Torre L.La, Tamime A.Y., Muir D.D. (2003) Rheology and sensory profiling of set-type fermented milks made with different commercial probiotic and yoghurt starter cultures. International Journal of Dairy Technology 56: pp. 163-170.
8. Palframan R.J., Gibson G.R., Rastall R.A. (2002) Effect of pH and dose on the growth of gut bacteria on prebiotic carbohydrates in vitro. Anaerobe 8: pp. 297-292.

VITAMINS IN OSTRICH MEAT

Janīna Ķivīte, Daina Kārkliņa
Latvia University of Agriculture
E-mail: daina.karklina@llu.lv

Abstract

Meat is muscle tissue from animals. It is a good source of protein. The meat of various species also is good source for micronutrients and vitamins.

Ostrich meat differs from the meat of other animals. It is not fat, it is lean and easily separated from bones and connective tissue. It is more digestible compared to other types of meat, soft and does not require long culinary treatment. Although it can be compared with beef due to its red colour and taste, ostrich meat is as tender as chicken meat, and is characterized by short muscle fibre.

The objective of study was to determine the A, E, B_1, B_2 and B_5 vitamins content in ostrich meat and compare it with beef and chicken produced in Latvia and available at retail. All vitamins are determined by standard methods according to AOAC Official Standard Methods: vitamin A – 974.29, vitamin E – 971.30, vitamin B_1– 986.27, vitamin B_2 – 970.25, and vitamin B_5 – 961.14.

The obtained results showed that ostrich meat contains significant quantities of vitamins B_1, B_2 and B_5. The highest content in ostrich meat was calculated for B_5 (11.45 mg $100g^{-1}$) and the lowest – for B_2 (0.098 mg $100g^{-1}$). Ostrich meat contains more than 18 % of vitamins B_1 and B_2 and more than 7.5 % of B_5 compared with beef, and more than 30 % of vitamins B_1 and B_2 and more than 27 % of B_5 compared with chicken. The content of vitamin E is highest in ostrich meat then follow chicken and beef. Regarding vitamin A, ostrich meat has only traces of it.

Keywords: meat, vitamins A, E, B_1, B_2, and B_5.

Introduction

Meat plays a very important role in diet by contributing quality protein, essential minerals and trace elements, and a range of vitamins (Sandler, Strain, 1999).

Ostrich meat differs from the meat of other animals. As mention some researchers, it is not so fat (Jensen, 2004). It is lean and easily separated from bones and connective tissue. It is more digestible compared to other types of meat, soft and does not require long culinary treatment. Although it can be compared with beef due to its red colour and taste, ostrich meat is as tender as chicken meat, and is characterized by short muscle fibres.

The ostrich is a relatively new agricultural animal in Latvia (Horbacuks, 2005; Bundze –Zdanovska, 2005). There have not been carried out studies regarding vitamin content in ostrich meat.

The objective of the study was to determine the A, E, B_1, B_2 and B_5 vitamin content in ostrich meat and compare it with beef and chicken produced in Latvia and available at retail.

Materials and Methods

The research was performed at the Laboratory of Biochemistry and Physiology of Animals of the Institute of Biology of the University of Latvia.

Meat samples were obtained from Latvian meat producers. Ostrich, beef and poultry meat was frozen and stored in a freezer before analysis. All meat samples were ground in food blender to ensure homogeneous consistence of meat samples for analysis.

The amounts of A, E, B_1, B_2, and B_5 vitamins were determined by standard methods – AOAC Official Standard Methods: vitamin A – 974.29, vitamin E – 971.30, vitamin B_1– 986.27, vitamin B_2 – 970.25, and vitamin B_5 – 961.14 respectively.

The chemical analyses were repeated five times; mean value and standard error were calculated.

Results and Discussion

Vitamin A is present in many animal tissues, especially in liver. One of the most important consequences of vitamin A deficiency is dryness of the eyes eventually leading to blindness. It remains one of the main causes of blindness in the world. Night blindness is also an eye complication of early vitamin A deficiency. The leaner meats have only small quantities of vitamin (Batless, 1998). In our case the highest concentration of vitamin A was found in chicken – 0.23 mg $100g^{-1}$, in beef and ostrich meat samples – only traces; compared to the data in the literature, vitamin

A is more concentrated in animal liver (Batless, 1998).

Vitamin E is a mixture of several related compounds known as tocopherols. The alpha-tocopherol molecule is the most potent of the tocopherols. Vitamin E originates from plants. Animals acquire vitamin E from plants directly, or by eating other animals that have derived their vitamin E from plants and stored it in their liver, muscles and fat. Vitamin E is a major lipid soluble antioxidant. One of its primary functions is to maintain and protect biological membranes against lipid peroxidation. It is considered to function as a free radical quencher in biological membranes. The major function of vitamin E is to act as a natural antioxidant by scavenging free radicals and molecular oxygen. In particular vitamin E is important for preventing peroxidation of polyunsaturated membrane fatty acids. The rate and extent of lipid oxidation in meats are dependent on the vitamin E concentration in the tissue (Batless, 1998).

The alpha-tocopherol content of different meat was examined. Ostrich meat had the highest vitamin E content, which was followed by chicken and beef (Figure 1.). The content of this vitamin differs significantly ($p < 0.05$) in different meat kinds. The obtained data regarding vitamin A confirm to the results described in the literature (Batless, 1998).

Meat is an important dietary source of the water soluble B - complex vitamins that in general take part in the utilization of energy, help regulate many chemical reactions, and support

normal vision and healthy skin. The amount of B vitamins in meat can depend on such factors as the species, age, and degree of fatness (Batless, 1998). Thiamine is known as vitamin B_1. Thiamine is derived from a substituted pyrimidine and a thiazole which are coupled by a methylene bridge. Thiamine is rapidly converted to its active form, thiamine pyrophosphate, TPP, in the brain and liver by a specific enzymes, thiamine diphosphotransferase. TPP is necessary as a cofactor for the pyruvate and a-ketoglutarate dehydrogenase catalyzed reactions as well as the transketolase catalyzed reactions of the pentose phosphate pathway. A deficiency in thiamine intake leads to a severely reduced capacity of cells to generate energy as a result of its role in these reactions. Average value of vitamin B_1 for all meats was from 0.14 mg 100 g^{-1} to 0.22 mg 100 g^{-1} (Table 1).

Riboflavin is known as vitamin B_2. Riboflavin is the precursor for the coenzymes flavin mononucleotide (FMN) and flavin adenine dinucleotide (FAD). FAD is synthesized from riboflavin and ATP. Vitamin B_2 concentration in ostrich meat was essentially higher compared with other meat ($p < 0.05$) (Table 1).

Pantothenic acid is known as vitamin B_5. Pantothenic acid is formed from ß-alanine and pantoic acid. Pantothenate is required for synthesis of CoA and is a component of the acyl carrier protein (ACP) domain of fatty acid synthase. Pantothenate is, therefore, required for the metabolism of carbohydrate via the TCA cycle and all fats and proteins. At least 70
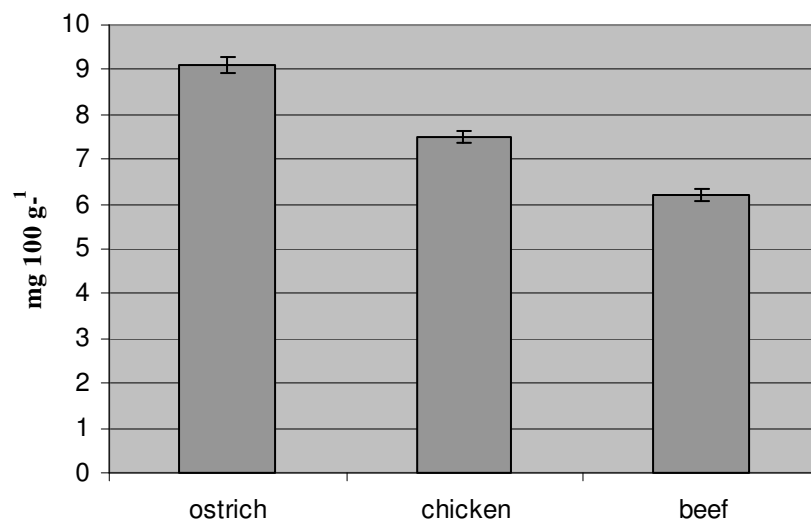

Figure 1. Vitamin E content in meat.

The concentration of thiamine, riboflavin, and pantothenic acid in meat

Meat	Vitamin concentration, mg 100 g^{-1}		
	Thiamine (B$_1$)	Riboflavin (B$_2$)	Pantothenic acid (B$_5$)
Ostrich	0.22 ± 0.02	0.098 ± 0.003	11.45 ± 0.02
Beef	0.178 ± 0.003	0.087 ± 0.001	10.60 ± 0.03
Chicken	0.14 ± 0.01	0.066 ± 0.001	8.32 ± 0.02

enzymes have been identified as requiring CoA or ACP derivatives for their function.

The highest content for B$_5$ was calculated in ostrich meat (11.45 mg 100 g^{-1}) and the lowest – in chicken (8.32 mg 100 g^{-1}) (Table 1).

The obtained results showed ostrich meat contains more than 18% of B$_1$ and B$_2$ vitamins and more than 7.5% of vitamin B$_5$ compared with beef, and more than 30% of B$_1$ and B$_2$ vitamins and more than 27% of vitamin B$_5$ compared with chicken. The vitamins content of all meat samples produced in Latvia was found to be similar with the data found in the literature (Sandler, Strain, 1999).

Conclusions

Ostrich meat contains significant quantities of vitamin B$_1$, B$_2$, and B$_5$. The highest content in ostrich meat was calculated for vitamin B$_5$ (11.45 mg 100 g^{-1}) and the lowest – for B$_2$ (0.098 mg 100 g^{-1}). It contains more than 18% vitamins B$_1$ and B$_2$ and more than 7.5% of vitamin B$_5$ compared with beef, and more than 30% of vitamins B$_1$ and B$_2$ and more than 27% of vitamin B$_5$ compared with chicken.

Ostrich meat had the highest vitamin E content, and then followed chicken and beef.

Regarding vitamin A, ostrich meat has only traces of it.

Acknowledgements

References

1. Baltess V. (1998) Pārtikas ķīmija (Food Chemistry). Rīga, 20 – 31.lpp. (in Latvian).
2. Bundze Zdanovska I. (2005) Strauskopības attīstība un ražošanas iespējas Latvijas tirgū. (Development of ostrich farming and possibilities of production for Latvian market). Zinātniskais darbs profesionālā pārtikas higiēnas maģistra grāda iegūšanai. LLU, Jelgava, 67 p. (in Latvian).
3. Edit by Jensen W.K. (2004) Encyclopedia of Human Nutrition. Academic Press, pp. 1272 – 1273.
4. Edit by Sandler M.J., Strain J.J., Caballero B. (1999) Encyclopaedia of Human Nutrition, T.2, Academic Press, pp. 1272 – 1282.
5. Horbančuks J.O. (2005) Strausi (Ostrich) Rīga, 164 lpp. (in Latvian).

UNTRADITIONAL BEER DRINKS

Ingmārs Cinkmanis, Ilze Čakste
Latvia University of Agriculture
E-mail: ingmars@latnet.lv

Abstract

A research has been done on the possibility to increase the range of beer drinks by substituting hops with additives of other plants in the wort boiling process. Obtained data present evidence of the possibility of substituting hops by oak bark, yarrow, wormwood and oak acorn.

Keywords: untraditional beer, oak bark, acorn, yarrow, wormwood.

Introduction

Important raw material in beer brewing is hop. Basic hop constituents are bitter substances (α- and β-acids), and volatile oils. Hop α - and β-acids are generally recognized as traditional partial formers of the specific aroma and taste of beer. They also oppress proliferation of grampositive and gramnegative bacteria in the fermentation process but, at the same time, do not have any influence on yeast cells (Buckwold, 2004).

Also other plants, including herbs of many grass teas, contain bitter substances. Therefore their admixture to hop or individual use would enable to obtain new sorts of beer drinks, which would increase the existing assortment. The bitter taste of wormwood is created by the volatile oils present in them ($\sim$2%), as wellas bitter substance glycosides absinthine and unabsinthine with the sensation threshold $1.3 \cdot 10^{-1}$ mmol L^{-1} (Ternes, 2006).

The explanation of the concept "beer" is differs in different countries. Summarizing the concepts found in the literature (Bundesgesetzblatt, 1993; Regeln, 1993; Deckblatt, 1996), the following definition has been made: "Beer is a fermented and aromatized drink that has been obtained from the products containing carbohydrates". Such formulation would be universal because it would admit the possibility of use of various additives.

Russian scientists assert that recently there has arisen an interest in the beer in which production various fruit, roots and berries have been used the product has been named Fitobeer (Фитопиво). That beer has not yet been introduced in to the production its technology elaboration and development is still in progress. This task is not simple because in many cases the experimentally obtained fitobeer had unpleasant taste and aroma (Оюун, 2005).

In China, fruit are added to the wort that has been boiled together with hop and afterwards cooled, then the wort in aerated with oxygen and fermented. During the main fermentation, specific aroma and color appear depending on the added fruit. Chinese call this drink not beer but an alchocolic drink made on the basis of malt (Mori, 2003).

Historically, beer mixed with various grass teas, has been used in medicine. In Germany, in 14th century, there was the house book 'Colerus' with 18 recipes of medical beer. In the 17th century in Hanover area it was possible to purchase grass beer (*Giffhornsche Kräuterbier*) that was used for medical treatment of definite diseases. Also different spices - mostly cardamon, coriander, gingseng, anise, and pepper roots - were added to beer (Papazion, 1994).

Use of coriander (*Coriandrum sativum L.*) in beer industry was studied by Russian scientists in 2005. Beer was fermented in the laboratory conditions for 7 days at 6-8 °C, after that to the newly brewed beer there were added coriander volatile oils that had been obtained by variously extracting coriander seeds (by CO_2, by water steam, by 70% spirit). Best organoleptical indices were for the beer using volatile oils that had been obtained by 70% spirit (Ливинска, 2005).

Since 2000 Chinese scientists have been making an extensive research on beer using various additives – chrysanthemums, green tea, American gingseng (*Panax guinguefolium*), aloe juice, rice, etc. (Song et al., 2001; Zhang et al., 2001).

In some countries also other additives are used: plant leaves, flowers, stems, seeds, nuts, twigs,
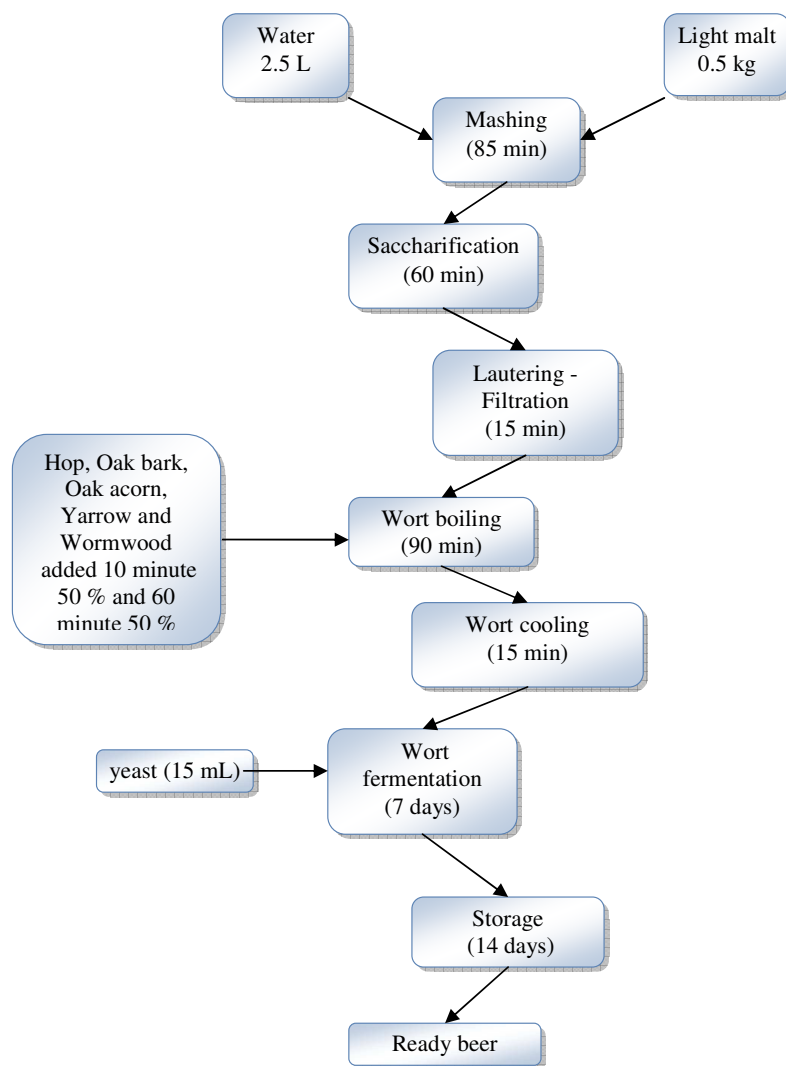
Figure 1. The scheme of the technological process of beer and untraditional beer drinks production.

chocolate, coffee, etc. The brewery 'Würzgrund' in Karlstad in 1997 began to produce oak leave beer without adding hop in a specially made wort pot. The brewery of brothers Williams 'Heather Brewery' produces beer without hop, too, using pine tree twigs and fir tree shoots and call it *Alba scots* pine ale, (http://www.heartherale.co.uk). In Egypt, not far from the pyramids, Pharaonen beer obtained from wheat malt, millet, hulled wheat, dates, figs, citriuses, cloves, and cinnamon, can be purchased (Bach, 1998).

The purpose of the present research is to find out a possibility of substituting hops by oak bark, acorn, yarrow and wormwood of Latvia flora.

Materials and Methods

Five series of experiments have been carried out with adding different additives of the Latvia's flora suchas oak bark, acorn, yarrow, wormwood, and hops as the control sample during the wort boiling process. The conditions of obtaining untraditional beer drinks and traditional beer have been standardized according to the scheme in Figure 1.

To characterize the influence of the yarrow, wormwood, oak bark and acorn additives on the quality of the obtained untraditional beer drinks and to evaluate it comparing with the indices of beer with hops obtained in analogous standardized conditions, there were made the following analyses: vicinal diketon content (VDC), pH, color, alcohol quantity, and content
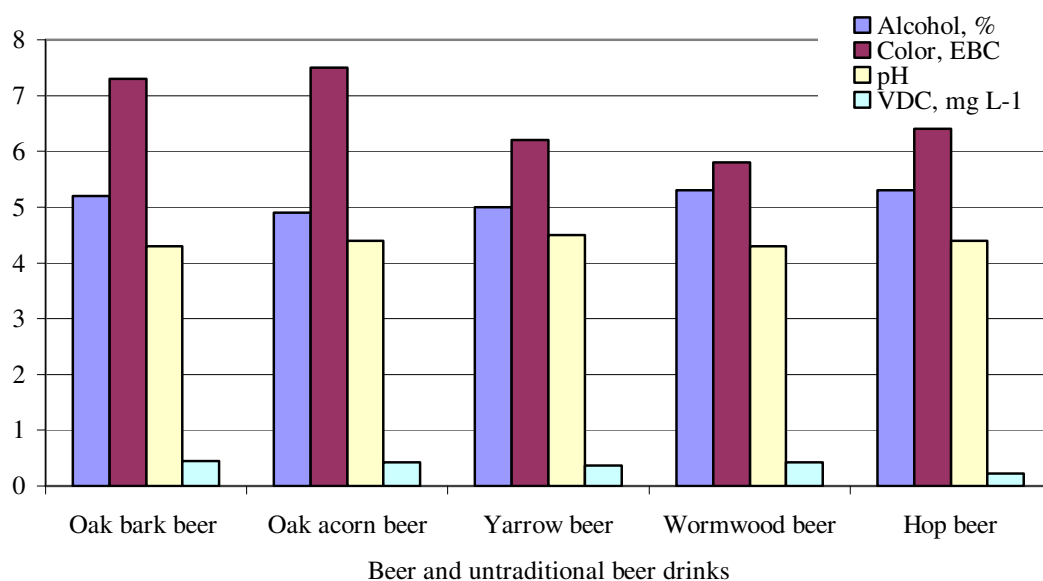
Figure 2. Physicochemical indices of beer and untraditional beer drinks.

Table 1

Color, aroma, taste, and froth stability of the obtained beer and untraditional beer drinks

No.	Beer and untraditional beer drinks	Quality indices of the obtained beer drinks
1	Wormwood beer	Clear, light golden-greenish, aromatic, but with very bitter taste. Small froth stability because the obtained beer is not saturated with carbon dioxide.
2	Yarrow beer	Clear, light golden-greenish, tender aroma, slighty bitter taste. Small froth stability because the obtained beer is not saturated with carbon dioxide.
3	Oak bark beer	Clear, light reddish, pronounced tannin aroma and taste. Changes its taste features depending on the amount of extract substances: smaller amount of extract substances gives soft taste, larger amount gives – softly-sweet taste. Middle froth stability notwithstanding the fact that the beer is not saturated with carbon dioxide.
4	Oak acorn beer	Turbid, opalescing, paste – type consistence that most possibly has arisen in the wort boiling process from the insufficiently saccharized (30%) starch present in oak acorn. Average tannin aroma and taste. More tender than oak bark beer. Small froth stability.
5	Hop beer	Clear, light golden, pronounced hop aroma with pleasant malt taste, small froth stability because the obtained beer is not saturated with carbon dioxide.

of bitter substances was determined in hop beer, but for the rest ones this method has not been standardized and therefore the evaluation of the presence of bitter substances is expressed in the evaluation of taste features in Table 1.

Materials

1. Oak bark (*Cortex quercus*) and acorn (*Quercus kerrii*).
2. Yarrow (*Achillea millefolium*).
3. Wormwood (*Artemisia absinthium*).
4. Hop (*Humulus lupulus*).
5. Light malt.
6. 'Livu' source water: Ca^{2+} – 50-75 mg L^{-1}, Mg^{2+} – 10-25 mg L^{-1}, SO_4^{2-} – 5-20 mg L^{-1}, $C1^{-1}$ – 5-15 mg L^{-1}, and Fe^{2+} – 0.01-0.05 mg L^{-1}.
7. Beer yeast (*Saccharomyces carlsbergenesis*)

Methods

Physicochemical indices of ready beer were determined content of ethanol using beer analyzing system "Anton Paar beer Alcolyzer Plus" analyzer, color and VDC – with spectrophotometer "Jenway" UV/VIS 6400/6405, but pH was analyzed potentiometrically at the Department of Chemistry of the Faculty of Food Technology, LLU, by employing WTW pH meter (pH 338) with electrode (Sen Tix 97T), using the AOAC 945.10 method.

Aroma, taste and froth stability of the obtained beer drinks were defined by tasting in brewery "Lāčplēša alus".

Results and Discussion

Hop, yarrow, wormwood, oak bark, and acorn contain bitter substances but their chemical composition, quantity, and sensoral features differ. Hops contain α- and β-acids, yarrow contain achilin, and wormwood contain absinth (Ternes, 2006).

In the experiments, using dry yarrow, wormwood, oak bark, and acorn, in the wort boiling, all the above mentioned basic conditions that refer to the obtaining of qualitative wort have been taken into account.

The color of beer and untraditional beer drinks was from 4.3 to 7.6 EBC points. Color changes can be explained by the use of different additives: boiling oak bark and acorn in water makes a pronounced brownish reddish color, whereas yarrow, wormwood and hop make it light brownish green.

The content of alcohol varied from 4.9 to 5.3 %, wich complies with the indices of light beer and is directly connected with the result of extract substances in the wort.

The lowest content of total vicinal dicetons (0.22 mg L^{-1}) was defined for the beer inwhich production hop was used in the wort boiling process; however, this indice approximately 0.05 mg L^{-1} higher than the amount of vicinal dicetons in the products of Latvia breweries. Using oak bark, acorns, yarrow, and wormwood as the sources of bitter substance, the content of vicinal dicetons varied from 0.37 to 0.45 mg L^{-1} exceeding the admissible norm by 0.05 – 0.10 mg L^{-1}. Formation of vicinal diceton is connected with various technological factors of beer production (Kunze, 1998) therefore, for example, even small fluctuations in the temperature of beer brewed in small amounts in laboratory conditions, can change the temperature of the fermenting wort in a short time, wich occurs slowly in beer produced in large quantities.

For all the obtained beer drinks and hop beer, after fermentation pH was within the range of 4.2 – 4.6, which correspounds wth the indices of a qualitative beer.

Quality indices of the products obtained in the experiments prove that not depending on the bitter substances in the plants used in the research, they can be used in the obtaining of untraditional beer drinks with different taste and specific aroma.

Conclusions

1. Wormwood can be added in the wort boiling process to obtain untraditional beer drinks which quality indices comply with those of traditional hop beer obtained in standardized conditions.
2. The wormwood beer drink is characteristic of an aromatic but very bitter taste therefore, compared to other plants used in the experiment, a smaller amount of wormwood is needed in the wort boiling process.
3. Yarrow beer drink is lighty bitter with the aroma characteristic of yarrow.
4. Oak bark beer drink has pleasant taste with a light redisch color and compact froth.
5. Oak acorn beer drink differs from the other beer drinks with its turbid consistence, and additional research on the stages of its technological production process is needed.

References

1. Bach A. (1998) Die Pharaonen und ihr Bier (Pharaoh and his beer). Ein fächerübergreifendes Unterrichtsprojekt In: Naturwissenschaften im Unterricht - Chemie 9, Nr. 43, pp. 43-46. (in German).

2. Alba scots pine ale (2007) Available at: http://www.heartherale.co.uk, 16.03.07.

3. Buckwold V.E., Wilson R.J.H., Nalca A., Beer B.B., Voss T.G., Turpin J.A., Buckheit R.W., Wei J.Y., Wenzel-Mathers M., Walton E.M., Smith R.J., Pallansch M., Ward P., Wells J., Chuvala L., Sloane S., Paulman R., Russell J., Hartman T., and Ptak R. (2004) Antiviral activity of hop constituents against a series of DNA and RNA viruses. Antiviral Research. vol. 61(1), pp. 57-62.

4. Bundesgesetzblatt (1993) Teil 1 Seite 1399, Bekanntmachung der Neufassung des Vorläufigen Biergesetzes Vom 29. Juli 1993 pp. 1399.

5. Deckblatt (1996) SR 817.02 Lebensmittelverordnung 38. Kapitel: Bier, Art. 394 Definitionen. (Law SR 817.02 Food decree 38. Chapter: Beer, Art. 394 Definition) pp. 394 (in German).

6. Kunze W. (1998) Tehnologie brauer und mälzer (Brewery and malt technology), VLB, Berlin, 910 p. (in German).

7. Ternes W., Täufel A., Tunger L., Zobel M. (2006) Lexikon der Lebensmittel und der Lebensmittelchemie (Food and Food chemistry lexicon). Wissenschaftliche Verlagsgesellschaft mbH, 4. Auflage . X, pp. 2134 (in German).

8. Mori K. (2003) Manufacture of malt-based spaekling alcoholic beverage usin fruits, Jpn.Kokai Tokkyo Koho JP 2003, 310, 241, 5.nov 2003, Appl.2002/162, 182, 24.apr.2002. 3 p.

9. Regeln des österreichischen Lebensmittelbuches (1993) (Regulation of Austrian Food book) Codex Alimentarius Austriacus, Codexkapitel B 13 p. 25 (in German).

10. Song B., Du C., Jiang S. (2001) Production of 8 chrysanthemum beer of alc.degree 8 by the dilution method., Niangjiu Zazhi Bianjibu, Niangjiu, 28 (3), 80 p.

11. Papazion C. (1994) The home brewers companion. Avon books. 245 p.

12. Zhang S., Duan M., Zhang L. (2002) Technology report on development of American ginseng beer., Niangjiu Zazhi Bianjibu, Niangjiu, 29 (5), pp. 90-91.

13. Оюун М., Ливинская С.А., Ермолаева Г.А. (2005) Использование кориандра Монголии в пивоварениии (Mongolian coriander to apply in brewery). Пиво и Напитки, 1, стр. 58-59 (in Russian).

FOREST SCIENCES

DID THE AMBIENT OZONE AFFECT FOREST ECOSYSTEMS IN BALTIC REGION?

Algirdas Augustaitis
Lithuanian University of Agriculture
E-mail: algirdas.augustaitis@lzuu.lt

Abstract

The presented study aimed to explore the relationships between different indices of ambient ozone (O_3) and tree defoliation, radial increment, and specific diversity and abundance of soil micro-arthropods, stream macro-invertebrates, small mammals (mainly rodents) in order to test the hypothesis that changes in the considered objects of forest ecosystem could be related to changes in ambient ozone concentration. The observations have been carried out on 3 integrated monitoring stations located in Aukstaitija (LT-01), Dzukija (LT-02) National Parks (NPs) since 1994 and Zemaitija (LT-03) NP since 1995. The obtained data revealed that only peak ozone concentrations (from 125 to 215 μg m^{-3}) had significant effect on changes in the considered components of forest biota. Radial increment and crown defoliation of Scots pine, a little lower the diversity of soil microarthropods, and the least diversity of small mammals were found to be the most sensitive to ozone exposure.

Keywords: ambient ozone, crown defoliation, radial increment, soil micro-arthropods, small mammals.

Introduction

Ozone (O_3) air pollution has been recognized as a major phytotoxic agent in North America and Europe since the middle of the last century (Hill et al., 1970; Smith, 1981; Reich and Amundson, 1985; Schmieden and Wild, 1995; Alonso et al., 2001; Bytnerowicz et al., 2002; Manning, 2005) which is likely to increase in future (Krupa and Manning, 1988; Hutunnen et al., 2002; Percy et al., 2003).

Ambient ozone may interrupt cell membrane function what in turn will affect metabolic activity in other parts of the cell, either plant or animal (Smith, 1990). The phytotoxic effect of ambient ozone on plants is well known. The most important symptoms are as follows: decrease in foliar chlorophyll content and necrotic spots (Reich, 1983; Smith, 1981; Chappelka et al., 1999), acceleration of leaf senescence and reduction in leaf life-span (Stow et al., 1992; Pell et al., 1999; Skelly et al., 1999), photosynthesis (Reich, 1983; Reich and Amundson, 1985; Utrainen and Holopainen, 2000), growth and productivity (Schmieden and Wild, 1995; Karnosky et al., 1996, 2006; Matyssek and Innes, 1999; Manning, 2005). However, on a regional scale, this effect is subtle and difficult to detect, or often fails (Percy and Ferretti, 2004; Paoletti, 2006).

More limited is our knowledge in the field of ambient ozone effect on the other components of biota in forest ecosystem such as soil microarthropods, small mammals and stream invertebrates. Negative ozone effect on some terrestrial arthropods is established (Laurence, 1998; Cairney and Meharg, 1999; Chappelka and Chevone, 1992; Trumble and Vickerman, 2003; Loranger et al., 2004). However, since ozone is unlikely to penetrate the soil, its direct impact is hardly plausible in real world situations (LaCoss, 2000).

Mammals are considered to be the highest form of life in the forest ecosystem. However, only under elevated exposure, ozone markedly affects their lung tissue (Graham et al., 1998) and several hematological parameters (Calabrese et al., 1985), including decreases in red blood cells (Moore et al., 1984), and increase in death possibility (Smith, 1990; Newman et al., 1992). On the regional scale, relationships between ozone exposure, and diversity and abundance of small mammals could be useful for analyzing causative effect of ozone on forest ecosystem in general.

In most cases, passive sampler methodology was used to analyze ozone effect on biota. The lack of data on hourly air ozone concentration detected by continuously methodology could be attributed to uncertainties in this study. The present study was performed at Integrated monitoring stations (IMS) established according to the Integrated Monitoring program (UN-ECE, 1993) where continuous monitoring of air ozone concentrations with active samplers are conduced.

The aim of this program is to determine the long-term state of terrestrial ecosystem and its changes, with respect to the regional variation and impact of air pollutants, including ambient ozone, on biota. Therefore, as a hypothesis we would like to see if temporal and spatial changes in station-wise mean value of tree defoliation and stem increment, abundance and specific diversity of soil micro-arthropods, stream macro-invertebrates and small mammals in natural forest ecosystem are related to changes in ambient ozone concentrations. To test the hypothesis, correlative coefficient of different ozone concentrations and station-wise mean values of different components of biota were compared. This was done to find the most sensitive to ozone component of biota and the most acceptable concentration or index of ozone exposures to be used in the more thorough studies which has recently become of the greatest concern.

Materials and Methods

The study was based on the observed data available from 3 Integrated Monitoring Stations (IMS) located in Aukstaitija (LT-01), Dzukija (LT-02) National Parks (NPs) in 1994 and Zemaitija (LT-03) NP in 1995 (Fig. 1). In 2000 due to the limited funding the LT-02 station was closed and the monitoring terminated. Therefore, only the data on pollution and considered components of biota for the period 1994-1999 were used for this study.

Tree crown condition was assessed using the methodology of the ICP Forest monitoring programme (UN-ECE, 1994). More than 1000 trees (Scots pine trees – 20%, Norway spruce – 70% and birch – 10%) on 50 permanent observation plots (POPs) at LT-01; 1200 trees (pine trees – 90%, spruce and birch – 10%) on 58 POPs at LT-02, and 600 (pine trees – 10%, spruce – 85% and birch – 5%) trees on 37 POPs at LT-03 located in IMS basins were monitored annually from the end of August through the beginning of September. Based on these data mean annual defoliation of the considered tree species per IMS was computed.

From this permanent observation stand sets we chose 3 premature pine stands at each site to detect O_3 effect on pine stem radial increment. Totally, more than 200 dominant and co-dominant trees were chosen for the increment boring. Standard dendro-chronological technique was used to assess tree growth rates. Radial growth was assessed by measuring the width of annual rings in stem cores. Each ring was measured to the closest 0.01 mm using an electronic transducer and binocular scope fixed over the moving stage.

The diversity and abundance of the soil microarthropods were investigated in autumn annually on prevailing forest type of catchments: in Aukstaitija IMS in haplic arenosol of mixed pine-spruce overmatured stand, in Zemaitija IMS in albic arenosol of premature spruce stand and in Dzukija IMS in haplic arenosol of pure premature pine stand.
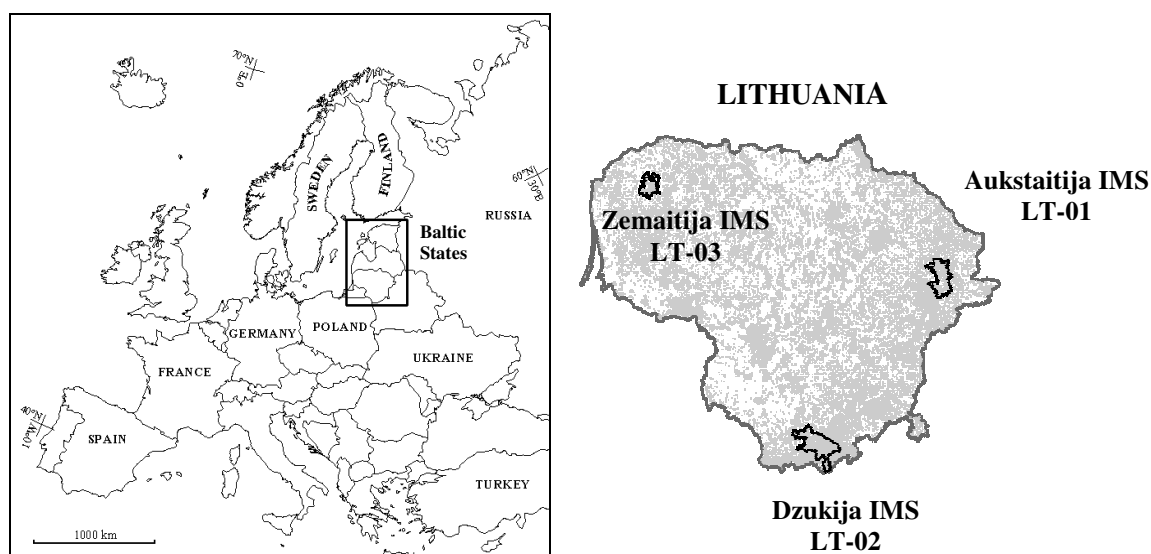
Figure 1. Location of integrated monitoring stations in Lithuania.

Algirdas Augustaitis

DID THE AMBIENT OZONE AFFECT FOREST ECOSYSTEMS IN
BALTIC REGION?

Small rodents were investigated in bilberry pine-spruce forest and nemoral bog spruce wood in Aukstaitija IMS, in cowberry pine forests in LT-02 and in suboceanic bilberry spruce forest in LT-03. Small mammals in each IMS were caught by 150 snap traps over 3 day period. Specific diversity of small mammals community was assessed by number of species (unit), while abundance - by total number of caught small mammals (ind. per ha).

Investigation of the abundance and diversity of the mentioned components of biota was carried out according to the Manual for Integrated Monitoring (UN-ECE, 1993). Station-wise mean annual values were computed for each IM station.

Ozone concentrations were measured continuously using commercial UV-absorption ozone monitors O_3 41M (Environnement S.A., France) and ML9811 (Monitor Labs) with an air inlet at the height of 2.5 m above ground (Girgzdiene et al., 2006). Hourly data on peak ozone value, their annual average and average from April through August were used in the analysis. AOT40 values, which define the potential risk of O_3 for vegetation (Fuhrer et al., 1997) were calculated according to the requirements of the 2002/3/EC directive. For crops the critical level is set to 3.0 ppmh (AOT40-1), for forest trees - 10 ppmh (AOT40-2) (NABEL, 1999). Exceedance of the AOT40-2 threshold would indicate a risk of tree biomass loss of more than 10% (LRTAB, 2004).

The possible effect of ambient ozone on forest ecosystem was analyzed by a correlative analysis of different concentrations of ozone and station-wise means of the considered response variables using 'Statistica 6.0' software.

Results and Discussion

Trend in ambient ozone level in forest ecosystem

Ozone concentration data at IMS show no clear trend in temporal changes in the annual

Figure 2. The variation in ozone concenytration over 1994 – 2005 period,
a. - annual and April-August period mean; b. - peak concentrations.

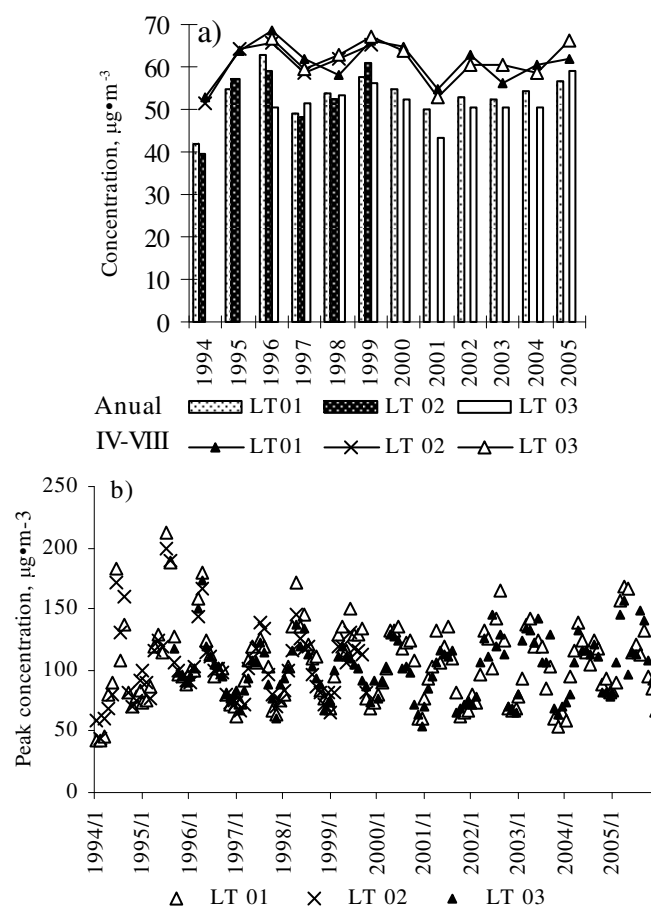mean, and mean values from April through August as well as in the AOT40. However, decline in the peak concentrations from 215 to 125 $\mu g \cdot m^- 3$ was observed until 2001 (Fig. 2). After 2001 no significant increase in both means (annual and April-August period) and peak concentrations was observed. The peak hourly O_3 concentrations varied from 125 $\mu g \cdot m^{-3}$ to 165 $\mu g \cdot m^- 3$ mostly during the spring period and were typical for other parts of Central Europe including Baltic region (Bytnerowicz et al., 2002, 2004; Solberg et al., 2005).

The computed AOT40 values for the protection of forest at LT-01 and LT-02 ranged from 8000 to 21000 μg m^{-3} h^{-1} while at LT-03 only from 5000 to 12000 μg m^{-3} h^{-1} and exceeded the AOT40 value for the protection of vegetation (6000 μg m^{-3} h^{-1} for almost all considered years (Girgzdiene et al., 2006)). The critical level 20000 μg m^{-3} h^{-1} for the protection of forest was observed only at LT-01 in the year 1999.

Relationships between ozone and considered components of forest biota

The peak value of ozone concentrations had the most significant impact on changes in birch and pine defoliation ($p < 0.05$ and $n = 28$) (Table 1). Mean defoliation of the considered tree species was more related to the AOT40 index for forest than crop vegetation; however, these relationships in most cases were not significant ($p > 0.05$).

The peak value of ozone concentrations had the most significant impact on changes in pine stem radial increment (Table 2) as well as on defoliation. Radial increment was more related to the AOT40 index for forest than crop vegetation as well and contrary to defoliation its effect on increment was

significant ($p < 0.05$). Relationships among different ozone indices and the considered micro arthropod parameters revealed that peak O_3 concentrations demonstrated more significant relationships with micro arthropod diversity than their abundance (Fig. 3). The strongest relationships were established between peak ozone concentrations and *Oribatidae, Acaridae,* and mineralization–humification (M/H) ratio, what most likely indicated their susceptibility to ozone exposure.

There was no significant trend in changes in species number and mammal abundance. However, peak in both diversity and abundance was recorded in 1998-99 (41). Analysis of the correlation coefficients showed that only relationship between peak O_3 concentration and diversity of small mammals was significant ($p < 0.05$).

At a global scale, ozone is the most widespread ambient air pollutant (Krupa and Manning, 1988; Hutunnen et al., 2002; Manning, 2005). However, much of what we know on its effects is based on its phytotoxicity under artificial conditions (Manning et al., 2004). Therefore, the presented study could be considered as an attempt to gain more insight in the relationship between the ambient ozone and biota of forest ecosystem to answer the question if ambient ozone may cause changes in forest biota north-eastern part of Europe, where O_3 concentrations seldom reaches the phytotoxic level for forest.

Tree species response to ozone exposure is most likely related to differences in stomatal conductance and subsequent ozone uptake (Reich and Amundson, 1985; Taylor et al., 1992). This is why responses of plants to O_3 vary considerably among species (Chappelka and Samuelson, 1998). P.Reich stated that chronic exposure to ozone has a greater effect on conifers with long-

Table 1

Relationships between ambient ozone and defoliation of considered tree species on IMS territories over 1994-2005 and their significance

Tree species	Main statistics	Mean value		Peak value	AOT40	
		Annual	IV-VIII		for vegetation	for forest
Betula spp.	r	-0.268	-0.189	0.465	0.060	0.181
	p	0.196	0.365	0.019	0.795	0.431
Picea abies	r	-0.260	-0.077	0.353	0.139	0.510
	p	0.210	0.716	0.084	0.547	0.018
Pinus sylvestris	r	-0.142	-0.122	0.549	-0.161	0.077
	p	0.471	0.538	0.002	0.485	0.740

Table 2

Relationships between ambient ozone and stems radial increment and their significance

| Parameter | Main statistics | Mean value | | Peak value | AOT40 | |
		Annual	IV-VIII		for vegetation	for forest
Radial increment	r	0.078	0.110	-0.721	-0.336	-0.498
	p	0.717	0.608	0.000	0.186	0.041

lived needles than on deciduous (Reich, 1987). Higher significance of the relationships between pine defoliation and ozone than between birch defoliation and ozone confirmed this statement.

Estimated changes in soil fauna biodiversity and abundance were in full agreement with the changes in tree crown defoliation (Augustaitis et al., 2005). Therefore, it was expected that the same ozone concentrations, which resulted in changes in pine defoliation would result in changes in biodiversity of arthropods. The relationship between the peak ozone concentrations and arthropods diversity verified our assumption. In case if this relationship was verified in future, we would be able to state that the effect of O_3 on trees is reinforced by the changes in arthropod structures.

The relationship between peak ozone concentration and diversity of small mammals was significant as well. Most likely, it could be explained by the indirect ozone effect. The changes in plant cover, frequency or biomass and seed yield for plant species (Thwaites et al., 2006) - main nutrition sources could be the key factor resulting in changes in diversity and abundance of small mammals.

Hierarchical approach in investigating the effect of the ambient ozone concentration allowed us to verify the hypothesis that peak O_3 values could significantly affect various components of forest biota. Decrease in significance of peak O_3 value effects, in the analysis of the changes in forest biota from the most sensitive components of biota (lower life forms – plant and pedobionts) to the least sensitive (higher life form – small mammals) could be presented as proof of the causative effect of peak O_3 concentrations on forest ecosystem in the Baltic countries.

Conclusions

1. Ozone concentration data at IMS shows no clear trend in temporal changes in the annual mean, and mean values from April through August fluctuated between 50 – 60 μg m^{-3} and 60-65 μg m^{-3} respectively. The highest peak ozone value 213 μg m^{-3} was observed only in the year 1995, while higher than 160 μg m^{-3} value – at the beginning of observation and recently, in the years 2002 and 2005. These ambient ozone concentrations were typical for the other
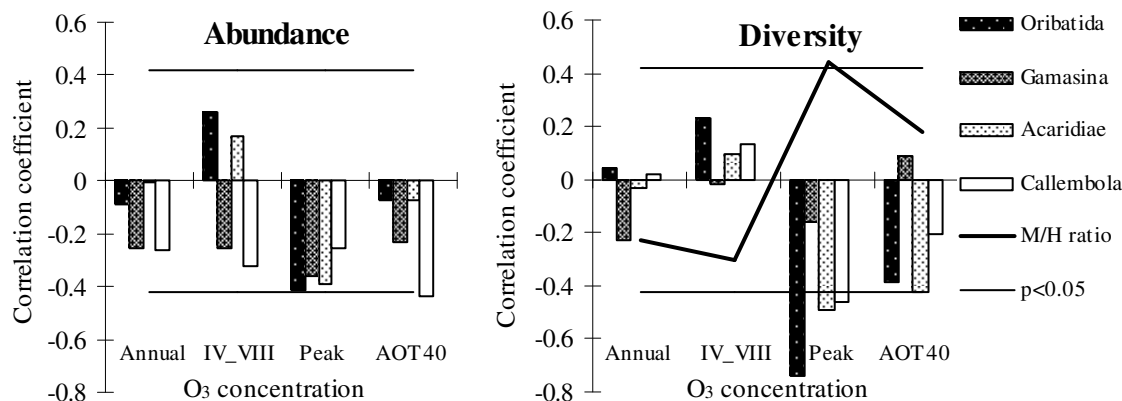

Figure 3. Relationships among ambient ozone and soil arthropod abundance, diversity, and mineralization-humification (M/H) ratio.

parts of Central and Northeastern Europe.

2. Short periods of peak ozone concentrations seem to have significant effect on forest ecosystems, negatively affecting tree crown conditions, diversity of soil arthropods, and in some cases small mammals. Decrease in significance of peak O_3 value effects in the analysis of changes in forest biota from the lower life forms – tree and pedobionts to the higher life forms – small mammals, could be presented as anargument to prove the causative effect of peak O_3 concentrations on forest ecosystem in the Baltic region.

References

1. Alonso R., Bytnerowicz A., Arbaugh M. (2001) Vertical Distribution of Ozone and Nitrogenous Pollution in Air Quality Class I Area, the San Geargonio Wilderness, Southern California. TheScientificWorld, 2, pp. 10-26.

2. Augustaitis A., Augustaitiene I., Kliucius A., Bartkevicius E., Mozgeris G., Sopauskiene D., Eitminaviciute I., Arbaciauskas K., Mazeikyte R., Bauziene I. (2005) Impact of Acidity Components in the Air and their Deposition on Biota in Forest Ecosystems. Baltic Forestry, 2, pp. 84-93.

3. Bytnerowicz A., Szaro R., Karnosky D., Manning W., Mcmanus M., Musselman R., Muzika R.M. (2002) Importance of International Research Cooperative Programs for Better Understanding of Air Pollution Effects on Forest Ecosystems in Central Europe. In R.C.Szaro, A.Bytnerowicz and J.Oszlanyi (eds.) Effect of Air Pollution on Forest Health and Biodiversity in Forest of the Carpatian Mountains, NATO Science Service, pp. 13-22.

4. Bytnerowicz A., Godzik B., Grodzinska K., Fraczek W., Musselman R., Manning W., Badea O., Popescu F., Fleischer P. (2004) Ambient Ozone in Forests of the Central and Eastern European Mountains. Environmental Pollution, 130, pp. 5-16.

5. Cairney J.W.G., Meharg A.A. (1999) Influences of Anthropogenic Pollution on Mycorrhizal Fungal Communities. Environmental Pollution, 106, pp. 169-182.

6. Calabrese E.J., Moore G.S., Grinberg-Funes R. (1985) Ozone Induced Hematological Changes in Mouse Strains with Differential Levels of Erothrocyte G-6-PD Activity and Vitamins E Status. Journal of Environmental Pathology, Toxicology and Oncology, 6, pp. 283-291.

7. Chappelka A., Chevone B. (1992) Tree Responses to Ozone. In: Lefohn A.S. (ed.) Surface Level Ozone Exposures and Their Effects on Vegetation, Chelsea, MI, Lewis Publishers, Inc, pp. 271-324.

8. Chappelka A.H., Samuelson L.J. (1998) Ambient Ozone Effects on Forest Trees of the Eastern United States: a review. New Phytologist, 139, pp. 91–108.

9. Chappelka A., Skelly J., Somers G., Renfro R., Hildebrand E. (1999) Mature Black Cherry Used as a Bioindicator of Ozone Injury. Water Air and Soil Pollution, 116 (1-2), pp. 261-266.

10. Fuhrer J., Skärby L., Ashmore M.R. (1997) Critical Levels of Ozone Effects in Europe. Environmental Pollution, 97, pp. 18–29.

11. Girgzdiene R., Bycenkiene S., Girgzdys A. (2006) Variations and Trends of AOT40 and Ozone in the Rural Areas of Lithuania. Environ Monit Assess. DOI.10.1007/S10661-006-9283-9.

12. Graham J.A., Overton J., Costa D.L., Schneider T. (1998) Toxicology of Ozone as Characterized by Laboratory Animals and Extrapolated to Humans. Studies in environmental science, 72, pp. 465-481.

13. Hill A.C., Heggestad H.E., Linzon S.N. (1970) Ozone. In: J.S.Jacobson and A.C.Hill (des.) Recognotion of Air Pollution Injury to Vegetation: A Pictorial Atlas. Air Pollution Control Association. Pitsburg, Pennsylvania. B1-B6.

14. Hutunnen S., Manninen S., Timonen U. (2002) Ozone Effects on Forest Vegetation in Europe. In: R.C.Szaro, A.Bytnerowicz and J.Oszlanyi (ed.) Effect of Air Pollution on Forest Health and Biodiversity in Forest of the Carpathian Mountains. NATO Science Service, pp. 43-49.

15. Karnosky D.F., Gagnon Z.E., Dickson R.E., Coleman M.D., Lee E.H., Isebrands J.G. (1996) Changes in Growth, Leaf Abscission, and Biomass Associated with Seasonal Tropospheric Ozone Exposures of Populus tremuloides Clones and Seedlings. Canadian Journal of Forest Research, 26, pp. 23-37.

16. Krupa S.V., Manning W.J. (1988) Atmospheric Ozone: Formation and Effects on Plants. Environmental Pollution, 50, pp. 101-137.

17. LaCoss R. (2000) Ground-level Ozone: An Assessment of the Effects on Human and Forest Health with Implications for Transportation Policy. Graduate Program in Sustainable Development and Conservation Biology University of Maryland, College Park, pp. 46.

18. Laurence J.A. (1998) Ecological Effects of Ozone: Integrating Exposure and Response with Ecosystem Dynamics and Function. Environmental Science and Policy Environmental Science and Policy, 3, pp. 179-184.

19. Loranger G.J., Pregitzer K.S., King J.S. (2004) Elevated CO2 and O3 Concentrations Differentially Affect Selected Groups of the Fauna in Temperate Forest Soils. Soil Biology & Biochemistry, 36, pp. 1521–1524.

20. LRTAB (2004) LRTAB Mapping Manual. UNECE. Available at: http://www.icpmapping.org, 10.04.2007.

21. Manning W.J. (2005) Establishing a Cause and Effect Relationship for Ambient Ozone Exposure and Tree Growth in the Forest: Progress and an Experimental Approach. Environmental Pollution, 137, pp. 443-454.

22. Manning W.J., Cooley D.R., Tuttle A.F., Frenkel M.A., Bergweiler C.J. (2004) Assessing Plant Response to Ambient Ozone: Growth of Young Apple Trees in Open-top Chambers and Corresponding Ambient Air Plots. Environmental Pollution, 132, pp. 503–508.

23. Matyssek R., Innes J.L. (1999) Ozone - a Risk Factor for Trees and Forests in Europe? Water, Air and Soil Pollution, 116, pp. 199-226.

24. Moore G.S., Calabrese E.J., Schulz E. (1984) The Effect of in Vivo Ozone Exposure to Dorset Sheep, an Animal Mmodel with Low Levels of Erythrocyte Glucose-6-phosphate Dehydrogenase Activity. Journal of Environmental Pathology, Toxicology and Oncology, 5, pp. 71-8.

25. NABEL (1999) NABEL, Luftbelastung 1998. Herausgegeben vom Bundesamt für Umwelt, Wald und Landschaft (BUWAL), Bern. pp. 26.

26. Newman J.R., Schreiber R.K., Novakova E. (1992) Air Pollution Effects on Terrestrial and Aquatic Animals. In Barker, Jerry R., David T. Tingey. (1992) Air Pollution Effects on Biodiversity. New York, Van Nostrand Reinhold., pp. 322.

27. Paoletti E. (2006) Impact of Ozone on Mediterranean Forests: A Review. Environmental Pollution, 144, pp. 463-474.

28. Pell E.J., Sinn J.P., Brendley B.W., Samuelson L., Vinten-Johansen C., Tien M., Skillman J. (1999) Differencial Response of Four Tree Species to Ozone-induced Acceleration of Foliar Senescence. Plant, Cell and Environment, 22, pp. 779-790.

29. Percy K.E., Ferretti M. (2004) Air Pollution and Forest Health: Toward New Monitoring Concepts. Environmental Pollution, 130, pp. 113-126.

30. Percy K.E., Legge A.H., Krupa S.W. (2003) Tropospheric Ozone: a Continuing Threat to Global Forests? In: Karnosky D.F., Percy K.E., Chappelka A.H., Simpson C., Pikkarainen J. (Eds.), Air Pollution and Global Change and Forests in the New Millennium. Development in Environmental Science, 3, pp. 85-118.

31. Reich P.B. (1983) Effects of Low Concentrations of O3 on Net Photosynthesis, Dark Respiration, and Chlorophyll Contents in Aging Hybrid Poplar Leaves. Plant Physiology, 73, pp. 291-296.

32. Reich P.B., Amundson R.G. (1985) Ambient Levels of Ozone Reduce Net Photosynthesis in Trees and Crop Species. Science, 230, pp. 566-570.

33. Reich P.B. (1987) Quantifying Plant Response to Ozone: A Unifying Theory. Tree Physiology, 3, pp. 63-91.

34. Schmieden U. and Wild A. (1995) The Contribution of Ozone to Forest Decline. Physiologia Plantarum, 94, pp. 371-378.

35. Skelly J.M., Innes J.L., Savage J.E., Snyder K.R., Vanderheyden D., Zhang J., Sanz M.J. (1999) Observation and Confirmation of Foliar Ozone Symptoms of Native Plant Species of Switzerland and Southern Spain. Water, Air, and Soil Pollution, 116, pp. 227–234.

36. Smith W. (1981) Air Pollution and Forests. Springer-Verlag, New York, pp. 379.

37. Smith W.H. (1990) The Health of North American Forests: Stress and Risk Assessment. Journal of Forestry, 88, pp. 32-35.

38. Solberg S., Derwent R.G., Hov O., Langner J., Lindskog A. (2005) European Abatement of Surface Ozone in a Global Perspective. Ambio, 34, pp. 47-53.

39. Stow T.K., Allen H.L., Kress L.W. (1992) Ozone Impacts on Seasonal Foliage Dynamics of Young Loblolly Pine. Forest Science, 38, pp. 102-119.

40. Taylor Jr., G.E., Hanson P.J. (1992) Forest Trees and Tropospheric Ozone: Role of Canopy Deposition and Leaf Uptake in Developing Exposure-response Relationships. Agriculture, Ecosystems and Environment, 42, pp. 255–273.

41. Thwaites R.H., Ashmore M.R., Morton A.J., Pakeman R.J. (2006) The Effects of Tropospheric Ozone on the Species Dynamics of Calcareous Grassland. Environmental Pollution, 144, pp. 500-509.

42. Trumble J.T., Vickerman D. (2003) Impact of Pollution on Terrestrial Arthropods. In: J. Capinera (Ed.), Encyclopedia of Entomology, Kluwer Academic Press, pp. 170-173.

43. Utrainen J., Holopainen T. (2000) Impact of Increased Springtime O3 Exposure on Scots Pine (Pinus sylvestris) seedlings in central Finland. Environmental Pollution, 109, pp. 479-487.

44. UN-ECE (1993) Manual for Integrated Monitoring Programme. Phase 1993-1996. Environmental Report 5. Helsinki: Environmental Data Centre. National Board of Waters and the Environment, pp. 114.

45. UN-ECE (1994) Manual on Methods and Criteria for Harmonized Sampling, Assessment, Monitoring and Analysis of the Effects of Air Pollution on Forests, UN ECE, ICP, 178 p.

WASTE WATER SEWAGE SLUDGE FERTILIZATION EFFECT ON SOIL PROPERTIES AND SHORT ROTATION TREE PLANTATION PRODUCTIVITY

Dagnija Lazdiņa[1], *Imants Liepa*[2], *Andis Lazdiņš*[1]

[1]Latvian State Forestry Research Institute 'Silava'

[2]Latvia University of Agriculture

E-mail: dagnija@silava.lv

Abstract

Main factors raised interest about biomass as the source of energy increase renewable resource demand in the context of Green house gases emissions decrease and the problem of environmentally friendly and efficient waste utilization. Legislation of waste water sewage sludge use is becoming stricter now. After cutting away top peat layer of peat quarry, the owners have two alternatives: the first, to flood the fields and transform them into bogs, the second, to carry out some economic activities - one of which must be field afforestation with traditional or fast growing tree species. Before planting trees it is necessary to fertilize the fields, and waste water sewage sludge will be one of potential fertilizers.

Aims of research were to determine the impact of waste water sewage sludge fertilization 10 t ha^{-1} on tree growth and soil properties. Concentration changes of N, P, K, and Ca, Mg in different depth and concentration of S and total C and heavy metal in soil top layer during the year 2006 were determined. The effect of fertilization on tree growth and stock was determined by the non-destructive method, data were calculated by height and root core diameter of trees.

Fertilization stimulates tree growth as weed growth too. On peat areas observed soil acidity decreasing. Despite of sufficient amount of nutrients willows were not suitable for peat fields. To avoid increasing of heavy metals content in soils, only qualitative waste water sewage sludge or waste water sewage sludge composts is acceptable for fertilization.

Keywords: Waste water sewage sludge, emptied peat fields, fertilization, plantations, tree.

Introduction

There were produced 28,000 tons of dry matter (t$_{dm}$) of waste water sludge in the year 2005 in Latvia. These amounts are equivalents to 1,400 t of nitrogen (N), 1,100 t of phosphorus (P). Amount of processed sludge, which will be allowed to use was 20,000 t$_{dm}$ in 2005. During the year this amount of waste water sludge can be utilized as the fertilizer for establishing 2000 ha of short rotation tree plantations or plantation forests. During five year period which is minimal interval of fertilization allowed by legislation, the plantation must be cultivated on 10,000 ha. Biomass production must be 80,000 t$_{dm}$ or 320,000 MWh per year (for total mean wood chips prices 2,700.000 LVL per year) (LVA, 2006).

EU Soil politics determines that plantation forests must be one of potentially most perspective waste water sewage sludge and wood ash utilizing directions with less impact on environment at the same time allowing substantially to increase productivity of stands and amount of energy wood resources.

In 2006 the Cabinet of Ministers accepted the project of Ministry of Environment 'Basic Regulations of Renewable Resources Use in the period of 2006-2013'. The main renewable recourses mentioned there are biomass (wood) and waterpower. The main aim of this document is determination of more effective use of renewable resources taking into account economical, geographical, technical potential in the context of international and EU political objectives in Latvia (Vides ministrija, 2006). Ministry of Economics presented the strategy and expressed the official point of the government of Latvia towards bio energy use in energy power production 'Statements of Energy Evolution 2007-2016'. Activities which are considered in the context of bio energy as energy wood must convince that there is a necessity to expand renewable energy recourses and effectively produce electricity power in the process of cogeneration. The other objective is safety of environment in the context of Kyoto protocol and 'Climate Change Reduction Program for the Period of 2005-2010 in Latvia' defined targets for carbon emissions decrease (Ekonomikas ministrija, 2006).

Wider and more effective use of renewable energy resources is one of priorities in European Union energy politics. Renewable resources decrease dependency of import energy

resources, decrease emissions of greenhouse gases, increase reliability of delivery, stimulate local entrepreneurial activity in rural regions and create work places (EU Green Paper, 2006; Weih, 2004). European Union Emission trade system (EU ETS) started in January of the year 2005, and it is the major project in the world with the aim to stimulate decrease of amount of greenhouse effect gases emissions in the atmosphere; the system is based on EU directive 2003/87/EC, 25 October, 2003 (EUBIONET, 2007).

Finland is one of the most experienced countries in cultivating energy wood plantations and most competent of peat land afforestation (Hytonen, 1995; Hytonen and Wall, 1997; Tahvanainen and Rytkonen, 1997). In Latvia one of the greatest owners of cut away peat lands is Riga municipality Agency of Forestry, 6965 ha of bogs belong to them.

Cut away peat land areas can be separated in two groups by left pet layer depth: areas where peat is cut away up to mineral soil and areas where there is 20-80 cm deep peat layer left. Both areas before short rotation plantations are made must be fertilized. If peat is completely cut away, mineral soils contain insufficient content of organic substance and mineral elements P, K (Bušs et al., 1974; Hytonen and Wall, 1997). This problem in mineral soils can be solved by fertilization with qualitative waste water sewage sludge. Soil of peat lands is usually acid with good supplement of N, but there is K and P deficit. Waste water sewage sludge contains P, but it is necessary to use minerals or wood ash for K supply and liming of soil in peat (Hytonen, 1998).

Due to the forest regeneration according to Latvian legislation it is allowed to plant less number of trees per hectar in plantation forests. If plantations are planted in abundant agricultural lands, intensive fertilization is allowable in reclaimed fields. Plantation forest must be cut down before reaching harvesting age.

Trees have different requirements for soil fertility, water regime and soil pH. Pines *(Pinus sylvestris* L.)* grow in humid enough acid soft soils, dry sand soils, peat soils, bogs (Hytonen and Wall 1997; Liepa et al., 1991). Pines that grow in rich soils have wide annual ring and many thick branches (Булыгин, 1985). Pines are flexible and can grow in soils with various water supplement; however, they make only V-Va productivity index in bogs. Ground water level up to 1.5-1 m decrease growth rate and pine productivity (Харитонович, 1968). Pines are trees that love sunny places; overshadow slows

down their growth. In young forest stands and plantations deciduous trees and caulescent plants overgrow and overshadow pines lessening their natural regeneration capacity (Mangalis, 1989).

Both birch species Silver birch (*Betula pendula* Roth.), downy birch *(Betula pubescens* L.) are typical pioneers (Hytonen and Kaunisto, 1999). A silver birch grows in low acid under neutral mineral soils, whereas a downy birch grows in fibric histosols (peat). Birches like light, even humid, humus rich soils, acid and alkaline eutric podzoluvisols,the best growth results for both species are in humid mould soils. A silver birch can grow even in dry soils and peat, but stands have low productivity (Lange et al., 1978; Нестерович, 1967). For a downy birch it is problematic to root into hard impacted loamy soils. Birches have wide deep root system allowing them to grow even in poor dry soils (Харитонович, 1968; Lange et al., 1978). Silver birches are first species to come into coniferous trees clearings. Birch has a thin crown, stand intensively thinning out below birches crowns developed advanced growth and caulescent plants (Булыгин, 1985). Successful regeneration for a downy birch can take place only in good light conditions; other trees and caulescent plants cause high mortality of a downy birch (Харитонович, 1968). A downy birch productivity in dry soils is low, but it is high in humid soils haplic histosoils. Increase of soil humidity stimulates seedling development (Нестерович, 1967; Lange et al., 1978). A downy birch is frost resistant species with wide area in North (Харитонович, 1968; Булыгин, 1985). Birches are fast growing species; for example, a Silver birch its full height achieves at the age of 40-50 years (Lange et al., 1978). Both birch species successfully regenerate with stools and seeds (Харитонович, 1968).

Pines, birches and spruces are used successfully in the areas where peat has been cut away and peat land afforestation in Scandinavian countries (Hytonen and Wall, 1997). The main problem in afforested areas management is necessity to use less productive lightweight equipment and wood extraction becomes more expensive (Sirén, 2004).

Willows *(Salix sp.)* are adapted to wide growth conditions from light dry sand soils under peat lands. Acid and wet soils with low aeration are not suitable for willows. Cut away peat lands with thick peat layer are not suitable for willows (Hytonen, 1995; Hytonen, 1998; Tahvanainen and Rytkonen, 1999; Puttsepp 2004). Cut away peat lands with completely cut down peat

layer under mineral horizon must be suitable for afforestation with willows (*Salix sp.*) and aspens (*Populus tremula*) (Hytonen and Kaunisto, 1999). Possibility of fast growing willows species to accumulate large amounts of nutrient elements N, P, K, in biomass, is widely used in municipal waste water treatment plants (Hytonen, 2003; Mathe-Gaspar and Anton, 2005). Willows are widely used for reclamation of quarries and mining sites (Weih and Nordh, 2002). Willows are used for soil reclamation from heavy metals especially Cd; however, different willow species have various capacity of metal assimilation. Bark always contains more heavy metals (Adler et al., 2005).

In Poland initiative of growing willow plantations comes from wastewater sludge producers and managers. In Latvia these questions are still in the initial stage (Лаздиня et al., 2006). In Poland the main reason for waste water sewage sludge use as the fertilizer is its lower price compared to minerals (Komorowski et al., 2005).

Use of waste water sewage sludge and wood ash as the fertilizer for areas reclamation before cultivating fast growing tree species plantations solve different problems: it is a way of environmentally friendly utilization of municipal waste recycling organic and mineral matter and improvement of soil chemical properties before cultivation of plantations at the same time decreasing establishing cost (Gemste and Vucans, 2006).

Materials and Methods

Aims of research were to determine the impact of waste water sewage sludge fertilization 10 t ha^{-1} on wood biomass production and soil properties and concentration changes of the main nutrient elements N, P, K, and Ca, Mg in different depth during the year 2006 on emptied peat fields after peat output. Plantation of silver birches (*Betula pendula* Roth.), hybrid aspens (*Populus sp.*), black alders (*Alnus glutinosa (L.)* Gaertn.), pines (*Pinus silvestris* L.), willows (*Salix sp.*) clone *Sven* had been established on cut away peat land with thick peat layer in 1 ha area in 2005 waste water sewage sludge dose 10 tdm ha^{-1} had been used as the fertilizer. Waste water sewage sludge with moisture content 80% came from Riga waste water treatment plant. Both plantations are located nearby Riga. Geographical coordinates of plantation are 565056'28 N 240632'76 E, at the sea level. Other plantation area 2 ha with the same species and fertilization scheme had been established on cut away peat land with completely

cut away peat layer mineral soil. Geographical coordinates are 565132'76 N 235839'84 E, 7 m above the sea level.

Soil samples had been collected from both plantations fertilized and control fields by soil probe sampling depths 0-20 cm, 21-40 cm, 41-60 cm and 61-80 cm. Three completes of samples had been collected on May 22, 2006 and October 22, 2006. In the laboratory soil samples had been dried (<40 °C), milled and sieved through 2 mm sieve according to LVS ISO 11464 standard. Sieved samples had been mixed for testing of chemical properties.

Ammonium nitrate N-NH$_4$ had been tested from naturally dry samples following sampling, by colorimetric method with Nesler reagent in 0.1 n NaCl extract (Pāvule, 1978; LVS ISO/TS 14256–1). Soil acidity (pH) had been tested according to LVS ISO 10390.

In dried samples had been tested:

- heavy metals zinc (Zn), chromium (Cr), cadmium (Cd), nickel (Ni), lead (Pb) and cooper (Cu) according to LVS ISO 11047;
- plant nutrient elements phosphorus (P) by colorimetric method in 0.2 n HCl solution (Manual IIIa, 2003);
- potassium (K) by Atomic Absorption Spectrometer in CH$_3$COONa solution (AAnalyst User Manual CD, 2004) had been tested;
- total nitrogen content (N$_t$) had been tested according to LVS ISO 11261;
- total carbon content (C) according to LVS ISO 10694:1995;
- total sulphur content (S) had been tested according to Operation Manual CS-500 Carbon/Sulfur Determinator (ELTRA GmbH, 2004).

All chemical analyses had been done in Latvia State forest research institute 'Silava' Soil laboratory

Tree growth was characterized by the current year argument, bottom diameter and tree height. The survey was done in October 2006. Data statistical analysis T-test, ANOVA was done by software SPSS. Data statistical analysis by Kolmogorov-Smirnov test shows that data were adjusted to normal distribution.

Results and Discussion

Supply of nutrient elements in peat and mineral soil of used peat cutaway areas differ ($p < 0.001$). It was determined that ammonium

nitrogen content in all control plantations and fertilized fields was sufficient.

Fertilized field soil samples contained a bit more N than control plots (p∼0.046). In fertilized fields caulescent plants developed fast and nitrogen from soil in biomass was carried out. Soil samples from fertilized fields collected in autumn had less nitrogen (Table1). Soil top layer had the smallest nitrogen concentration in the controlled peat soils and fertilized fields. Concentration of total and ammonium nitrogen in autumn was lower than in spring and at the end of 2005. At the end of 2006 N content in peat soils with large biomass productivity was increased (p∼0.043).

Phosphorus supplement in mineral soil was sufficient. In 2005 supplement of phosphorus in fertilized fields was better than in 2006, but in pilot fields phosphorus supplement did not change in 2005-2006. In autumn the least amount of phosphorus was in depth 20-40 cm (p∼0.010). In 2006 autumn the fertilized fields and control fields supplement with phosphorus in mineral soil was similar, but in spring better phosphorus supplement was in fertilized fields. Fertilized peat soils in the spring of 2006 contained more phosphorus than in autumn. Phosphorus supplement at the end of 2006 was low and similar in the control and fertilized fields in peat soils.

The control field potassium supplement in 2005 and 2006 was similar. The fertilized field

on mineral soils in spring 2006 contained less potassium as it was in autumn, but the control field had higher potassium content in soil samples taken in spring. In soil samples taken from peat soils, the lower potassium content was in fertilized fields. Plants got a lot of phosphorus and potassium from soil and fixed them in biomass.

In spring fertilized field soil had more nitrogen in top layer, but in autumn nitrogen concentration in top layer 0-20 cm was not significantly higher as it was in deeper layers (Table1).

Doing statistical analysis on soil chemical analyses data, difference of element content changes that may be indicative for nutrient element leaching into deeper layers (p∼0.9-0.2) was not observed. After fertilization, soils under 40 cm depth contain more Ca and Mg (Table1).

Use of waste water sewage sludge does not significantly change peat soil acidity in general (p∼0.52), but in the top layer of fertilized mineral soil pH_{KCl} changes from pH_{KCl} 5.6 to pH_{KCl} 6.6 (Figure1).

The aim of carbon content analysis was to determine soil mineralization. In top layer of fertilized mineral soil organic matter content (total carbon concentration) decreased. Analyses of peat soils showed the tendency of soil top layer (Figure 2) mineralization.

Sulphur with its usual concentration in waste water sewage sludge was analyzed in different soil depth in order to determine mobility of

Table 1

Mean macro element (N, P, K) concentration in mineral soil and peat soil in different sampling depth

| Soil	Deepth cm	N mg 100 g^{-1} May	N mg 100 g^{-1} October	P mg 100 g^{-1} May	P mg 100 g^{-1} October	K mg 100 g^{-1} May	K mg 100 g^{-1} October	N$_{total}$ g kg^{-1}	Ca mg 100 g^{-1}	Mg mg 100 g^{-1}
Peat - control	0-20	19.5	68.8	0.6	0.3	12.8	10.0	6.1	314.7	77.2
	20-40	35.9	62.1	1.1	0.0	18.4	1.0	5.1	306.2	24.4
	40-60	49.4	60.6	0.7	0.0	11.3	29.0	9.5	306.9	62.2
	60-80	39.2	83.0	0.6	0.4	12.0	12.0	8.7	345.5	22.4
Peat - fertilized	0-20	8.9	20.1	1.6	0.7	5.5	9.2	9.0	484.0	88.6
	20-40	15.2	50.4	2.7	0.2	8.2	11.0	8.7	401.3	49.0
	40-60	38.5	73.2	0.6	0.1	12.4	11.5	7.0	294.5	92.5
	60-80	24.1	43.1	0.4	0.2	7.5	11.1	6.7	213.2	63.4
Mineral soil - control	0-20	4.6	1.0	1.0	2.1	2.1	3.8	10.6	71.2	11.5
	20-40	5.6	1.3	0.4	1.9	1.7	2.8	8.8	50.0	10.4
	40-60	5.7	0.2	1.4	2.9	1.9	4.3	1.3	44.1	6.6
	60-80	6.6	13.4	1.8	3.2	1.4	18.6	6.7	54.8	10.6
Mineral soil - fertilized	0-20	13.5	0.5	3.8	2.0	2.5	3.2	20.2	173.2	37.6
	20-40	6.2	1.1	1.3	1.7	2.3	2.1	10.3	119.3	34.4
	40-60	5.6	0.5	1.0	1.9	2.3	3.0	1.6	24.1	4.5
	60-80	6.1	1.3	1.7	4.4	2.5	8.1	0.5	19.6	10.4
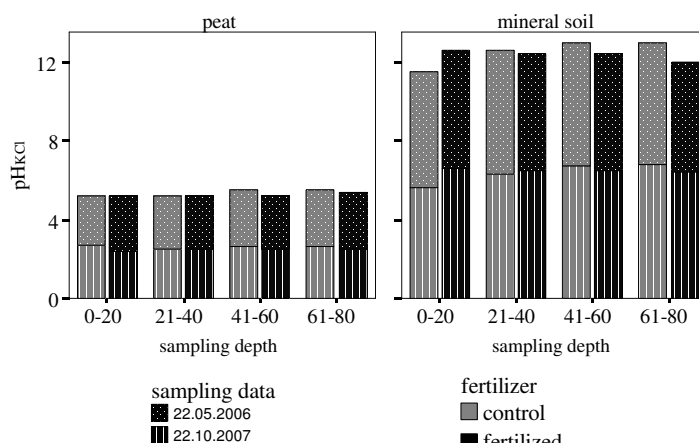
Figure 1. Soil pH$_{KCl}$ changes.

this element. Changes of sulphur concentration in lower soil layers can represent heavy metal movement. The movement of sulphur into deeper soil layers was not observed. The top layers of soils from fertilized fields contain more sulphur than those from the control fields. (Figure2)

There were not found heavy metal concentration changes in soil top layer that were above the norms defined in legislation of Latvia (Table 2) with the exception of zinc (Zn) and copper (Cu) concentration in peat soil.

Waste water sewage sludge fertilization effect on tree growth was determined by measuring year increment, diameter of stump at the bottom and calculated stock. Trees that grew in mineral soil in fertilized fields were more vigorous, but they had less year increment and stock than the trees from the control fields. Tree year increments correlate with wood stock. In peat soil more vigorous trees were in the control fields. Fertilization caused the

best growth condition, and higher year increments of trees were observed in fertilized fields. In mineral soil in Mārupe fertilized field stock of black alders (M-Ma), pines (M-P), aspens (M-Ap), birches (M-B) are less than in the control plot, since in fertilized fields mortality was higher than it was in the control plots. In peat soils in Virši higher stock in fertilized fields were for black alders (V-Ma), pines (V-P), aspens (V-Ap), birches (V-B) (Figure 3).

Trees growing in fertilized peat soil had thicker stems than those that grew in control fields, but trees growing in mineral soil had similar stem diameters.

Trees planted in peat soil survived better than those in mineral soil. Trees in mineral soil suffered from weed rivalry, especially pines, but in peat soils they suffered from animal damage; willows in peat soil suffered from acid soil (Table 3).
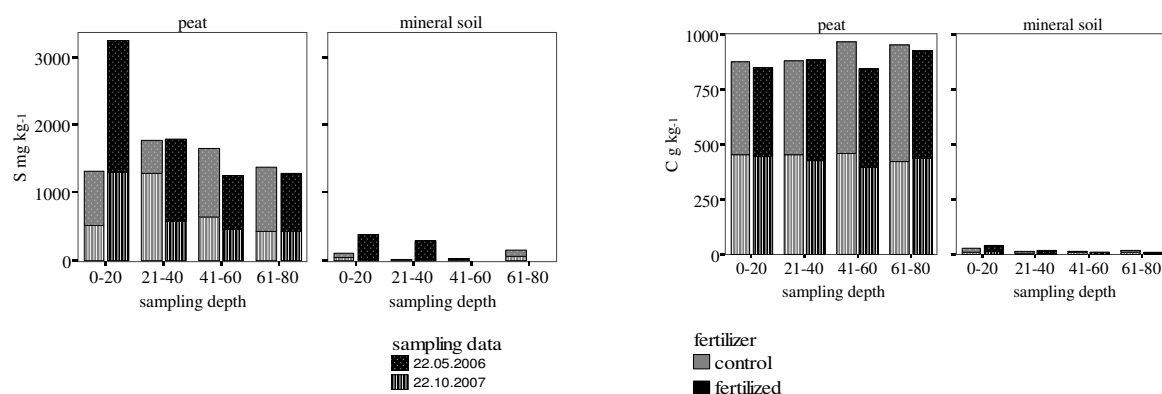

Figure 2. Sulphur and carbon concentration changes in different soil layers.

Table 2

Heavy metals content changes in soil top layer

Soil /object and norms defined in legislation	Heavy metals mg kg^{-1} drymatter					
	Cd	Cu	Ni	Pb	Zn	Cr
Mineral soil before fertilization - control	0.21	3.31	3.23	6.21	11.13	1.72
Mineral soil after fertilization 2005	0.31	9.14	5.31	9.31	59.92	7.01
Mineral soil fertilized fields 2006	0.46	8.54	4.18	10.18	19.45	4.18
Rules of Cabinet of ministers 388/304	0.08-8	4-150	3-200	13-300	16-700	4-350
Peat soil before fertilization - control	0.33	10.12	11.52	14.72	20.41	8.03
Peat soil after fertilization 2005	0.42	38.12	13.22	19.53	96.62	19.71
Peat soil fertilized fields in 2006	0.38	39.12	14.16	21.23	98.34	21.4
Rules of Cabinet of Ministers Nr.362	0.5-0.6	15-25	15-25	20-25	50-65	40-50

In mineral soil in Mārupe willows clone *Sven* shoots had much better growth rate in fertilized fields, but results are similar. Mean shoot height on fertilized field was 162 cm bottom diameter 12.3 mm but in control field shoot height was 165 cm shoot diameter 10.9 mm. Total stocks in fertilized fields 1.05 m^3 ha^{-1} was not enough for a short rotation plantation. Willows in peat soil did not show good growth results and had high mortality; willows would not grow in peat land with pH 4.5 without liming. In 2005 all shoots of *Sven* died due to the fact that the top layer heated up to 34 $^{\circ}$C and new roots withered.

Data statistical analysis with multiply factor interaction showed that interaction of all factors except soil and fertilization were significant for shoot year increment ($p < 0.000$). Soil, fertilization, height, year increment and interaction of these factors had significant effect on the stem diameter ($p < 0.05$).

Conclusions

1. Deciduous trees (black alder, birch, aspens, and willows) will be more suitable for short rotation plantations and plantation forests with mineral soil using wastewater sewage sludge fertilization. Coniferous were overshadowed by weeds.
2. On abundant peat cutaway areas with deep peat layer and high groundwater level in first two seasons pines, black alders, birches from fertilized fields showed better growth results. Willows were not suitable for such fields.
3. Amount of nutrient elements in soil from abundant peat cutaway areas with deep peat layer and completely cut away up to mineral soils were significantly different.
4. After the use of wastewater sewage sludge fertilization 10 t ha^{-1} most significantly changed total nitrogen concentration in both soils, but especially in mineral soil. After fertilization, the concentration of potassium and phosphorus increased, but in
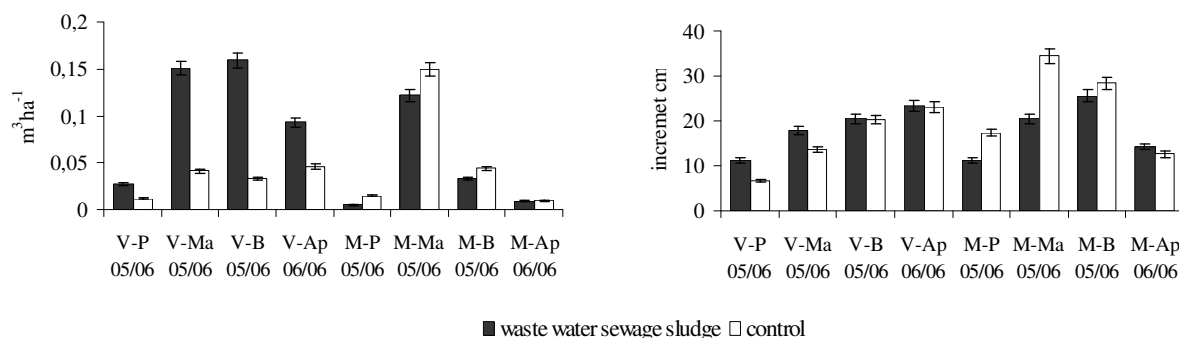

Figure 3. Fertilization effect on different wood species wood stock (m^3 ha) and year increment (cm).

Table 3

Survival of trees in different growth conditions

Soil /object	Survival in per cent in October, 2006							
	black alder		birch		pine		salix sp. *Sven*	
	control	fertilized	control	fertilized	control	fertilized	control	fertilized
Virsi /peat soil	94	86	96	93	86	80	6	7
Mārupe / mineral soil	63	73	79	47	54	11	75	70

October 2006 plants used out these reserves.

5. Fertilization with waste water sewage sludge decreased soil acidity for 0.5-1 unit.

6. Peat soil fertilized fields top layer was decomposed and mineral fraction proportion Increased.

7. In fertilized fields soil top layer sulphur concentration increased, but there were not observed sulphur and heavy metal leaching into deeper soil layers.

8. There were not fair changes in heavy metal content in top soil layer (0-20 cm) in 2005-2006.

Acknowledgements

References

1. Analyst User Manual (2004) AAnalist User manual. Available at: http://www.perkinelmer.com, 10.11.2005.

2. Adler A., Verwijsta T., Aronsson P. (2005) Estimation and relevance of bark proportion in a willow stand. Biomass and Bioenergy, 29, pp. 102–113.

3. Bušs M., Kāposts V., Sacenieks R. (1997) Meža mēslošana (Forest fertilization), Latvijas Republikāniskais zinātniski tehniskās informācijas un propagandas institūts, Rīga, 54 p. (in Latvian).

4. Ekonomikas ministrija (2006) Enerģētikas attīstības pamatnostādnes 2007. – 2016.gadam (Statements of Energy Evolution 2007-2016). Available at: http://www.em.gov.lv/em/2nd/?cat=14281, 12.02.2007 (in Latvian).

5. ELTRA GmbH (2004) Operation Manual CS-500 Copyright © 2004 by ELTRA GmbH Germany (CD).

6. EU Green Paper (2006) Eiropas stratēģija ilgtspējīgai, konkurētspējīgai un drošai enerģijai (A European Strategy for Sustainable, Competitive and Secure Energy). Available at: http://ec.europa.eu/energy/green-paper-energy/doc/2006_03_08_gp_document_lv.pdf., 5.03.2006. (in Latvian).

7. EUBIONET (2006) WP1 reports, ET-BIOENERGY-New Bioenergy Business During Emission Trading. Available at: http://www.eubionet.net, 4.03.2006.

8. Gemste I., Vucāns A. (2006) Notekūdeņu dūņas (Waste water sewage sludge), Jelgava, Latvijas Lauksaimniecības universitāte, 276 p. (in Latvian).

9. Hytonen J. (1995) Effect of Fertilizer Treatment on the Biomass Production and Nutrient Uptake of Short-Rotation Willow on Cut Away Peatlands. Silva Fennica, 29(1), pp. 21-40.

10. Hytonen J. (1998) Effect of Peat Ash Fertilization on the Nutrient Status and Biomass Production of Short-rotation Willow on Cut-away Peat Land Area. Biomass and Bioenergy, Vol 15 (1), pp. 83-92.

11. Hytonen J. (2003) Effects of Wood, Peat and Coal Ash Fertilization on Scots Pine foliar Nutrientt Concentrations and Growth on Afforested Former Agricultural Peat Soils. Silva Fennica, Vol 37 (2), pp. 219-234.

12. Hytönen J., Kaunisto S. (1999) Effect of Fertilization on the Biomass Production of Coppiced Mixed Birch and Willow Stands on a Cutaway Peatland. Biomass and Energy, 17(6), pp. 455-469.

13. Hytonen J., Wall A. (1997) Nutrient Amounts of Afforested Peat Fields and Neigbouring Peatland Forests. SUO, 48 (2), pp. 33-42.

14. Komorowski H., Karczmarczyk A., Mosiej J. (2005) The Role of the Wastewater Irrigation and Sludge Utilisation in Sustainable Rural Development– Case Study from Łódz Region. In: ICID 21st European Regional Conference, pp. 1-6.

15. MANUAL IIIa (2003) International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on forests MANUAL on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests. Institute for Forestry and Game Management, Belgium, 108 p.

16. Lange V., Mauriņš A., Zvirgzds A. (1978) Dendroloğija (Dendrology), Rīga, Zvaigzne, 304 p. (in Latvian).

17. Liepa I., Mauriņš A., Vimba E. (1991) Ekoloğija un dabas aizsardzība (Ecology and Protection of Nature), Rīga, Zvaigzne, 302 p. (in Latvian).

18. LVA (2006) Latvijas Vides, ğeoloğijas un meteoroloğijas ağentūra, Valsts statistikas pārskats 'Nr.2 – Ūdens' (State statistic data water-2). Available at: http://www.meteo.lv/public/26653.html, 21.12.2006 (in Latvian).

19. Mangalis I. (1989) Meža kultūras (Forest crops), Rīga, Zvaigzne, 348 p. (in Latvian).

20. Máthé-Gáspár G., Anton A. (2005) Study of Phytoremediation by Use of Willow and Rape. In: Proceedings of the 8th Hungarian Congress on Plant Physiology and the 6th Hungarian Conference on Photosyntesis, Acta Biologica Szegediensis, 49(1-2), pp. 73-74.

21. Pāvule A. (1978) Agroķīmiķa rokasgrāmata (Hanbook of agricultural chemistry), Rīga, Liesma, 338 p. (in Latvian).

22. Puttsepp U. (2004) Effects of Sustainable Management Practices on Fine Root Systems in Willow (Salix viminalis, Salix dasyclados), Grey Alder (Alnus incana) and Norvay Spruce (Picea abies) Stands, Doctoral Thesis Swedish University of Agricultural Sciences, Uppsala, 23 p.

23. Sirén M. (2004) Harvesting on Peatlands – a Challenge. Wise Use of Peatlands. In: Proceedings of the 12th International Peat Congress, International Peat Society, Finland, pp. 514-520.

24. Tahvanainen L.and Rytkonen V.-M. (1999) Biomass Production of Salix Viminalis in Southern Finland and the Effect of Soil Properties and Climate Conditions on its Production and Survival. Biomass and Bioenergy, 16, pp. 103-117.

25. Vides ministrija (2006) Atjaunojamo energoresursu pamatnostādnes 2006.-2013.gadam (Basic Regulations of Renewable Resources Use in the period of 2006-2013) Available at: http://www.vidm.gov.lv/lat/informacija_presei/preses_relizes/?doc=3372, 14.02.2007 (in Latvian).

26. Weih M. (2004) Intensive Short Rotation Forestry in Boreal Climates: Present and Future Perspectives. Canadian Journal of Forest Research, 34, pp. 1369-1378.

27. Булыгин Н.Е. (1985) Дендрология (Dendrology), Москва, Агопромиздат, 1985, 280 стр. (in Russian).

28. Лаздиня Д., Лаздиньш А., Мартинсоне К., Кариньш З., Капостс В., Лиепа И., Хрол Ю. Долацис Я. (2006) Соответствие некоторых пород ивовы (Salix) и их селекционных клонов для получения энергетической древесины (Suitabulity of Different Willow Species and Clones for Energy Wood Production). Annals of Warsaw Agricultural University – SGGW Forestry and Wood Technology, 59, стр. 39-43. (in Russian).

29. Нестерович Н.Д., Дерюгина Т.Ф (1967) Влияние влажности условий произрастания на некотоые анатомические особенности древесных растений (Impact of moisture content of soil on anatomical and morfological properties of trees), 'Дендрология и лесоведение', Минск, стр. 93-99. (in Russian).

30. Харитонович Ф.Н. (1968) Биология и экология древесных пород (Biology and ecology of wood crop), Москва, 'Лесная промышленность', 304 стр. (in Russian).

PROBLEMATIC CHARACTER OF FOREST LAND TRANSFORMATION

Gunta Bāra
Latvia University of Agriculture
E-mail: metrajs@inbox.lv

Abstract

In order not to decrease the significance of a forest in the environmental maintenance and its role in the national economy, Latvian Forest policy needs to ensure that the existing forest areas are not decreasing, establish forest land transformation restrictions, thus, maintaining a long lasting development of forests. The preconditions for the change of the forest land usage is one of the instruments for the state policy realisation, with the help of which a long-term development of forests can be ensured. At the moment working out the land policy in Latvia on a country level is being started. The publication is in the context of setting strategic targets for forestry and human resource development planning strategy, within the framework of Latvian forest and related department national programme. Due to the reasons mentioned, the topic discussed in the article is a problem of the day, and the research in this direction has got both theoretical and practical significance. The author investigate the forest land transformation process, by analysing normative acts and political documents in the article, as well as by summarising statistical data about the relevant processes in Latvia and in the world, during last six years. The issues, related to the forest land transformation process have been covered in the article; it has been analised whether there are cases when a necessity arises to review the existing normative regulations. The answers have been given how to eliminate identified shortcomings, contradictions or problems.

Keywords: change of land-use type, afforestation, territorial planning.

Introduction

The forest land transformation or change of land-use type is a process, which due to people's active economic activities, is still taking place on a global scale. A variety of restricting measures have been performed, which in all possible ways try to slow down this process or ensure the accept of well-thought decisions. According to the latest FAO information, there are 13 067 421 thousand hectares of forests in total in the world, including 2 260 180 thousand hectares in Europe. Thus, in the time period from 2000 to 2005, forest land areas decreased for 7317 thousand hectares per annum or about 0.18% (FAO, 2006) in the world, which substantially decreased wood resources on a global scale, resulting in ecological threat excalation. To minimise the negative influence of this process on biological diversity, climate changes and other environmental problems, numerous international documents have been adapted in the world, such as conventions, resolutions and the like.

As the result of these processes, the forest land areas are not decreasing in total in the developed countries, and their increase has been observed. Thus, in Europe the forest area has increased on average for 661 thousand hectares per annum or by 0.07% (FAO, 2006) from 2000 to 2005. That has happened thanks to the EU Forest Action Plan, the overall goal of which is to faciliate a long-lasting management of forests and multifunctional significance of forests. There was written that forests for society mean a long-term, multifunctional forestry, which fulfills the needs of the society now and in the future, and which support forest-related sources of living. A multifunctional forestry gives its input for economics, environmental, social and cultural fields, and it has a significant role in the development of economy, employment and growth in Europe, and particularly in rural areas (Communication from..., 2006).

Based on that author has formulate three main tasks of this article: to describe the forest land transformation process and legislative instruments regulating it; to analyse national and international legislative instruments in the context of transformation; to identify main problems connected with changing lad use type and hold out how to solved it.

Materials and Methods

Comparative, analytical and historical methods have been mainly used in the article, applying the complex and interdisciplinary approach, taking into consideration the dinamic nature of normative acts in time, and investigating questions, related to natural science, economics

and politics, for perriod starting from 2000 to nowadays. The requirements of legal, political documents (rules and regulations issued by the Cabinet of Ministers of Latvia and several countries of Europe) have been investigated, as well as their influence on an individual and the society in general. Statistical data from Central Statistical Administration of Latvia, State Forest and State Land services, Ministery of agriculture of Latvia have been summarised and analysed in time on land balance changes in Latvia, connected to natural and artificial land transformation.

Results and Discussion

Latvia is one of the European Union member states, which has got a positive forest balance; moreover, it has a tendency to increase it with every year. Thus, in 2006 forest coverage reached 45% (2 950 267.3 ha), or during the whole period of existence it has increased by more than one half, i.e. in 1923 – 24.7%. (Mežu aizņemtā platība..., 2007; Mežu aizņemtā..., 2006, Meža nozare..., 2007). This high jump of woodland growth is considered as the consequence of human inactivity in the post war period: however, the slow, nevertheless increase of the last years is more like the result of a conscious and purposed activity – afforestation of land not utilised for agricultural purposes.

The afforestation of unutilised agricultural lands is being encouraged by the state, using different methods. The possibility to receive a guaranteed amount of money to cover the costs of afforestation should be mentioned as a well-known

example, which is available in the form of state and European Union grant for any enthusiastic person. EU co-financing has been forseen up to 75% from all the afforestation costs. In total the following costs have been considered: soil preparation, plants, planting, but not more than 400 EUR ha^{-1}, as well as newly planted forest and naturally grown new forest cultivation and protection costs for two years, including the year of the take-over – 140 EUR ha^{-1} per annum (Valsts un ES atbalsts..., 2007). Thus, in 2005, nearly five thousand hectares of agricultural land have been afforested; besides, the receipt of the agricultural land transformation permission serves as the precondition, which in the last accounting period has been issued for thousand hectares more than in the previous two years, see the Figure 1. (LIZ transformācija, 2006).

A planned afforestation of their property is being carried out also by legal persons – such as Joint Stock company 'Latvijas Finieris', the state forest manager, State Stock Company 'Latvia's State Forests', which influence significantly the growth of forest resources in the future. Also, such a fact should not be overlooked that in addition foreign investors and large amount of small local enterprises buy real property from physical persons every year, intending to afforest the agricultural lands unutilised for agricultural purposes with productive economic tree species.

The permissions for forest land transformation issued increase by every year – from 176 permissions issued in 2001 to 647 in 2006.
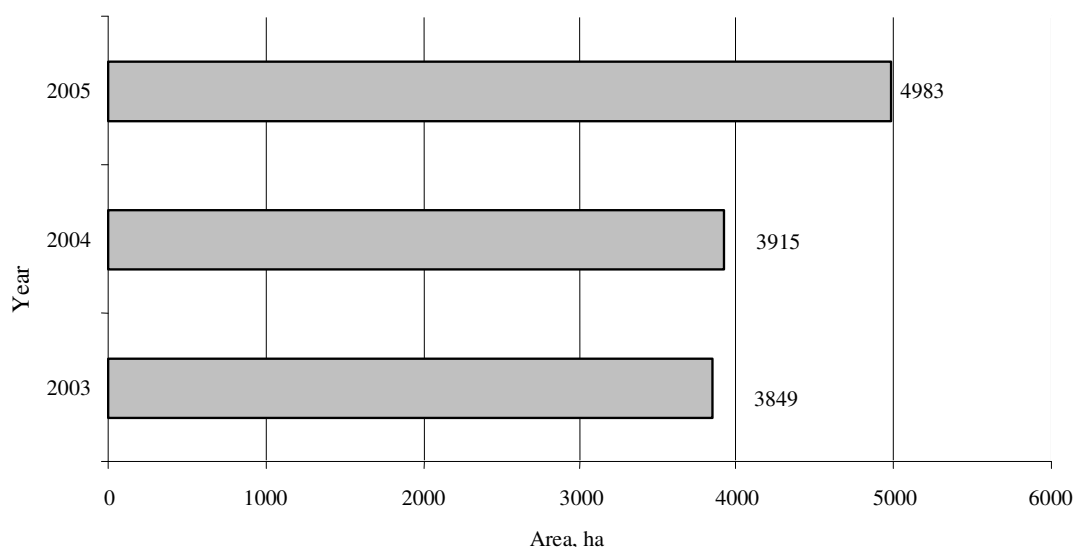

Figure 1. Transformed Agricultural Lands to Forest Lands.

The same changes are observed regarding the calculated payment for performing transformation or loss calculation, which is collected by the State for the destruction of the natural forest environment due to the transformation from the initiators of transformation, who are acting without state or municipal co-financing. Since 2001 the calculated amount of losses has increased more than ten times, which is connected with the fact that the loss calculation is bound to the minimum wages in the country, with the increase of the purchasing power of people and with a row of other social and economic factors. Thus, during this period it has increased from 133 thousand LVL to 1.4 million LVL, by which the state budget has been supplemented with. The pace of the dynamics of the transformed areas in time is not as even that can be explained by the goal of transformation and the different volumes of the relevant area provision, see Figure 2. (Meža zemes transformācija..., 2006).

Regardless the ratio of agricultural land areas managed incompletely, remaining in the Land balance, the owners try to manage their property more intensively, investing financial means in the change of land-use type. Based on the latest statistical data, the largest areas are used for building (sand and gravel) pits, which naturally occupy large parts of the territory. It has to be marked that pit building volumes are connected with faciliating and supporting of the rapid planning of the building and renovation of infrastructure objects on a country level. And the construction is connected, in turn, with socioeconomic situation in the country, see Figure 3. (Meža zemes transformācija..., 2006).

Analysing the statistical information of the last three years, the biggest amount of the transformation permissions is for Riga-Ogre regions, which is connected to the building intensity in Riga Bay zone and territories near Riga city. Among other regions, Cēsis, Rēzekne, Zemgale, Krāslava and Daugavpils regions maintain a persistent activity according to the permissions issued. Also Liepāja, Limbaži and Madona regions show particular activity during the last year. When compared the transformed forest land areas according to hectares, it should be concluded that the largest ones are those of the territory of Central Latvia, then come Vidzeme and Zemgale. The transformed areas in Kurzeme and Latgale are approximately the same. Thus, the regions with high woodlands, such as, Ventspils, Alūksne, Talsi are not the most active ones, which can be seen from the transformation permissions issued, as well as from
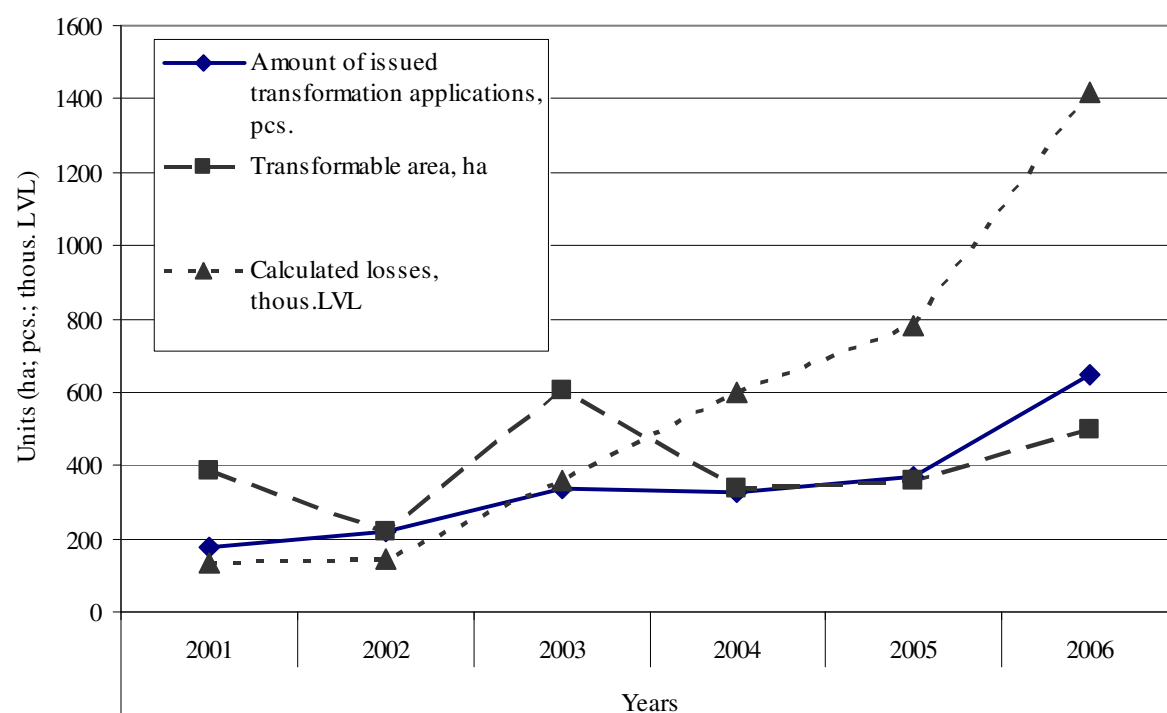

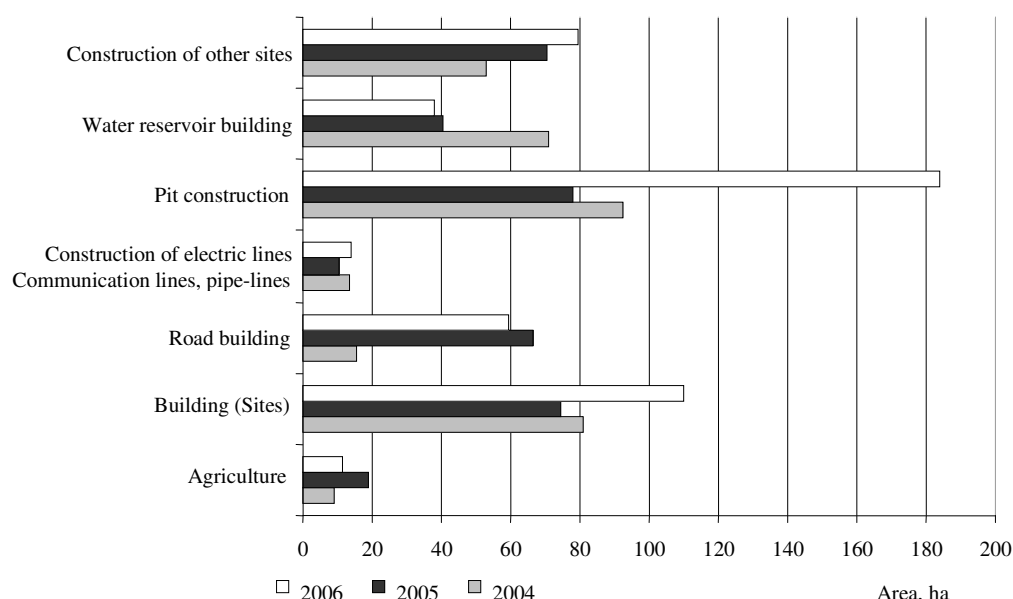Figure 2. The Dynamics of the Main Indices of Transformation.

Figure 3. Area Division According to the Goal of Transformation.

the transformed areas.Weighing the woodlands area of each region, it can be concluded that socioeconomic factor and geographical placement have more significant impact on transformation intensity than accessibility of wood, see in Figure 4. (Mežu īpatsvars..., 2006). The municipality is the uniting element of territorial planning and forest land transformation processes, as it is an institution that works out and confirms the planning of its administrative territory, as well as gives an opinion about the substantiality about forest land's transformation and the correspondence of the planned activity to the allowed usage of the municipality territorial planning. Local municipality territorial planning relates to all the territory owned by the municipality, and it contains the information about usage of the administrative territory of the local municipality; it determines the planned and allowed territorial usage for the time period up to 12 years, as well the restrictions for the territorial usage. The goal of the territorial planning is to co-ordinate two different interests – private persons on one hand and those of the society on the other; thus, social, economic and environmental interests are taken into consideration in the planning process (Noteikumi par teritorijas..., 2000).

Several territorial planning principles are being applied in the territorial planning, which have been determined by the Territorial Planning Law. Thus, the principle of long-lasting is the main one in the territorial planning

that secures qualitative environment, balanced economic development, rational usage of natural, human, material resources, development and preservation of natural and cultural heritage. This principle protects the rights of the next generations to the accessibility of the natural resources. The principle of interest co-ordination is significant ensuring generation of the territorial planning in accordance with other territorial plannings and the state, municipal and private interests are co-ordinated in this planning. The diversity principle ensures that the diversity of natural, human, material resources and economic activity are taken into account when working-out a territorial planning. The principle of openness ensures that the territorial planning is done, involving the society and securing the oppenness of information and decision taking. Every physical and legal person has got the rights to get acquainted with the existing territorial plannings, released for public discussion, take part in their discussion, to express his opinion, to submit proposals and references about territorial plannings and receive reply on them dates defined (Teritorijas plānošanas..., 2002).

The forest land transformation depends on the territorial planning and environmental protection interests. Different interests of territorial culture, environment development and economic fields can be co-ordinated with the territorial planning. A territorial planning in force is a legal basis for decision adoption on a certain territorial
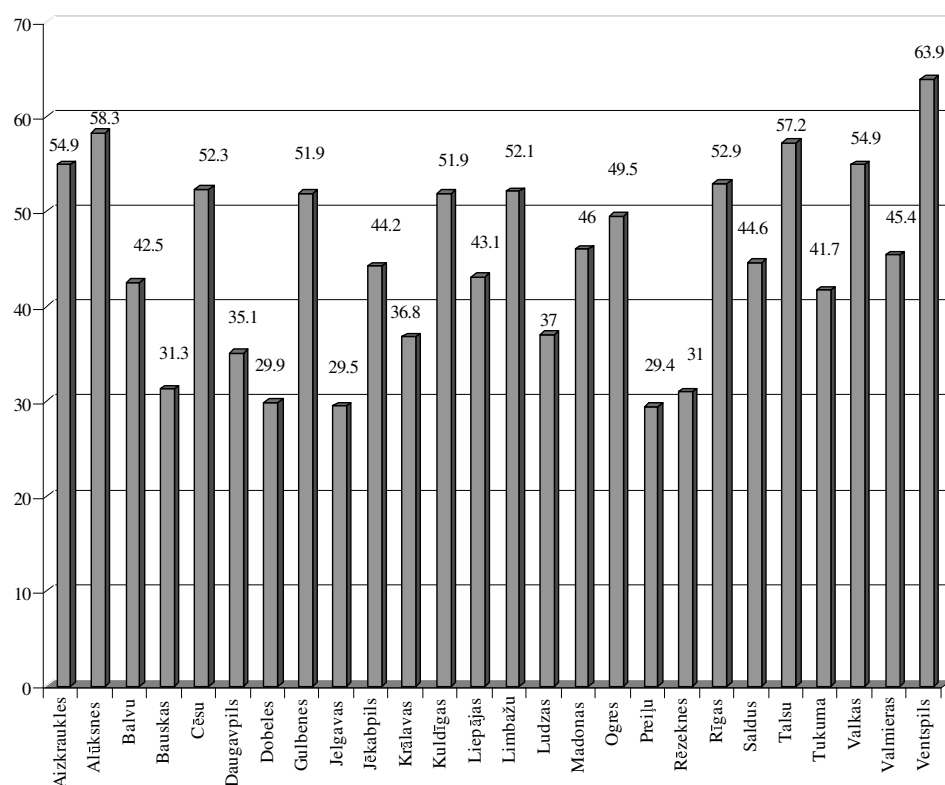
Figure 4. Forest coverage due to the Regional Division.

usage. Parts of territorial planning, detailed planning are confirmed as binding regulations of municipalities, which are considered as external normative acts. Therefore, if the municipality comes up with a negative opinion about the substantiality of transformation, then the head forestry issues a motivated rejection for the forest land transformation to the transformation initiator (Žagare, 2006).

The forest is an ecosystem in all its development stages, dominated by trees the height of which in the particular forest site may reach at least seven metres, and the present or potential tree crown cover accounts for at least 20% of the stand area. The forest land comprises the land carrying forest, the land under forest infrastructure facilities, as well as overflowing clearings, bogs and gaps in the forest and contiguous to it (Meža likums, 2000).

According to the parts two and three of the section 34 and parts three and six of the section 39 of the Forest Law, the Regulations No.169 regarding have been accepted on 15th April, 2003. Forestland categories, their types for the forest management and types of the land usage are listed in the Annex 1 of these Regulations (Meža valsts

reģistra..., 2003). According to the 'Real Estate State Cadastral Law' real estate usage purpose and land area within jurisdiction for the usage purpose is determined for the unit of the land and a part of a land unit, registered in the information system of the cadaster. It is determined by the local municipality, in the territory of which the particular unit of the land and a part of the unit of the land is located, according to the procedure, established by the Cabinet of Ministers and according to the usage, determined by the local municipality (Nekustamā īpašuma valsts..., 2005). The local municipality has got the rights to inspect the land unit, notifying in advance the cadastral subject about it, in order to determine the purposes of the usage of the real property.

The classification of the purpose of the usage and determination and change of the purpose of the usage of the real property is determined by the Regulations No.496 of the Cabinet of Ministers from 20 June 2006, in accordance with the delegation of the above mentioned section 9 of the corresponding law. The purpose of the usage of the real property is the current and determined usage of the land and buildings or planned (allowed) usage of the land, which for the needs of

cadastral evaluation has been stated for a unit of the land, a part of the unit of the land according to the detail planning, territorial planning of the local municipality or land's or building's usage, started according to the procedure, stated in the normative acts. When determining or changing the purpose of the usage, the area of the land assigned, is determined or changed according to the purpose of the usage. The area of the land assigned for the purpose of the usage in cities is determined in square metres, but in rural areas - in hectares (Nekustamā īpašuma lietošanas..., 2006).

The land, on which building is not considered the primary land usage method, according to these regulations, are territories, used for agriculture, forestry, water objects, minerals' extraction, or territories used for natural foundation and recreation, including the land under buildings and yards, if it is connected with the mentioned land usage. Till these regulations were accepted i.e. up to 1st July 2006, the Regulations Nr. 158 from 1996 were in force, where the term was defined more clearly, where the 'types of the land usage' are – land areas that differ by their natural features and which several years in a row have been used for a definite purpose. It followed from the stated that the forest land is a land on which there is a forest, as well as land, and it is used for forestry needs (Nekustamā īpašuma valsts..., 1996).

The legislative norms cannot be only economically justified; they should be also socially driven. Normative acts should not be created only with the consideration that they will be avoided or violated.

Weighing all the normative acts, statistical data reviewed earlier, investigating the assessment of the responsible specialists from the Ministry of Agriculture on MC Regulations No.806 (Žagare, 2006), as well as examining the practical progress of the forest land transformation process, based on the personal experience, it is possible to identify several major problems and shortcomings that need to be eleminated in the nearest future.

Shortcomings, Problems Traced, Their Solutions

- The supervision of the normative acts becomes problematic in cases when for building in the real property, with the territory about 0.1 ha in the cities and the forest land is being transfomed only below the projected building and access roads, but the rest of the area is not being transformed; as the result of which, several tens of square metres of the forest land

remain enclosed. Section 3 of the Forest Law does not regard an area, separate from the forest that corresponds to the forest definition and is less than 0.1 ha, as a forest. For avoiding that Regulations No.806 should be supplemented with the standard that the building construction not only transforms the forest land on which it has been planned to erect houses, but also the forest land, on which according to the detail planning, the elements of infrastructure, facilities and communications for the building maintenance and functioning have been designed. For an automobile road and railroad building, the forest land is transformed as foreseen in the normative acts for an automobile road and railroad divisional lane width.

- Performing construction in the urban territories, the area in most cases is less than 0.1 ha. According to the Regulations No.496 from 20th June 2006, the area of the land assigned for the purpose of the usage in cities is determined in square metres and in rural territories – in hectares. The Regulations of the CM No.806 should be supplemented with the requirement where the transformable area for urban territories should be expressed in the square metres for transformation applications, permissions and rejections.

- At the moment purposes for which it is allowed to request and issue forest land transformation permissions, are strictly limited, not leaving any chance to choose some other purpose outside the defined ones. It has to be marked here that a park should not be identified as a cultural or territorial object with facilities in all the situations. It has been determined by them that: if it has been planned to design a park, by changing the type of a forest or the agricultural land usage, after the project co-ordination at the Board of Building, the land transformation is performed in accordance with the normative acts on land transformation. The Regulations No.819 should be supplemented with the relevant subsection, determining that the permitted purpose of transformation is meant for the arrangement, reconstruction, expansion of the park, as well as for the building, arrangement, reconstruction and expansion of other objects (Parku ierīkošanas kārtība..., 2006).

- Thus, the lawmakers could avoid the necessity to work out the following amendments for the CM Regulations, which is a time consuming process; at that time clerks could work undisturbed at the work planned before, not losing the efficiency and productivity of work. I suggest carrying out a serious research on the topic if it is necessary at all to enlist specifically all the purposes of the forest land use type change. It is due to the fact that not always it is possible to predict such needs that could appear in the future. It would be sufficient enough if the cases are enlisted in those CM Regulations that according to the binding legislative acts are not considered the land transformation, for instance, forestry roads, places of taking water and alike, which is one of the types of land usage.

- The procedure is not established for the termination of a started forest land transformation and dealing with the consequences of unauthorised forest land transformation, as well as forest land transformation permission issuing procedure and regulations have not determined the cases when unlawful forest land transformation has been traced and administrative penalty and losses have been covered. The situations should be defined clearly, when and how it is possible to receive the transformation permission after the penalty and losses have been paid, and when it is not possible; thus, setting the transformation process in better order. It should be determined in CM Regulations No.806 that, when an unauthorised forest land transformation has been traced, it is within the competence of the Latvian Forest Service to inform the relevant municipality about the fact, the revision of the case of the administrative offence, the application of an administrative penalty to the guilty person and recovering the loss in the favour of the state in triple amount from the forest owner or legal supervisor.

- The Ministry of Agriculture is not competent to evalute the submitted documents and the transformation correspondence to the normative acts in cases when the order of the Cabinet of Ministers is needed for the issue of the transformation permission each time. It would allow before the preparation of the project, according to

the delegated, to evaluate the conformity of the transformation and give the recommendations and acknowledgements before further promotion of the project. The Regulations No.806 should be supplemented with the section where the competency of the Ministry of Agriculture in the evaluation of the transformation conformity for the submitted documents would be determined.

- In connection to the fact that the requirement to receive the permission for forest land transformation before receiving the building permission in cases when it is necessary before the construction of buildings and premises, has not been mentioned in these regulations, leads to the situation that in many cases the construction works are started without receiving such a permission. The started building on the forest land without the mentioned transformation permission should be regarded as unlawful and the building should be demolished. The General Building Regulations of the CM from 01st April, 1997 should be supplemented, where the requirement about the necessity of the receipt of the transformation permission should be added as one of documents to be submitted.

- In territorial plannings in concert with CM Regulations No. 833 (Vietējās pašvaldības..., 2004), in the section Regulations for the territorial usage and building regulations - the reception of the building permission and building, the necessity of the transformation permission are not mentioned either, which relates to the CM Regulations No.112 (Vispārīgie būvnoteikumi..., 1997). Change of the forest land use type without the permission issued by the State Forest Service, is unlawful and an administrative penalty should be applied. The designed territorial plannings should be supplemented with the section where the requirement to receive the permission for the forest land transformation in cases, when the building is planned and the change of the forest land use type on the forest lands, following it is mentioned.

Conclusions

1. Latvia is a European Union member country, rich in forest resources where, thanks to the state and EU financial support, the forest land areas increase every

year; thus, realising what was determined by the Forest Policy.

2. The forest land transformation is a complicated process that begins with the determination of a planned activity prospective for municipal territorial plannings, taking into consideration the state, municipal and private interests which can be realised by requesting and receiving the transformation permission, with or without municipal co-financing, and ends with the introduction of the amendments in the State Cadaster, after a complete change of the forest land use type.

3. There is a need to introduce supplements to several normative documents related to the forest land transformation in order to eliminate the existing shortcomings; thus, eradicating a possibility of an unlawful building or other object creation with unlawful land transformation following those processes.

4. The forest land transformation regulations should be supplemented by several articles where the types of activities would be determined, when the permission is not to be issued or supplemented with a range of new types of activities, as well as the competence of the Ministry of Agriculture defined for the cases when there is a necessity to draft the regulations of the Cabinet of Ministers, as well as give a detailed description, how to act in the situations when an unlawful forest land transformation, including construction, has been established.

Acknowledgements

References

1. Communication from the Commission to the Council and the European Parliament on an EU Forest Action Plan. (2006) COM Brussels 302 p.
2. FAO (2006) Global Forest Recource Assessment 2005, 323 p.
3. LIZ transformācija (Transformation of Lands Available for Agriculture) (2006) ZM, Available at: http://www.zm.gov.lv/index.php?sadala=466&id=242, 20.03.2007 (in Latvian).
4. Menģele-Stillere L. (2006) Pretrunas starp īpašuma tiesībām uz mežu un tiesībām dzīvot labvēlīgā vidē (Contradictions Between the Property Rights on a Forest and Rights to Live in a Favourable Environment), Riga: LU Faculty of Law, Summary for the Promotional Study, 23 p. Available at: http://www.lu.lv/aktualitates/index.html?id=1503, 20.03.2007 (in Latvian).
5. Mežu aizņemtā platība Latvijā uz 2006. gadu (Forest coverage in Latvia for 2006) Available at: http://www.vmd.gov.lv/?sadala=2, 20.03.2007 (in Latvian).
6. Mežu aizņemtā platība 20. un 21. gadsimta sākumā. (Forest Coverage in the 20th Century and at the Beginning of 21st century) Available at: http://www.lvm.lv/lat/mezs/par_mezu/apraksts/, 20.03.2007 (in Latvian).
7. Mežu īpatsvars Latvijas Republikā (Forest Ratio in the Republic of Latvia) (2006) ZM, Available at: http://www.zm.gov.lv/index.php?sadala=466&id=2467, 20.03.2007 (in Latvian).
8. Meža likums (The Forest Law) (2000) Latvijas Vēstnesis, 2000.March 16, No.13. (in Latvian).
9. Meža nozare Latvijā 2006 (Forest Sector in http://www.zm.gov.lv/index.php?sadala=1030&id=3742, 20.03.2007 (in Latvian).
10. Meža zemes transformācija 2001-2006 (Forest Land Transformation, 2001-2006) (2006) ZM, Available at: http://www.vmd.gov.lv/?sadala=372, 20.03.2007 (in Latvian).
11. Meža zemes transformācijas noteikumi nr.806 (Forest Land Transformation Regulations No.806) (2004) Latvijas Vēstnesis, 1st October 2004, No.156. (in Latvian).
12. Meža valsts reģistra informācijas aprites noteikumi nr.169 (Forest State Register Information Circulation Regulations No.169) (2003) Latvijas Vēstnesis, 15th April 2003, No.2825. (in Latvian).
13. Nekustamā īpašuma valsts kadastra noteikumi nr. 158 (Real Property State Cadaster Regulations No.158) (1996), Latvijas Vēstnesis, 30th April 1996, No. 563. (in Latvian).
14. Nekustamā īpašuma lietošanas mērķu klasifikācija un nekustamā īpašuma lietošanas mērķu noteikšanas un maiņas kārtība nr.496 (Real Property Purpose of Usage Classification and Real Property Purpose Determination and Procedure of Change No.496) (2006), Latvijas Vēstnesis, 11th July 2006, No.3476. (in Latvian).
15. Nekustamā īpašuma valsts kadastra likums (Real Property State Cadaster Law) (2005), Latvijas Vēstnesis, 22nd December 2005, No.3363. (in Latvian).

16. Noteikumi par teritorijas plānojumiem nr.423 (Regulations On Territorial Planning No.423) (2000) Latvijas Vēstnesis, 8th December 2000, No.446/447. (in Latvian).

17. Parku ierīkošanas kārtība un apsaimniekošanas pamatprincipi nr.819 (Park Designing Procedure and Basic Principles of Management nr.819) (2006), Latvijas Vēstnesis, 6th October 2006, No.160. (in Latvian).

18. Teritorijas plānošanas likums (Territorial Planning Law) (2002) Latvijas Vēstnesis, 12th June 2002, No.88. (in Latvian).

19. Valsts un ES atbalsts mežu ieaudzēšanai; Struktūrfondi (State and EU Support for Afforestation; Structural Funds) (2007) ZM, Available at: http://www.zm.gov.lv/?sadala=278, 20.03.2007 (in Latvian).

20. Vietējās pašvaldības teritorijas plānošanas noteikumi nr.883 (Local Municipality Territorial Planning Regulations No.883) (2004) Latvijas Vēstnesis, 3rd November 2004, No.174. (in Latvian).

21. Vispārīgie būvnoteikumi nr.112 (General Building Regulations No.112) (1997) Latvijas Vēstnesis, 4th April 1997, No.88. (in Latvian).

22. Žagare I. (2006) Meža zemes transformācijas tiesiskais regulējums (Forest Land Transformation Legal Regulation). Riga: LU Faculty of Law, Thesis, 53 p. (in Latvian).

USE OF SIMULATION METHOD FOR THE ANALYSIS OF WOOD RESOURCE FLOW

Jānis Ošs
Latvia University of Agriculture
E-mail: janis.oss@e-koks.lv

Abstract

The task of this paper is to create a simulation model of wood resource flow, enabling analysis of the flow of resources to the customer. The model consists of four modelling steps – the study of the system, the creation of conceptual and logical model, as well as data analysis. The model has been developed in UML (*Unified Modeling Language*) diagrams and the simulation model has been created using software EXTEND Industry. For the simulation of the model the scenario has been created. Based on this scenario, extended scenarios have been developed. Model of basic simulation represents the loading of resources into the transport, transportation, discharging from the transport and the return to the loading point. Using this basic scenario, the extended scenario has been created. This scenario analyzes the flow of wood resources to the customer, taking into account two criterions restricting the flows – assortment to be processed and the distance from the loading place to the customer's location. Extended scenario allows to analyze the load of each sector, as well as to follow each unit existent in the process of simulation. There are attributes of information (type, assortment etc.) added to the unit equivalent to $1m^3$ of wood resources. These attributes can provide information about the unit flow within any part of the process.

Keywords: Wood resources, modeling, simulation.

Introduction

Forests and wood resources in Latvia are one of the main national treasures of the country, created by a long-drawn and purposeful human action. These resources should be used effectively, taking into account principles of sustainable (inoverexploiting) forest management.

Forest sector combines forest resources and the production of forest goods, trade and consumption in a single system where elements are interrelated. It consists of forestry, timber industry, and chemical processing of wood non-wood products. Latvian forests are divided in two basic groups – state owned forests and others, consisting of forests owned by municipalities and private sector.

In order to obtain data about the load of wood resources market, as well as the types of final goods and wastes, it is necessary to analyze the resources, flow and the processing sector. There should be an ability to get as exhaustive information as possible on sectors within the flow while analyzing wood resource market, or the market in general, conflating all the sectors in a single flow.

By creating the model that represents the current situation, it is possible to obtain the most precise and complete information of wood resources flow. The main task of the model is to describe the flow of wood resources from the place of its extraction to the customer.

Using the model of wood resource flow, it is possible to get information on each object within the flow and its overall effect on the flow. Information about wood resource market can be used for all the sectors within the flow, as well as for the sectors indirectly connected with it. Participants of wood resource flow can use this model in order to plan loads and to analyze possible problems within the sector.

Materials and Methods

A model describing the system should be created for the analysis of wood resource flow. In the process of creating the model, potential idea is converted into detailed and specified form (Ballou, 2003; Law and Kelton, 2000). Process (see Figure 1) can be described in four steps:

- System (Environment to be examined)
- Conceptual model (conceptual interconnections of environment)
- Model of facts (logical interconnections of environment)
- Analysis of results

System - Forest and its resources fulfil economic, ecologic and social functions. Its source – the biomass (wood) is one of the main, although, not the only one. Wood resources and its flow to the customer is an environment to be observed
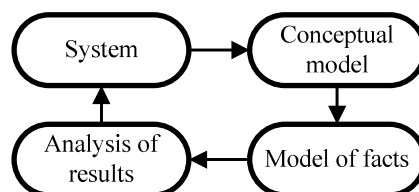
Figure 1. Process of modelling.

and analyzed. During the wood resource flow, movement of wood assortment from the place of acquisition to the customer is described. System consists of three main sectors:

- Resources;
- Transportation;
- Customer.

Each of these sectors can be examined separately, but the description of the flow can only be done jointly. The main sector of the system – the resources, is described with its geographical location, structure of assortment (saw logs, fine lumber, veneer blocks, pillars, pulpwood, and firewood) and the number. Data on the amount of logged wood starting from year 2000 can be obtained using information provided by forest owners and legal managers in reports on performance of economic activities in the forestlands during the year recorded in the State Forest register. If the information on economical activities performed during the last year is not provided, or officers of State Forest register have

doubts on the fairness of this information – it is audited by performing on-the-spot checks. There are cubic meters of liquid wood indicated in the amounts of logged wood. Available amount of wood resources each year is 11.5 million m^3 on average, where about 62% is an assortment of saw logs.

The sector of customers is very important (comprising processors of assortment and exporters). Customer is described by geographical location, species of wood to be processed, assortment and the capacity of processing. A conjunctive element of system is the transportation of resources. Transportation is described by carrying capacity of transport, the road network and restrictions of the transportation (Juslin and Hansen, 2003).

Conceptual model - each sector of wood resource flow can be regulated by many factors (see Figure 2). Factors regulating accessibility and the transportation of wood resources can be divided in two groups:
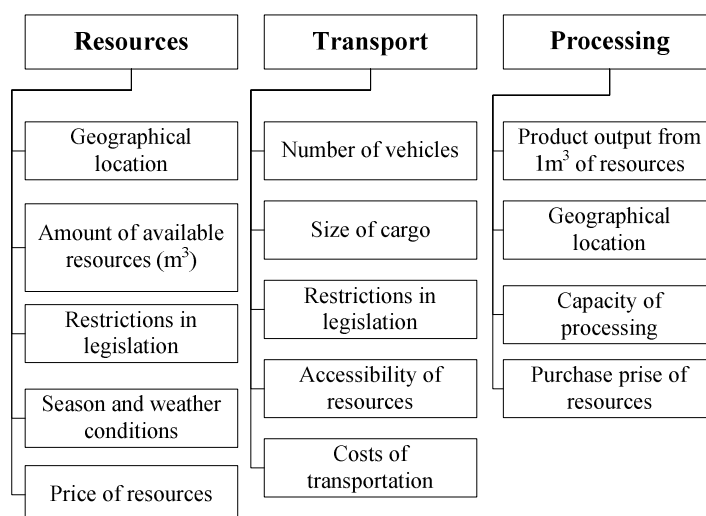
- Logical accessibility (regulated rate,

Figure 2. Flow regulating factors.

Purchasing of wood resources

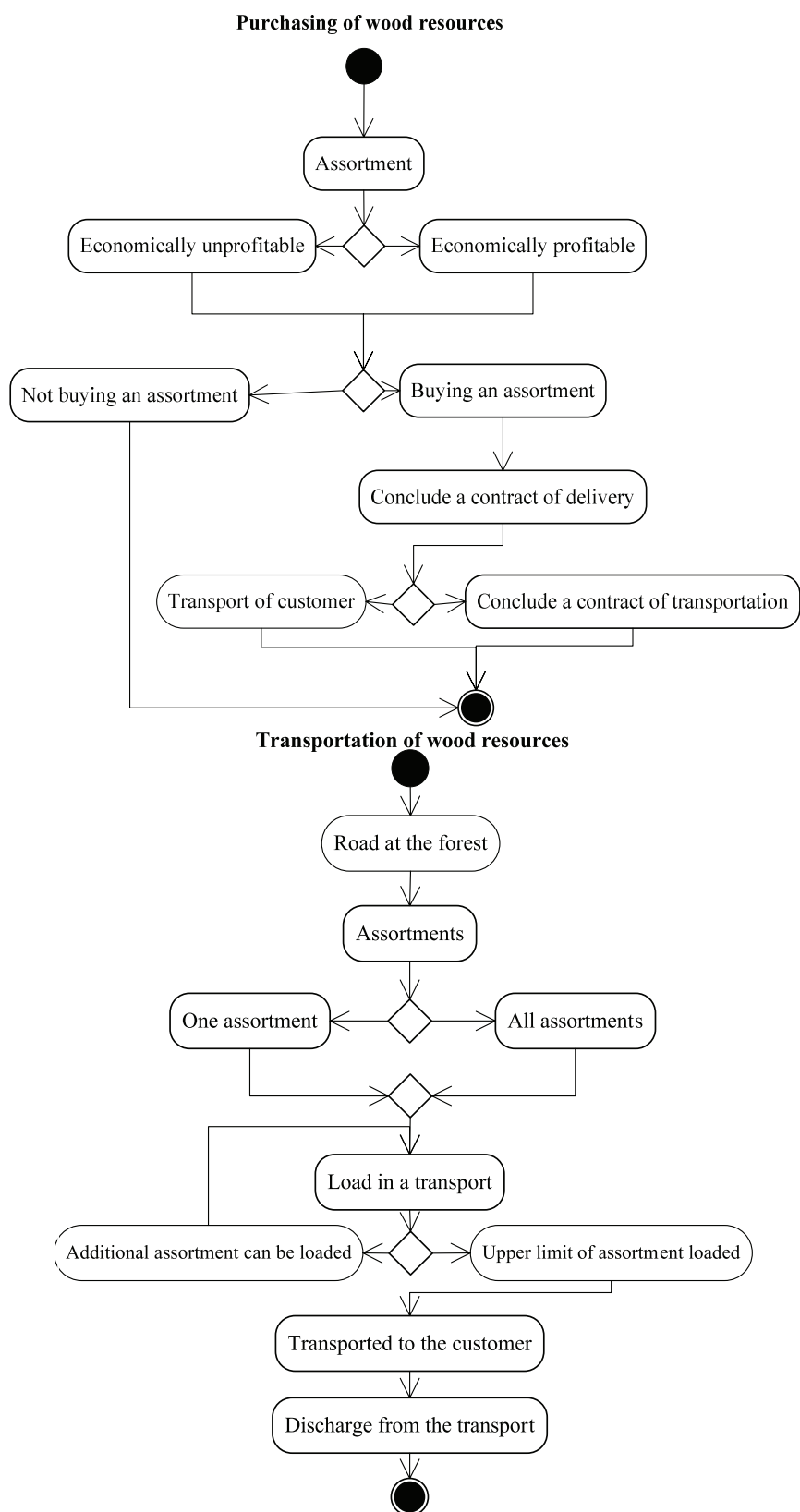**Transportation of wood resources**

Figure 3. Schemes of information (A) and resource (B) flow.

regulations of the Cabinet of Ministers and other laws and regulations);

- Physical accessibility (road conditions, sanitary conditions of forests, rotation of species etc.)

Altogether, there are two types of resource selling models – growing trees and round timber assortments. In case of producing and selling of round timber assortments, wood is directly delivered from the forest owner to the processor; therefore, an accessibility of assortments increases, as there are no intermediates buying all the round timber assortments at each felling of growing trees.

Model of facts - Wood resource flow starts with an evaluation of assortment offered and concluding with the contract of delivery. The process of the flow consists of two parts and the final result is the reception of assortment (Coyle, Bordi et al., 2003) (see Figure 3). The first process indicates buying but the second one – transportation of assortment.

Transportation of assortment is regulated by several factors: distance of transportation, duration of loading/discharging, amount to be transported (see Figure 4).

Duration of loading and discharging should be defined as a constant value, as there are too many factors not allowing to determine a precise mathematical formula to calculate the process. For the transportation of wood it is presumed, that wood resources are places on a roadside.

Time necessary to transport resources is stated in the following relation 1:

$$R = \frac{K \cdot (V_t + V_a)}{4L} \cdot T \qquad (1)$$

where:

R – resources transported (m^3 h^{-1});

K – cargo capacity (m^3);

V_t – average speed of going from place of acquisition of resources to the customer (km h^{-1});

V_a - average speed of getting from customer to the place of acquisition of resources (km h^{-1});

L – speed of driving;

T – number of means of transportation.

Duration of loading and discharging of wood resources depends on assortment, specification of the type of transport and standards set in the legislation.

Analysis of results – Software EXTEND Industry is used for the test of system modelling and simulations. For the creation of the model standard components are used. Based on methodology created by EXTEND, Discrete Event model is developed. In Discrete Event model additional attributes to each unit (value) can be added. Using data of attributes, the flow is created '(Diamond, 2002)' (see Figure 5).

In Discrete Even model attachment of data and their quantity is not cyclical. This feature allows one to enter values of any quantity in the model at any time. Model is created from units and they are connected to each other. Each unit has particular functions and tasks. Totality of all units represents three components of the model – resources, transportation and the order. Using components of database, prepared data from the database is downloaded in the model. This data reflects available resources. When data is flowing in the model, attributes are added. These attributes are used in organizing the flow (wood species, assortment). In the model 1 m^3 of wood resources one unit is represented that cannot be divided.

Results and Discussion

Model of wood resource flow can be used in order to create the flow scenarios and to test them with a simulation method. In its operation the simulation model wood resource
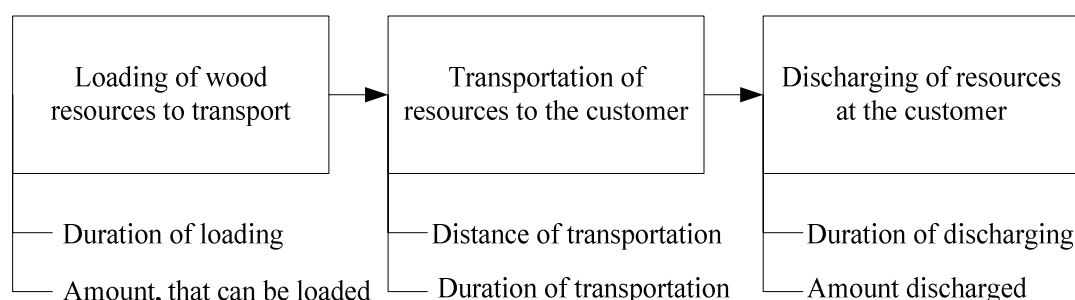

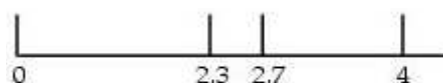Figure 4. Factors regulating resource transportation.

Figure 5. Discrete Event time curve.

flow is represented from the place of acquisition to the customer, comprising transportation of resources (see Figure 6).

Flow of resources is qualified by many criterions (Languna and Marklund 2004), as, for example, available and necessary assortment, or the purchase and the selling price. The model of wood resource flow does not give an answer to the question 'Why exactly is this product delivered to a certain customer?' because the answer is obvious – profit. But, when it is presumed that similar enterprises of pre-processing have an equal purchase price, then the uppermost factor of the flow is the distance of transportation. In case of ideal operation of the model – assortments would flow to the closest enterprises of pre-processing, working with the relevant assortment (matchwood – for the production of matches, veneer blocks – for the production of veneer etc.). The task of the model is to describe principles, how the resource flow operates and how it should operate.

Figure 7 represents principles of material flow model structure, describing the model as a black box having an input, an outlet, control and mechanisms to carry out activities. In the input of the model there is information about wood, describing its location, assortment and other things necessary for the operation of the model. Outlet of the model has information with an equal structural framework, but differing data. All the factors affecting flow contribute to the control mechanisms of the unit.

Units of the model (resources, transportation and processing) should provide the most extensive and precise information. Structure of the model is developed in a way so that it is possible to obtain information about each factor and its influence on the process of the flow within any unit of the flow.

Basically, the model is created taking into account the scenario that wood resources are transported to the customer. Transportation has a cyclical function – resources are loaded ->
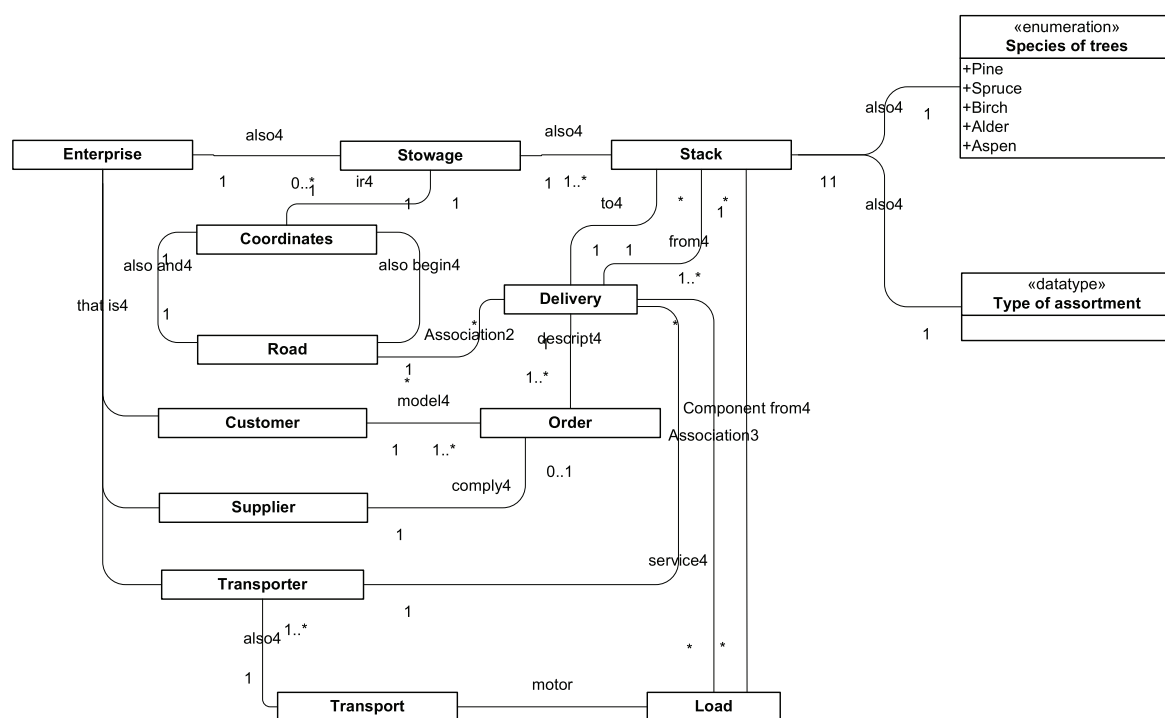

Figure 6. Semantic network of wood resource flow.
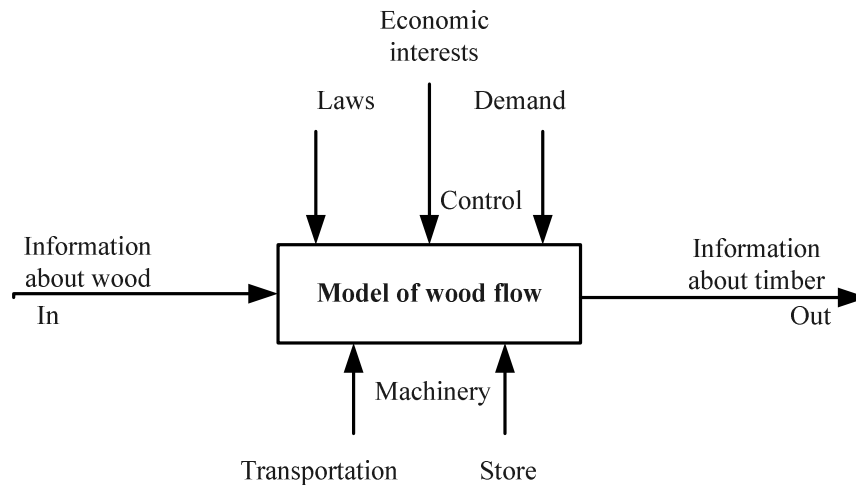
Figure 7. Structure of the wood resource flow model.

transported -> discharged -> returning to the point of loading. Cycle is repeated as long as all the resources are transferred to the customer. This basic model is used as a template for creating further scenarios. Scenarios for the system analysis are created adding criterions, restrictions and conditions to the template of the simulation model.

In one of the created models of simulation, the wood resource flow from the forest stack to the customer is analyzed by using the template of the basic model (see Figure 8) The scenario comprises two criterions: assortment can be received only by an enterprise processing it, and assortment is transported to the closest customer. The basic model function is to analyze the transfer of resources from the forest stack to the customer.

The simulation model consists of basic units of software EXTEND. Basic units (resources,

transport, and customer) use information from database, allowing to operate with the model dynamically and to supplement/change data anytime. During the simulation the first step is to identify a relevant customer for each assortment depending on assortment location. When potential customers are identified, road network is analyzed and the closest customer, receiving particular assortment, is found. The defined unit within the model is $1m^3$; therefore, information can be obtain on every cubic meter entered in the simulation flow. This opportunity allows to analyse each sector of the load, following the resource flow.

Conclusions

Model of wood resource flow reflects the flow from the place of acquisition to the customer. The flow consists of three sectors:
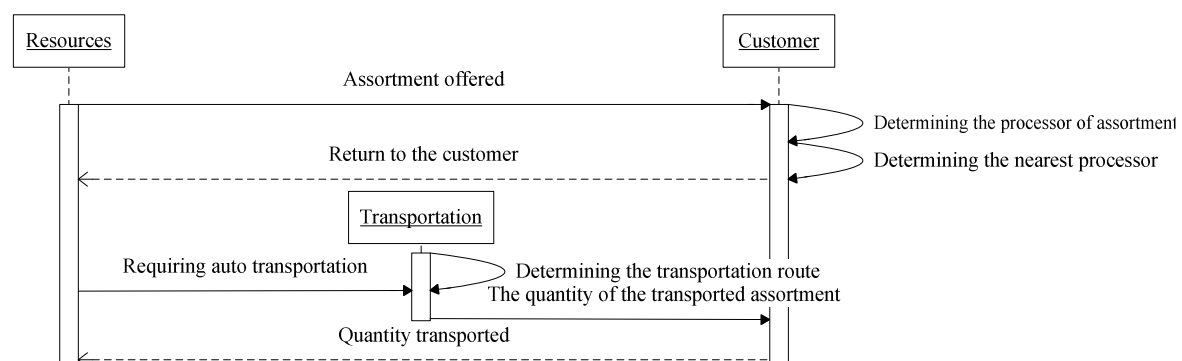
Figure 8. Cycle of wood resource flow.

- Seller of resources;
- Transporter of resources;
- Customer of resources.

The task of the model of the wood resource flow is to present a possible resource flow and its dependence on various factors.

The purchasing/selling price is the main factor of the flow. Resources are transported to the customer, offering the highest purchasing price in relation to the lowest costs of transportation. Distance of the transportation is one the factors, estimating where the resources are transferred to.

Each component of the flow has factors regulating and managing the flow – regulations and laws, roads, distances, etc.

In operation of the model, the most difficult thing is to comprehend that data of components are up to date and reflect the current situation. Statistical data reflects the results at the moment, when data is collected and entered into the system – data of this type can be used in order to test and analyze any of the specific scenarios.

The task of the model is to provide as complete information as possible on each component during its operation, for example, to view the load of each sector within the flow.

References

1. Diamond B. (2002) Extend v6. User Guide, Imagine That., USA 710 pp.
2. Coyle J., Bordi E., Langley C. (2003) The Management of Business Logistics: A Supply Chain Perspective, Transcontinental Lousiville, Quebec, Canada, 707 pp.
3. Juslin H., Hansen E. (2003) Strategic Marketing in the Global Forest Industries, EP Imaging Concepts, Shelton-Turnbull Solutions, USA, 610 pp.
4. Ballou H.R. (2003) Business Logistics/Supplu Chain Management, Prentice Hall College Div, USA, 789 pp.
5. Languna M., Marklund J. (2004) Business Process Modeling, Simulation and Design, Pearson Prentice Hall, USA, 429 pp.
6. Law A., Kelton D. (2000) Simulation Modeling and Analysis, McGraw-Hill, USA, 760 pp.

TEMPERATURE DISTRIBUTION IN WOOD FLOORINGS EXPOSED TO FIRE

Edgars Buksans

Latvia University of Agriculture

E-mail: edgars.buksans@e-koks.lv

Abstract

Wood construction elements are widely used in buildings and they can be used in construction elements such as roofs, floorings, windows and doors. As wood is combustible material, there are lot of fire regulations that should be fulfilled at the design stage of any building project. In Latvia, as in some other countries usage of wood in building constructions is limited. Wood materials are an ecologically friendly material and a renewable resource, and its usage should be promoted.

The paper presents an overview of heat distribution in wood floorings exposed to standard heat fluxes which is different compared to wood members exposed to high heat radiation.

Fire spread and self-ignition investigation on wood floorings is carried out in this research. The results show different kinds of the temperature distribution in the cross section of the wood member cross section depending on heat radiation and location of the temperature measurement point.

Temperature distributions in wood during fire can be completely different in dependence on heat radiation and cross section of the wood member. The wood materials in floorings do not reach the self-ignition temperature during standard heat radiation.

Keywords: wood, fire, heating, combustion, charring.

Introduction

It is well known that wood is a combustible material. Numerous experiments have been carried out in past to understand the wood burning process which is very important to predict the behaviour of wood construction in fire. Pyrolysis of porous char-forming solids, such as wood, exposed to fire is a very complex process. Figure 1 illustrates the major physical and chemical phenomena involved in the pyrolysis of an exposed slab of wood. Under practical conditions of use, wood products always contain a certain percentage of moisture. When exposed to fire, the temperature of the wood will rise to a point when the moisture starts to evaporate. Since the water is adsorbed to the cell walls (at least if the moisture content is below the fiber saturation point, which is approximately 30% by mass), evaporation requires more energy than needed to boil free water and may occur at temperatures exceeding 100 °C. The water vapor partly migrates toward, and escapes through, the exposed surface. A fraction also migrates in the opposite direction, and re-condenses at a location where the temperature is below 100 °C (Konig, 2006; Janssens, 2004).

The dry wood (zone 3) further increases in temperature until the fibers begin to degrade. The thermal degradation starts at around 200–250 °C.

In other literature sources it is mentioned that thermal degradation of wood starts at about 170 °C. The volatiles that are generated again travel primarily toward the exposed side, but also partly in the opposite direction. They consist of a combustible mixture of gases, vapors, and tars. A solid carbon char matrix remains. The volume of the char is smaller than the original volume of the wood. This results in the formation of cracks and fissures which greatly affect the heat and mass transfer between the flame and the solid. The combustible volatiles that emerge from the exposed surface mix with ambient air and burn in a luminous flame Janssens (2004).

Wood self-ignition temperatures have been investigated since 1887. Babrauskas has shown that wood self-ignition temperature varies from 204 to 530 °C depending on the heat flux radiation (Babrauskas, 2001; Babrauskas, 2003). Self-ignition time of wood has been investigated in different heat fluxes. A lower heat radiation means a lower temperature and longer time till ignition, but a higher heat radiation means higher temperatures and faster self-ignition of wood Tran and White (1992).

That is the reason why investigations on wood heating process are so significant to predict the behaviour of the wood construction in real fire.

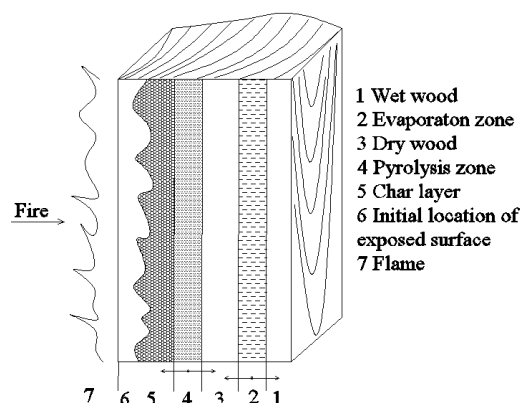Although wood products are classified as

Figure 1. Burning process of wood slab.

combustible materials, a properly designed timber structure has been recognized as performing very well in fire. The reason for it is formation of the char layer on the burning wood member. A thicker char layer means a worse heat transfer in wood member and a longer durability in fire. Also timber cross section dimension is a matter of great importance. Larger dimensions mean higher durability of wood construction in fire. White (2000) has investigated the durability of wood construction in fire. The fire performance of timber is dependent on the charring rate and the loss in strength and modulus of elasticity. The charring rate is more or less constant and depends on the density and moisture content of the wood and heat exposure.

The charring rate of wood has been investigated by a lot of researchers in past and some of the results are described by Schaffer (1967), Hakkarainen et al. (2005), Hietaniemi (2005), Hugi et al. (2007) and White (2000) as well as in the 'Encyclopedia of Materials: science and technology' (2001). Most of all research projects have been done in very high heat fluxes of up to 100 kW m^{-2} and in real fire. The wood charring rate is a very important factor of the behaviour of wood member in fire. Charring rate of wood is dependent on different factors such as wood moisture content, density, heat radiation, dimensions of specimen, grain orientation, and others. In different research projects, wood charring rate has varied from 0.5 to 2 mm min^{-1} Schaffer (1967), Hakkarainen et al. (2005), Hietaniemi (2005), Hugi et al. (2007) and White (2000). The standardized value of charring rate is 0.5-1 mm min^{-1} (European design standards EN 1995-1; 2). The temperature of burning wood surface also is different in low and high heat

radiation. Urbas and Parker (1993) have done an experiment on temperature measurements in wood specimens in different heat fluxes. There were about 600 °C surface temperature at 20 kW m^{-2} and about 800 °C in heat fluxes 35, 65 and 80 kW m^{-2}. It is not known what the temperature of wood top surface in low heat radiation is, but it is clear that there can be a big difference of wood behaviour in high heat fluxes.

Rezka and Torero (2006) have investigated the temperature distribution in wood specimens in high heat radiations and included the data into the model of wood burning process. There were different results obtained from temperature measurements in different depth in a wood specimen and it is clear that there is a very big difference between the top surface temperature and the core temperature. Rezka has mentioned that the heating rate of wood in high heat fluxes is different from the heating rate of wood in low heat fluxes. There are some wood burning models developed and lots of research done in wood heating investigations in high temperature radiations.

It is difficult to find the information about the temperature distribution in wood member exposed to low heat radiation for wood products such as floorings. And the main task of this research is to find out the temperature distribution in wood members exposed to low heat radiations. Other aims are to evaluate self-ignition possibilities of wood floorings and fire spread on it.

Materials and Methods

The experiment was carried out in March 2006 in the fire testing laboratory of Forest and wood products research and development institute.

The basic test material was sampled randomly from pine *(Pinus Sylvestris)* sawn timber with cross section dimensions 230x45 mm with initial moisture content 12 – 16%. Five specimens were selected for the experiment.

Sawn timbers were calibrated to constant thickness and were cut in 1050 mm length. The specimens were conditioned in a constant climate (20 °C temperature and 65% relative humidity) for one week.

Each specimen was divided in seven sectors starting at 110 mm distance from FRP (flooring radiant panel) corner with a step of 100 mm. Five holes for thermocouples in different depth were drilled in each sector line (5, 10, 20, 30 and 40 mm from a top surface of the specimen) (see Figure 2).

The moisture content of each board was measured in accordance with standard EN 13183-2:2003 method and the wood moisture content varied from 12 to 16%.

There were 35 thermocouples inserted in each specimen for temperature measurement in different board cross section sectors.

All FRP settings were set up in accordance with standard EN ISO 9239-1:2002, excluding one deviation from the standard. The propane mass flow was increased to reach a little higher heat radiation on a top surface of the specimen. This deviation from the standard method was done with the aim to get a wider temperature range distribution in the specimen.

The test equipment was calibrated before the experiments, and the measurement values are shown in Figure 3.

The maximal heat flux was at temperature 255 °C at thermocouples position line 110 mm from FRP corner and the lowest heat flux was 1.98 kW m^{-2} at temperature 93 °C at thermocouples position line 710 mm.

The duration of each experiment was about 4800 s. The specimen was ignited at the 2600s by inserting a pilot burner and the surface of the specimen started to burn with a flame. The experiments were stopped at about 4800 s when the temperature in wood started to decrease.

Descriptive statistic and regression analyses were used for data statistical analyses.

Results and Discussion

Five specimens were tested at different heat fluxes and temperatures. The first specimen was ignited by a pilot burner at 1500 s from the beginning of the experiment, but all other specimens were ignited at 2500 s. The experiment can be divided into two stages:

1. specimen heating up by constant heat radiation;
2. specimen heating up by heat radiation during burning process of the specimen surface.

A wood specimen heats up very slowly at different speed, which depends on the heat radiation. Temperatures were measured in one cross section at five different depths from a top surface of the specimen. The temperature difference in the specimen cross section is shown in Figure 4 where non-linear regression analysis is done and equation (1) is expressed as a power function at the top layer of wood at a 5 mm depth and exponential function equation (2) for the temperature calculation at the depth of 30 mm from the top surface of the specimen. Both equations have significant determination coefficients - 0.9629 and 0.9483:

$$T1 = 8.3436 \cdot x^{0.3598} \tag{1}$$

$$T2 = 25.183 \cdot e^{0.0003x} \tag{2}$$

where

$T1$ - wood temperature trend line at a 5 mm depth;
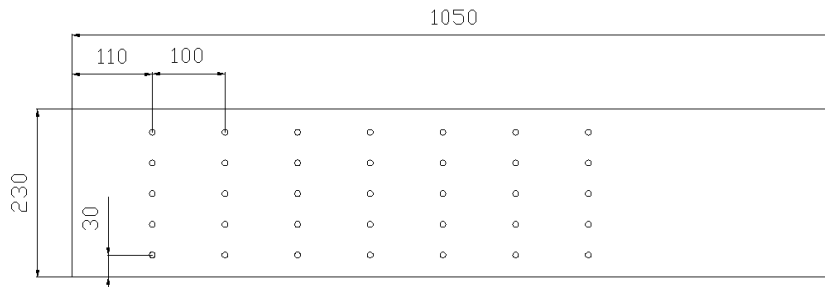
Figure 2. Placement of thermocouples in a specimen.
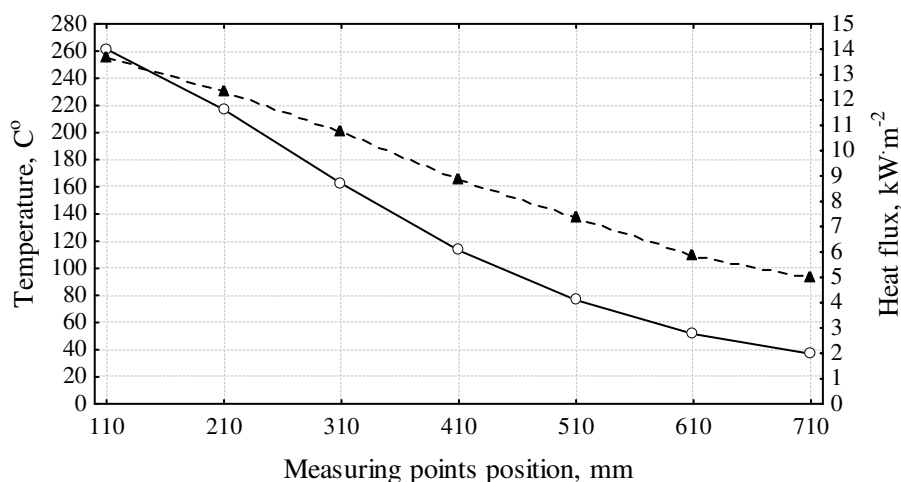
Figure 3. Temperature and heat flux distribution on a specimen surface: ▲ - temperature, ○ - heat flux.

$T2$ - wood temperature trend line at a 30 mm depth.

There were a different situation at the second stage of the experiment, when a specimen ignited by a pilot burner and a top surface of the specimen flashed with flames. The wood specimen starts to heat up much faster and the heat-up function is more linear (see Figure 5 and equations 3 to 5). Top layers of the wood specimen heats up faster that is shown by a trend line equation directional coefficients – 0.082 at a 40 mm depth and 0.529 at a 5 mm depth. A relative time function used for calculations by setting time to zero from the

moment of the specimen ignition was:

$$T1 = 46.5984 + 0.0821 \cdot x \qquad (3)$$

$$T2 = 114.5497 + 0.2626 \cdot x \qquad (4)$$

$$T3 = 158.1642 + 05321 \cdot x \qquad (5)$$

where
$T1$ – wood temperature trend line at a 40 mm depth;
$T2$ - wood temperature trend line at a 10 mm depth;
$T3$ - wood temperature trend line at a 5 mm depth.

The temperature distribution in a wood specimen during all experiments is shown in
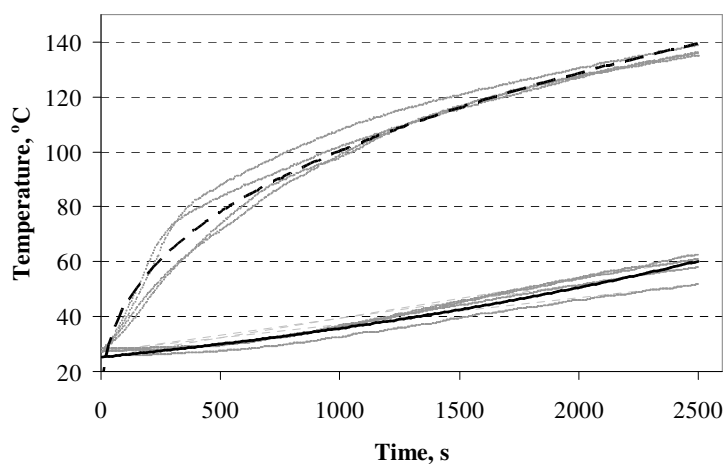
Figure 4. Wood heating up trend at a 5 mm and 30 mm depth from the top surface exposed to the 14 kW
m^{-2} heat flux:
- - - - 5 mm depth, — 30 mm depth.
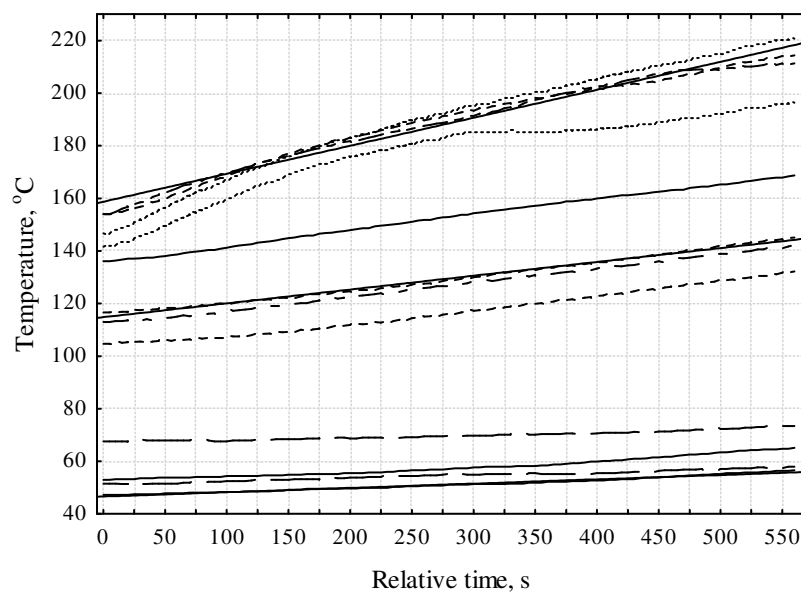
Figure 5. Wood heating up trend at a 40, 10 and 5 mm depth to the 14 kW m^{-2} heat flux after specimen ignition.

Figure 6. The top temperature curve is at 110 mm distance from FRP corner and the lowest curve is at 710 mm from FRP corner. The wood temperature is dependent on the heat radiation on a specimen surface, and this difference is very significant. There is also a very big difference between the temperature measurements at a 5 mm

depth from the top surface and at a 40 mm depth. The temperature in a wood member cross section differs more than three times comparing the top surface to the bottom surface.

During the experiment, the specimen did not ignite itself and at 2500 s was ignited by a pilot burner. The fire spread on pine wood floorings
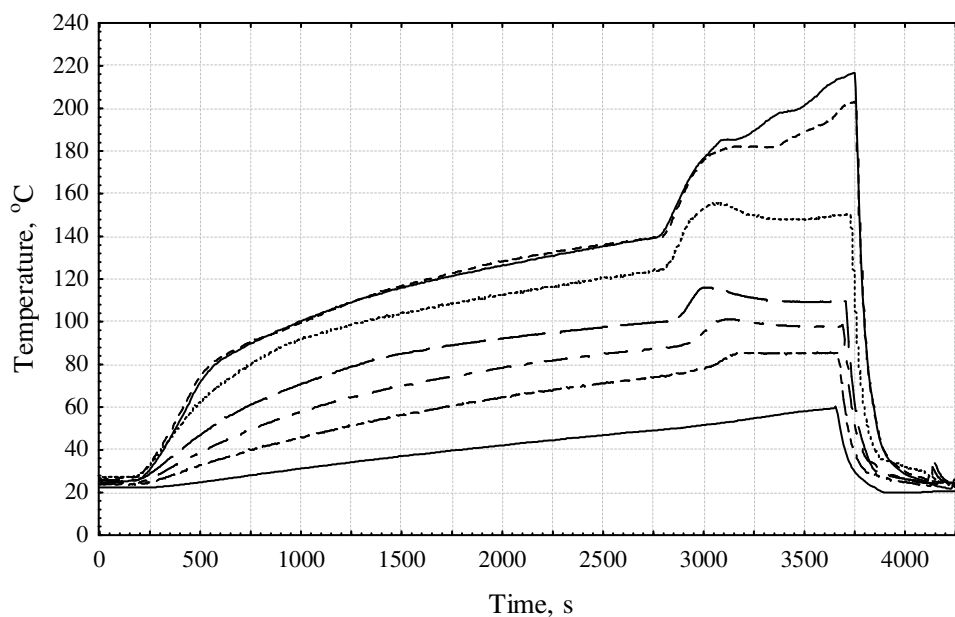
Figure 6. Temperature distributions in a wood specimen at a 5 mm depth from the top surface during the experiment in 7 different heat fluxes.
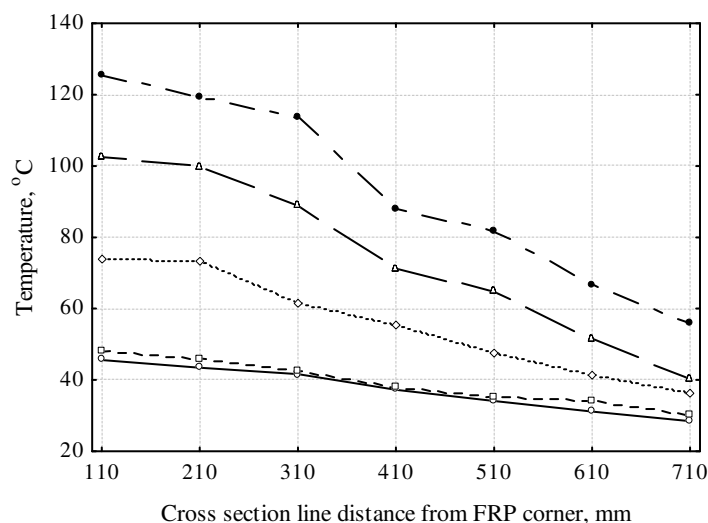
Figure 7. Temperature distributions in 7 cross sections of a specimen at different depth at 2000th s from the beginning of the experiment.

was about 700 mm. The fire spread would have been less if the specimen had been tested in accordance with the standard, because the pilot burner should be activated at the beginning of the test when the wood specimen is comparably cool. The temperature profile in the wood member cross section at one time moment is shown in Figure 7. If the wood is exposed to higher heat radiations, then temperature distribution is wider. In lower heat fluxes temperature distribution in the wood cross section is smaller. The heat flux values and temperatures are shown in Figure 3.

up process of wood is much slower than of wood construction elements used in walls and roofs. There is still a significant difference in temperature distribution in wood member cross section. During the 4000 s from the beginning of the experiment, the inside temperature of the specimen did not reach the self-ignition temperature, which means that wood floorings are not the critical construction elements in buildings. The temperature distribution curves in wood are completely different in dependence on the heat radiation and the cross section of the wood member.

Conclusions

As floorings get a comparably small heat radiation of up to 14 kW m^{-2}, the heating

References

1. Babrauskas V. (2001) Ignition of wood: A review of the state of the art, Interflam 2001, Interscience communications Ltd., pp. 71-88.
2. Babrauskas V. (2003) Ignition Handbook, Fire science publishers, Issaquah WA 98027, USA, 1116 p.
3. Encyclopedia of Materials: Science and technology, Wood products: Thermal degradation and Fire, (2001) Elsevier Science Ltd, pp. 9712-9716.
4. Hakkarainen T., Mikkola E., Östman B., Tsantaridis L., Brumer H., Piispanen P. (2005) State-of-the-art, InnoFireWood, 47 p. Available at: http://virtual.vtt.fi/virtual/innofirewood/stateoftheart/ifw-stateoftheart.pdf, 04.08.2006.
5. Hietaniemi J. (2005) A probabilistic approach to wood charring rate, VTT working papers 31 published by VTT information service, 53 p. Available at: http://www.vtt.fi/inf/pdf/workingpapers/2005/W31.pdf, 15.01.2007.
6. Hugi E., Wuerch M., Risi W., Wakili K. (2007) Correlation between charring rate and oxygen permeability for 12 different wood species, Journal of wood science, 57, pp. 71-75.
7. Janssens M. (2004) Modeling of the thermal degradation of structural wood members exposed to fire, Fire and Materials, 28, pp. 199-207.

8. Konig J. (2006) Effective thermal actions and thermal properties of timber members in natural fires, Fire and Materials, 30, pp. 51-63.
9. Rezka P., Torero J. (2006) In-depth temperature measurements of timber in fires, Proceedings of the 4th international workshop Structures in fire, pp. 921-930. Available at: https://www.era.lib.ed.ac.uk/bitstream/1842/1509/1/SIF2006.pdf, 15.01.2007.
10. Schaffer E. (1967) Charring rate of selected woods – transverse to grain, U.S. Forest service research paper FPL 69, published by U.S. department of agriculture Forest service, 22 p. Available at: http://www.fpl.fs.fed.us/documnts/fplrp/fplrp069.pdf, 15.01.2007.
11. Tran H., White R. (1992) Burning rate of solid wood measured in heat release rate calorimeter, Fire and materials, 16, pp. 197-206.
12. Urbas J., Parker W. (1993) Surface temperature measurements on burning wood specimens in the cone calorimeter and the effect of grain orientation, Fire and Materials, 17, pp. 205-208.
13. White R. (2000) Charring rate of composite timber products, The proceedings of Wood and fire safety 2000 (part one), pp. 353-363. Available at: http://www.fpl.fs.fed.us/documnts/pdf2000/white00b.pdf, 15.01.2007.

PRODUCTIVITY OF GREY ALDER (*ALNUS INCANA* (L.) MOENCH) STANDS

Olga Miezīte, Andrejs Dreimanis
Latvia University of Agriculture
E-mail: olga.miezite@llu.lv, Andrejs.Dreimanis@llu.lv

Abstract

Area of grey alder stands is 190.6 thousand ha that is 6.8% of the total area of forests in Latvia with average volume 31.3 million m^3 4.9% of total yield is in the state forests, but 95.1% in the forests of other managers. Scientific literature affirms that grey alder is easy growing trees species. Its stands are quick - growing and wood has high heating capacity. Empirical data in 1 - 10 years old stands are collected from 25 m^2 sample plots, 15 in each stand. Data from older (11 - 30 years) stands are obtained by 6 - trees - sample - plot method, from 180 trees in each stand. Number of trees (y) in the stands diminishes with age (x) that is characterized by regression equation $y = 72534x^{-1.1488}$. The division of the number of trees in diameter classes characterizes distribution of trees diameters in stands and trees differentiation processes within the stands. At the age of 1 - 5 years, grey alder stems were in diameter classes under 2 cm but at the age 6 - 10 years - 2 and 4 cm. In 11 - 15 years old stands 89% of all the measured trees are included in four (4 - 10 cm) diameter classes. It pointed to growing differentiation of diameters of the trees. Starting from age 16 - 20 years, 76 - 89% of the trees were of four to five diameter classes (10 - 18 cm). The average standing volume in 11 and 15 year old stands was 110 m^3 ha^{-1} and it increased step by step to 180 m^3 ha^{-1} in the stands of age 26 - 30 years. The basal area in the age of 15 - 30 years varied between 20 - 26 m^2 ha^{-1}. The average diameter reached 15 cm in stands of 25 - 30 years.

Keywords: stand density, diameter, height, stem volume, stand basal area, yield.

Introduction

Grey alder historically has been considered as a 'forest weed' for a long period. It was paid not enough attention. Recently, more and more clear-cut areas are left for natural regeneration in Latvia. Grey alder occupies these areas very often. Therefore it is important to analyze regeneration processes of grey alder in clear - cut areas, evaluate different features of these stands, including productivity and aboveground biomass. We have to consider the use of grey alder in energy wood plantations, as well as utilization of its wood for boxes and furniture production.

White burning the wood, carbon dioxide is exhausted in the atmosphere in the same amount as the tree has been assimilating during its life span. It means that using wood for heating will do less harm to environment compared to fossil fuel. Ashes of wood can be used for soil fertilizing. During the last decade, demand for firewood is increasing.

Grey alder can grow in clay, loam, sand and silt soils. In fertile soils first productivity class stands trees can reach up to 25 m height and 30 cm diameter (Mūrnieks, 1950). Grey alder needs light, it does not stand shadow. At the same time it can well tolerate spring and autumn frosts and winter cold.

Grey alder can be considered as an easy - growing species because artiodactyls do not harm it in contrast to coniferous trees, asp and ash, that can be heavily browsed and destroyed. Generally, grey alder does not have dangerous pests and illnesses but it suffers from grey alder leaf - beetle *Agelastica alni* L. in years, when population density of this insect is high (Lange et al., 1978). There are also grey alder leaf-beetle *Melasoma aenea* L., grey alder curculio *Cryptorrhynchus lapathi* L., as well as other species which larva damage leaves or wood during supplementary feeding or hibernation (Plīse and Bičevskis, 2001). First signs of rot show off in the stems of grey alder just at the age of 21 - 30 years. Cutting grey alder at the age of 25 years, we can get timber of high quality almost without any decay. In mineral soils, there are more rot infected trees as in peat soils (Pīrāgs, 1962). In Voronez district, 60 - 80% of grey alder at age 50 - 60 years have rot caused by fungus *Fomes igniarius f. alni* Bond. mainly in the middle and foot of the stem destroying cellulose and lignin (Vaņins, 1956). Fungus *Taphrina epiphylla* (Sadeb) Sacc. can cause disease for the branches of grey alder (Vimba, 2005).

Grey alder has remarkable propagation abilities, especially by stems and root sprouts. Light seeds of grey alder are produced each year

and wind disseminates them beyond borders of forest (Mūrnieks, 1950). Adjacent areas of grey alder stands are sown up to 50 meters from the borders, but wind can bring seeds even 100 - 150 meters far. Grey alder regenerates by roots sprouts very successfully. To get strong sprouts, grey alder, alike other species of deciduous trees, has to be cut in late autumn or winter when nutrients from aboveground part of the trees have moved to roots (Mangalis, 2004).

Grey alder is one of fast growing species because its reaches culmination of annual increment very early. Productivity class indicates potential fertility of soil in definite conditions. Productivity of the stand is characterized by stand yield per unit of area and time. Average increase of main yield of the stand culminates at age 16 - 18 years and then decreases stepwise. Stands of first productivity class have the highest average annual increment: 11.5 m^3 but to those of second productivity class - 9.0 m^3, and to those of third - 6.5 m^3 per a hectare in a year. Grey alder exceed other species of trees as wood producer. The most advantageous cutting age of grey alder is 17 - 20 years. The density of the cutting age stands is approximately 7 - 8 and volume - about 135 m^3 ha^{-1} (Mūrnieks, 1950).

Ozols and Hibners (1923) have pointed out that the cutting age of grey alder at riverhead of Lielupe is 15 years (Brants, 1929). In comparison with the other tree species, the short cycle of grey alder stands allows to obtain 2.5 - 3 times more wood from the same area during 100 years (Katkevičs and Lukašunas, 1986).

In few compartments experimental thinning has been done, when average height of trees in stand were 2 - 4 m, reducing stand density up to 1.5 - 2.0 thousand trees ha^{-1}. The result was excellent increase of increment (Zālītis, 2005).

In the light of developing usage of renewable resources in the energetic, mainly in heating, grey alder is considered as prospective trees species for burning trees biomass production. Growing grey alder for energy - wood is included in the forest energetic programs of Sweden and Austria (Daugavietis, 2006).

Successful regeneration, especially by sprouts, fast and rich wood production ability have given a motivation to form a typical group of coppice in some regions of Latvia, especially in those with sparse forest cover.

Grey alder covers 190.6 thousand ha or 6.8% of all forest area of Latvia, with total yields 31.3 million m^3 where 4.9% of total yield of grey alder stands are owned by the state and 95.1% - by the

other managers (Valsts Meža dienests, 2006).

Mass heating capacity for pine is 20.59 MJ kg^{-1}, for spruce - 20.31 MJ kg^{-1}, for grey alder - 20.05 MJ kg^{-1} (Dolacis and Hrols, 1999). Judging by the heating capacity, wood of grey alder is worthy to be utilized as firewood and it could be used not only in stoves of individual houses but also in suitable central heating boilers of flat blocks. Production of woodchips is the most prospective variant of grey alder stands usage.

Naturally grey alder has short life and at the age of 30 it stops to give good increment. We can get 180 - 310 m^3 ha^{-1} of wood from a 30 years old stand in good growing conditions. This wood has high enough heating capacity. Considering the high productivity of grey alder stands, their wood heating capacity and diminished amount of hazardous emissions, grey alder has perspective in firewood production. In order to be able to make economic calculations about utilization of grey alder woodchips for heating, we have to evaluate productivity of stands of these species. The most significant work about grey alder productivity has been made half a century ago by Mūrnieks (1963).

In current investigation study of structure of grey alder stands are made, which is the aspect not included in the analysis by Mūrnieks, 1963.

The aim of the research: estimate productivity of the stands of grey alder *Alnus incana* (L.) Moench. at different age.

The tasks of the research:

1. to study structure of grey alder stands:

   - to analyze the pattern of changes of number of trees in stands of grey alder;
   - to obtain information on division of the trees in diameter classes;

2. to analyze indices of inventory of grey alder stands.

Materials and Methods

Forty - seven grey alder stands of different age classes, productivity classes and density are used to study the number of trees, different tree parameters and stand productivity in Jelgava, Bauska, Ogre, Aizkraukle, Jekabpils and Valmiera regions. Unthinned stands, usually coppice, are selected for the research. The obtained data are grouped by age classes with an interval - five years (Table 1). Data of the research at the stands of I and II age classes (1 - 10 years old) are obtained by dividing them into 15 round or rectangular sample plots with area of 25 m^2. They are located diagonally or in transactions. The measured trees

Number of the researched stands by age class

Age class	I	II	III	IV	V	VI
Age (years)	1 - 5	6 - 10	11 - 15	16 - 20	21 - 25	26 - 30
Number of stands	3	4	11	13	7	9

are grouped by diameter classes of 2 cm. Trees with breast - high diameter up to 0.9 cm are included in nil diameter class. Heights of 15 - 20 trees are measured for calculation of the height curve of the stand.

Grey alder stands at age 11 - 30 years (age classes III - IV) are investigated using 6 - trees - sample plot method (Kramer and Akča, 1982). In each stand, 30 sample plots by 6 trees are arranged, so in total 180 trees are measured. The sample plots are arranged in even distance by the systematic principle, using transects by H.Kramer and A.Akča method (1982) (Fig. 1). In each sample plot, distance from its center to the middle of its nearest sixth tree is set, diameters and height of six trees are measured and their Kraft class is determined. First three Kraft classes are the dominant stand but the other two - suppressed stand (Skudra and Dreimanis, 1993).

For calculation of the number of trees per ha the following formulas have been used:

$$L_6 = 0.785 \cdot (2 \cdot R_6)^2 \qquad (1)$$

$$N_n = \frac{5.5 \cdot 10000}{L_6} \qquad (2)$$

$$Nvid. = \frac{\sum\limits_1^n N_n}{n} \qquad (3)$$

Where L_6 - area of the sample plot, m^2; R_6 - radius of the sample plot to the centre of the nearest sixth tree, m; N_n- number of trees per ha; $Nvid.$ - average number of trees per ha; n - number of the sample plots.

Inventory indices of grey alder are calculated using forest inventory methods as described in publications by Liepa, 1996, Sarma, 1949 and Kramer and Akča, 1982.

For data analysis (descriptive statistics, Hi - square, correlation) MS EXCEL is used. Distribution of the number of trees into diameter classes and their correspondence to normal distribution is tested by Hi - square method (Liepa, 1974; Arhipova and Bāliņa, 2003).

Results and Discussion

Structure of grey alder stands

The horizontal structure of the stands is characterized by a number of trees per hectare. It depends on age, stand density and on distribution of the trees in the stands. Information on distribution of the trees into diameter classes in different age classes is obtained and analyzed.

Vertical structure of grey alder stands characterizes the level of differentiation of the trees in stand at different ages that can be expressed as the number of dominant versus suppressed trees.

Number of trees in the grey alder stands

High number of trees haves been found in grey alder stands, that has an influence on tree crowns, in particular to their assimilation surface
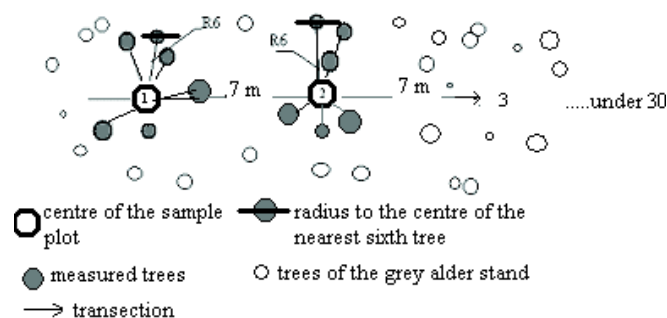

Figure 1. Six- trees- sample- plot method used in inventory of grey alder stands (Kramer and Akča, 1982).

through that also to wood increment of each particular tree. From the view of wood gathering, stands with fewer, bigger dimension trees are more advantageous than stands with large number of small trees. Solitary trees differ from trees growing in closed stands by their appearance and also biologically. Trees growing in stands are influenced by interactions and dependences that cause differentiation and other dynamic processes. The greatest variation of the trees is observed in each stand of grey alder: by height, diameter forms of crowns, their width, length and by quality of stems. Great differentiation of the trees is found: in the grey alder stands, some trees are developed very well but others are left behind, remaining small and form suppressed stand. In the stands of grey alder of III age class (11 - 15 years old), 15% of trees are suppressed, in stands of IV age class (16 - 20 years old) – 15%, in stands of V age class (21 - 25 years old) - 18% and in the stands of the VI age class (26 - 30 years old) - 16%.

In the grey alder stands at the age of 1 - 5 years, number of trees varies from 5240 to 21520 with average number 18480; at the age between 6 and 10 years - from 7120 to 10720 with average number 8680; at the age of 11 - 15 years - from 2130 to 6600 with average number 4270; between 16 and 20 years - from 1720 to 6200 with average number 2960; at the age of 21 - 25 years - from 1280 to 2180 with average number 1690 and between 26 - 30 years - from 910 to 2200 with average number 1510 (Fig. 2).

Distribution of trees in area is uneven also within one stand. It can be seen by coefficient of variation of the number of trees per plot, ranging from 5 - 64.5%. It means that places of high density are present in a stand and will have an influence on every individual tree and stand characteristics (parameters). The number of trees varies the most in new stands. With ageing of the stand, value of the coefficient of variation stabilizes. The analysis of a number

of trees reveals, that using 6 - trees - sample - plot method representation error is - ± 122...2590 trees per hectare but the corresponding standard deviation - ± 481...4487. J.Ozols and E.Hibners (1923) and P.Mūrnieks (1963), have investigated a number of trees in grey alder stands in Latvia. Compared to tables by P.Mūrnieks, it was stated that the number of trees in first four age classes (1 – 20 years) is the closest to 2nd productivity class but those of age classes between 21 and 30 years - to 1st productivity class.

About 6.7% of the inspected trees up to the age of 30 have stem rot up to 1 meter height. The obtained data confirm the research by Dz.Pīrāgs, (1962) that it is possible to get an absolutely healthy grey alder wood until the age of 25 years.

The number of the trees (y) in grey alder stands minimizes with age (x). It can be described by the regression equation $y = 72534x^{-1.1488}$ (Fig. 3.).

For wood harvesting, stands with fewer trees and greater dimensions are more advantageous. In the researched stands, it was stated that in the stands of age of 13 - 18 years, the number of trees varied in interval 2 to 7 thousand trees per hectare.

Distribution of the number of trees by diameter classes

One of the most important stand characteristics is the distribution of trees in diameter classes. From this information conclusions about differentiation processes in stand can be drawn. A great number of diameter classes indicate heavy differentiation of trees and uneven allocation of trees within the stand when one part of the trees has insufficient access to resources for growth while the other - use them in full amount.

Dealing with the stands of first and second age classes (1 - 10 years), we cannot speak of correspondence of distribution to normal distribution by diameter classes because most of the trees are included in two diameter classes
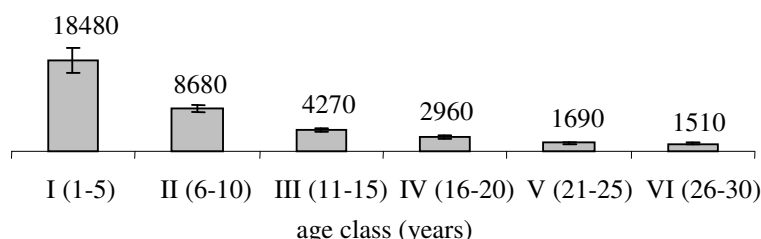
Figure 2. Average number of trees in grey alder stands in different age classes.
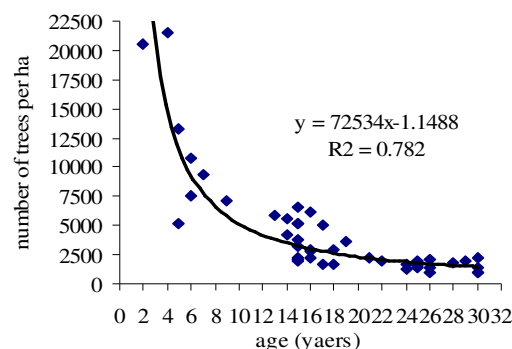
Figure 3. Changes in number of grey alder trees depending on age ($p < 0.05$).

with similar number of observations. In the rest of surveyed stands of different age classes, conformity to the normal distribution is seen not in all cases, in spite of small graphic differences between empirical and theoretical distribution. In age classes 4 – 6 (16 - 30 years) stands, after grouping all trees of one age class in one sample set, we have found that the diameter distribution of trees does not correspond to the normal distribution. The calculated value of Hi - square is more than the theoretical (level of significance $\alpha = 0.05$). Left asymmetry of the distribution of number of trees is observed in the fifth and sixth age classes (age 21 - 30 years). High number of thin trees in the stand can be explained by differentiation (as a result of competition among trees for resources) and lack of thinnings.

In 11 - 15 years old stands 89% of all the measured trees are included in four (4 - 10 cm) diameter classes. In 16 - 20 years old stands 89% of the trees are in diameter classes 6 - 12 cm, but in 21-25 years old stands - 76% of the trees compound four (10 - 16 cm) diameter classes. Similar division of the trees diameter classes is stated in 26 - 30 years old stands where 79% of the trees are in five (10 - 18 cm) diameter classes. Percentage of the number of trees in different diameter classes is shown in Table 2.

It is stated that the number of trees with diameter 22 cm and larger is a little bit over 3% in the stands of fifth and sixth age class. With ageing

Table 2

Distribution of the trees (%) in diameter classes depending on the age of the stand

Diameter class, cm	Age class interval, years					
	1 - 5	6 - 10	11 - 15	16 - 20	21 - 25	26 - 30
0	45.1	0.4	0.2	-	-	-
2	42.3	49.2	5.5	0.2	-	-
4	9.1	43.6	18.5	5.5	0.2	0.2
6	3.5	6.3	31.5	18.5	2.4	0.7
8	-	0.5	26.6	31.5	8.2	5.6
10	-	-	12.0	26.6	19.8	10.4
12	-	-	3.9	12.0	20.6	18.0
14	-	-	1.3	3.9	22.5	20.6
16	-	-	0.4	1.3	13.3	16.3
18	-	-	0.1	0.4	8.0	13.5
20	-	-	-	0.1	3.4	8.5
22	-	-	-	-	1.0	3.8
24	-	-	-	-	0.5	1.3
26	-	-	-	-	0.1	0.6
28	-	-	-	-	-	0.3
30	-	-	-	-	-	0.2

Table 3

Inventory indices of grey alder stands

Age classes (years)	Dg, cm	Hg, m	V, m^3	M, m^3 ha^{-1}	G, m^2 ha^{-1}	Density of the stand
III (11-15)	7.9 ± 0.26	11.1 ± 0.40	0.0271 ± 0.00199	110 ± 11.9	20 ± 2.0	10 ± 1.0
IV (16-20)	10.2 ± 0.60	13.3 ± 0.59	0.0547 ± 0.00892	140 ± 19.0	23 ± 2.6	10 ± 1.2
V (21-25)	13.6 ± 0.69	17.1 ± 0.77	0.1028 ± 0.01395	170 ± 19.4	24 ± 1.8	9 ± 0.8
VI (26-30)	15.0 ± 0.79	18.4 ± 0.70	0.1274 ± 0.01608	180 ± 20.9	26 ± 2.6	9 ± 0.8

of the stand, it is observed that differentiation level of the trees increases and they have wider range of diameter classes. At the same time only negligible number of trees is in smallest and largest classes.

Grey alder stand characteristics

Grey alder cutting age, mentioned most frequently in literature, is 15 years (Ozols, 1923, Brants, 1929, Mūrnieks, 1950, Katkevičs, 1986). That is why the stand characteristics of grey alder is analyzed starting from the third age class (Table 3).

The following symbols are used in the Table 3: Dg - average diameter, Hg- average height, V – average stem volume, G – stand basal area, M - average standing volume

Average diameter 7.9 cm (variation interval 6.4 - 9.0 cm) is found in eleven stands of the third age class. It reaches 15 cm and the dimensions suitable for wood processing in the 6th age class. The average height has reached 11.1 m (variation interval 18.6 - 13.0 m). Average volume of stem has increased 4.7 times but the stand yield as well as average height of trees in stand - 1.6 times. Relatively small change in the stand yield, if compared to remarkable change of the volume of stem, is connected with constant and fast diminishing of number of trees per ha from 4300 to 1500. The majority of out competed trees decay in stand and are not utilized but they have a great ecological value.

During 10 - year period (from age classes 3 to 5) stand yield is increasing by 60 m^3 ha^{-1}, but during the last five years only 10 m^3 ha^{-1}. It is concluded that growing grey alder over 25 years will cause the loss of yield and could be recommended only if the aim is to get bigger dimension stems for processing in sawmills. During 15 years (from third to sixth age class) stands basal area has increased 1.3 times. The average density of the stands is high (9 - 10) in all the age classes. It indicates stands of

great density and the connected differentiation processes accompanied by natural decrease in the number of trees. The diameter of the trees at the same age is bigger in stands of lower density. Thinnings in stands would decrease the number of suppressed and dying trees and increase dimensions of the trees in final felling. Such stands would produce wood suitable for different end - uses: firewood, boxes, furniture production.

The thinning of stands will be further investigated.

Comparing 40 surveyed stands at the age of 11 - 30 years with tables by P.Mūrnieks (1963), it is stated that in eleven cases stand yield is less than in full density stands of the third productivity class, in eighteen - corresponds to stand yield of the third productivity class, in four - is equal to growing stocks of the second productivity class, in five - to the first productivity class and in two - stand yield is higher than indices of the first productivity class.

Conclusions

1. The fastest decrease of number of the trees in natural grey alder stands is up to the age of 10 years.
2. In 11 - 30 years old stands 76 - 89% of trees are in 4 - 5 diameter classes between 4 - 18 cm.
3. At the age of 26-30 years the average diameter of trees reaches 15 cm, but trees with diameter 22 cm or more does not exceed 3% total number.
4. The average growing stock of grey alder reaches 170 m^3 ha^{-1} at the age of 21 - 25 years.
5. Growing grey alder over 25 years with high stand density is connected with decrease of the increment growing stock.
6. From the total amount of trees 15 – 18% is suppressed in grey alder stands at the age of 11 - 30 years.

179

Acknowledgements

References

1. Arhipova I., Bāliņa S. (2003) Statistika ekonomikā (Statistics in Economics). Risinājumi ar SPSS un Microsoft Excel (Solutions with SPSS and Microsoft Excel). Datorzinību centrs, Rīga, 352 pp. (in Latvian).
2. Brants J. (1929) Lauksaimnieka mežkopība (Farmer's Forestry). Rīga, LPI A/s Valters un Rapa, pp. 150 - 151. (in Latvian).
3. Daugavietis M. (2006) Baltalkšņa koksnes izmantošanas iespējas (Grey Alder Wood Application Possibilities). No grām.: Baltalksnis Latvijā. LVMI Silava, pp. 108 – 114. (in Latvian).
4. Dolacis J., Hrols J. (2001) Par baltalkšņa un melnalkšņa koksnes fizikāli mehāniskajām īpašībām (About Physically Mechanical Properties of Grey and Black Alder Wood). II Pasaules latviešu zinātnieku kongress. Tēžu krājums, Rīga, LLU, 546 pp. (in Latvian).
5. Katkevičs A., Lukašunas I. (1986) Augsnes sagatavošanas veida ietekme uz baltalkšņa stādījumu augšanu (Land Cultivation Effect on Grey Alder Plantation Growing). Rīga, Zvaigzne, pp. 59 – 63. (in Latvian).
6. Kramer H., Akča A. (1982) Leitfaden für Dendrometrie und Bestandesinventur (Influence of Some Factors on Grey Alder Vegetative Regeneration). Verlag, Frankfurt am Main, s. 93 – 99. (in German).
7. Lange V., Mauriņš A., Zvirgzds A. (1978) Dendroloģija (Dendrology). Rīga, Zvaigzne, 304 pp. (in Latvian).
8. Liepa I. (1996) Pieauguma mācība (Increment Science). Jelgava, LLU, 121 pp. (in Latvian).
9. Liepa I. (1974) Biometrija (Biometry). Rīga, Zvaigzne, 335 pp. (in Latvian).
10. Mangalis I. (2004) Meža atjaunošana un ieaudzēšana (Forest Regeneration and Forestation). Rīga, SIA Et Cetera, 455 pp. (in Latvian).
11. Mūrnieks P. (1950) Baltalkšņa Alnus incana Moench. augšanas gaita Latvijas PSR. (Development Course of Grey Alder Species Alnus incana Moench. in Latvia) // LPSR ZA Mežsaimniecības problēmu raksti, 2. sējums. Rīga: LZA, pp. 217 - 252. (in Latvian).
12. Mūrnieks P. (1963) Baltalksnis. No grām.: Sacenieks R., Matuzānis J. Mežsaimniecības tabulas. (Grey alder. In Forestry Tables) LVI, Rīga, pp. 112 – 113. (in Latvian).
13. Ozols J., Hibners E. (1923) Baltalkšņa audžu izplatība Latvijā, augšanas gaita un nozīme mežsaimniecībā (Distribution of Grey Alder Stands in Latvia, their Growth and Importance in Forestry) LMSI, Mežsaimniecības rakstu krājums, 1.sējums, pp. 43 – 52 (in Latvian).
14. Pīrāgs Dz. (1962) Alkšņu stumbru trupe (Alder Stem Rot). Rīga, Latvijas PSR ZAI, Jaunākais Mežsaimniecībā, 3, pp. 47 – 50 (in Latvian).
15. Plīse E., Bičevskis M. (2001) Meža entomoloģija (Forest Entomology). Jelgava, LLU, 295 pp. (in Latvian).
16. Sarma P. (1949) Meža taksācija (Forest Inventory). Rīga, LVI, 485 pp. (in Latvian).
17. Skudra P., Dreimanis A. (1993) Mežsaimniecības pamati (Forestry basics). Rīga, Zvaigzne, pp. 30 – 33. (in Latvian).
18. Vaņins S. (1956) Meža fitopatoloģija (Forest Pathology). Rīga, LVI, 278 pp. (in Latvian).
19. Valsts Meža dienests Meža statistika (2005) (State Forest Service, 2005). CD:/lv/indexhtml (in Latvian).
20. Vimba E. (2006) Taphrina epiphylla izraisa alkšņu vējslotas (Taphrina epiphylla induces the besom wind). Available at: http://latvijas.daba.lv/scripts/atteli/albums.cgi?d=senes&f=9-&k=apsarmes_un_veejslotas/, 07.03.2007.
21. Zālītis P. (2005) Baltalksnis (Grey Alder). No grām.: Lapu koku meži (Forest Hardwood). Rīga, SIA Et Cetera, pp. 182 – 183. (in Latvian).

RELATIONSHIP OF BIRCH (*BETULA* SP.) PLYWOOD BENDING PROPERTIES DETERMINED ACCORDING TO THE EUROPEAN STANDARDS EN 789 AND EN 310

Kaspars Zudrags, Henn Tuherm
Latvia University of Agriculture
E-mail: kasparz@inbox.lv

Abstract

The manufacturers of wood-based panels are interested to get easy and cheap method for determination of characteristic values of panels. The correlation between European standards EN 789 and EN 310 tests results can be used as an alternative procedure for determination of characteristic values of bending properties.

The correlations between two results of bending properties determined by testing methods of European standards EN 789 and EN 310 are studied in this paper. The ratio of EN 789 test results divided with EN 310 test results (ratio of EN 789/EN 310), depending on panel thickness and glue type, was examined. Samples from 846 panels of birch (*Betula* sp.) plywood with thickness ranging from 6.5 to 30 mm and two glue types – phenol formaldehyde and melamine urea formaldehyde resin – were used for verification of the correlations.

The results show that the panel thickness influences the ratio of EN 789/EN 310 and the highest ratio was found between 12 and 15 mm panels. When the panel thickness is increased or decreased, the ratio of EN 789/EN 310 decreases significantly. The regression equations for each thickness of plywood are presented.

The difference between plywood glued with phenol formaldehyde and melamine urea formaldehyde resin glues was not found.

Keywords: wood-based panels, strength, modulus of elasticity.

Introduction

The wood processing industry has a significant role in the economics of the European Union. The turnover of the European wood processing industry is 226 billion EUR and for wood based panels – more than 20 billion EUR. In 2005, 60.45-million m^3 of wood–based panels were produced and 6% of those were plywood (Döry, 5th European Wood-Based Panel Symposium, 2006). Plywood has excellent physical-mechanical properties and is widely used in construction.

All construction products should be complying with Construction Product Directive (CPD) of the European Union (Official Journal of the European Communities, 1989). In response to the CPD, European Committee for Standardization (CEN) has been developing 'harmonized standards' EN 13986:2004 'Wood-based panels for use in construction – Characteristics, evaluation of conformity and marking', where the requirements for wood-based panels used in construction are defined. The standard EN 13986 is applicable for wood-based panels for use in construction and specifies the relevant characteristics and the appropriate test methods for determination of these characteristics. It also specifies the procedure for the evaluation of conformity and the requirements for wood-based panel marking.

The standard EN 13986 generally divided all wood-based panels in two end-use groups:

1. wood-based panels for use as structural components;
2. wood-based panels for use as non-structural components.

The compliance with EN 13986 requirements should be demonstrated by:

- factory production control;
- initial type test;
- initial factory inspection and continuous surveillance.

In the factory production control, any manufacturer should establish a system for regular inspections, tests and assessment of raw material, production technology process, equipments and product, in order to ensure that product of appropriate quality is offered in the market.

One of the characteristics, which should be determined in the initial type test and regularly tested in the factory production control, is bending properties of the panel.

Bending properties of wood-based panels can be determined according to the following standards:

Kaspars Zudrags, Henn Tuherm

RELATIONSHIP OF BIRCH (*BETULA* SP.) PLYWOOD BENDING
PROPERTIES DETERMINED ACCORDING TO THE EUROPEAN
STANDARDS EN 789 AND EN 310

- EN 310:1993 'Wood-based panels – Determination of modulus of elasticity in bending and of bending strength';
- EN 789:2004 'Timber structures – Test methods – Determination of mechanical properties of wood based panels'.

The bending properties of wood-based panels for use as structural components should be determined according to the standards EN 310 and EN 789, but for panels that are used as non-structural components the standard EN 789 is not obligatory.

The standard EN 310 specifies a test method for determination of bending properties of wood based panels by testing small test pieces. This standard mostly is used for factory internal quality control and the results can be used for product comparison. These results can't be used in structural design.

The standard EN 789 specifies test methods for determination of some mechanical properties of wood-based panels by testing semi-small test pieces, like bending, compression, tension, panel shear and planar shear properties. EN 789 together with EN 1058:1995 'Wood-based panels – Determination of characteristic values of mechanical properties and density' can be used for determination of structural design values of wood panels. The standard EN 13986 specifies that strength and stiffness for structural use can be determined only once – in the product initial type test.

The panel tests according to the standard EN 789 are quite expensive and they require specific test equipment, which not all manufacturers have. Therefore it is necessary to find alternative test methods for determination of characteristic values of panels.

The standard EN 13986 specified that characteristic values for use in design might be taken from relevant part of the standard EN 12369. These characteristic values are more conservative than the values which can be determined according to the standards EN 789 and EN 1058.

The aim of this paper was to find correlations between EN 310 and EN 789 birch (*Betula* sp.) plywood bending test results. Such kind of correlations can give more appropriate characteristic values and can be used in the factory production control to insure that the bending properties of wood-based panels still correspond to the values which are determined in the initial type test according to EN 789.

Materials and Methods

The 846 panels of birch (*Betula* sp.) plywood were selected from regular production of one site. 10 samples according to EN 310 and 2 samples according to EN 789 were cut out from one panel; half of them have surface veneer grain direction parallel to longitude and half – perpendicular to longitude. The thickness of samples was from 6.5 to 30 mm, veneer thickness – 1.4 mm glued together with phenol-formaldehyde (PF) or melamine urea formaldehyde (MUF) resin glue.

Table 1

Thickness, quantity and lay-up of samples

Nominal thickness, mm	Quantity of panels with PF glue, pcs	Quantity of panels with MUF glue, pcs	Lay-up [a]
6.5	41	-	/ – / – /
9.0	71	-	/ – / – / – /
12.0	91	52	/ – / – / – /– /
15.0	83	85	/ – / – /– /– / – /
18.0	123	87	/ – / – / – /– / – / – /
21.0	67	-	/ – / – / – /– /– / – / – /
24.0	43	-	/ – / – / – /– / – / – / –/
27.0	50	-	/ – / – / – /– / – / – / –/– / – /
30.0	53	-	/ – / – / – /– / – / – / –/– / – / – /
Total	622	224	

[a]Lay-up:
/ – veneer with grain direction parallel to longitude;
– – veneer with grain direction perpendicular to longitude.

Kaspars Zudrags, Henn Tuherm

RELATIONSHIP OF BIRCH (*BETULA* SP.) PLYWOOD BENDING
PROPERTIES DETERMINED ACCORDING TO THE EUROPEAN
STANDARDS EN 789 AND EN 310

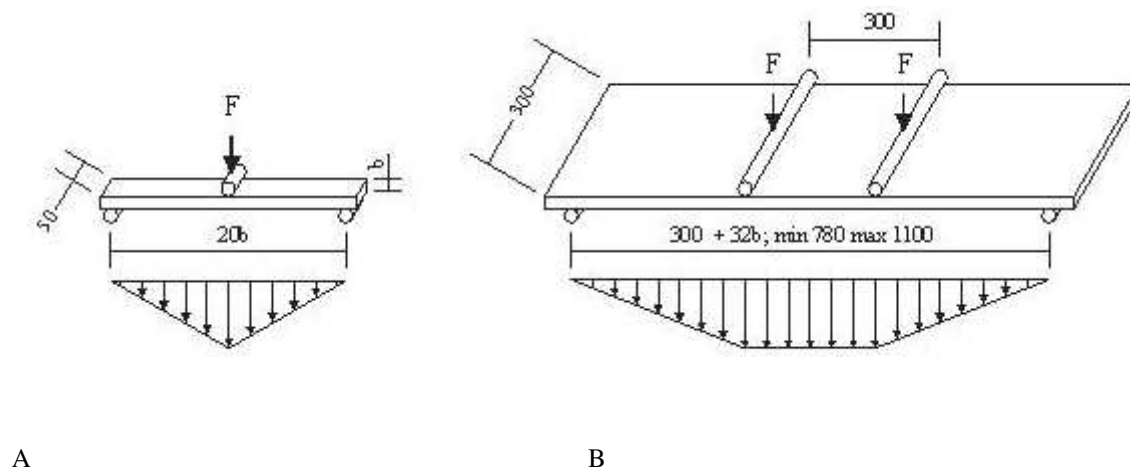A   B

Figure 1. Principal schemas of bending tests, dimensions in mm. (A – EN 310; B – EN 789).

The sample division by thickness and lay-up is presented in Table 1.

Standard methods according to EN 310 and EN 789 are used for determination of bending properties. The moisture content of samples was 8 ± 2 %.

The principal schema of the test methods is shown in Figure 1.

The ratio of EN 789 test results divided with EN 310 test results was used for determination of ratio, which changed depending on panel thickness. The average ratio value of each nominal plywood thickness was calculated.

The influence of panel thickness and glue type was evaluated by using multiple linear regressions analysis.

Results and Discussion

The correlation between EN 789 and EN 310 bending test results are significant with probability of 99% (Table 2). The better correlate results for samples with surface veneer grain direction parallel to longitude. The results of samples with veneer grain direction parallel to longitude have less variation (approximately 15% instead of 20% for EN 789 tests results).

Regardless of that, the background influence is very high (Figures 2 and 3).

It is necessary to point out that the requirements of sampling procedures according to EN 310 are to pick samples without any visible defects (knots on surface veneer, splits, etc.), but for samples according to EN 789 there are no special requirements.

As shown in Figure 1, the load zones with

Table 2

Coefficients of correlation

Test method	Strength EN 310ll$^\diamond$	Modulus of elasticity EN 310 ll	Strength EN 310_l_$^\square$	Modulus of elasticity EN 310 _l_
Strength EN 789 ll	0.597(**)			
Modulus of elasticity EN 789 ll		0.661(**)		
Strength EN 789 _l_			0.419(**)	
Modulus of elasticity EN 789 _l_				0.386(**)

$^\diamond$ll – surface veneer grain direction parallel to longitude;
$^\square$ _l_ – surface veneer grain direction perpendicular to longitude;
** Correlation is significant at the 0.01 level (2-tailed).

Kaspars Zudrags, Henn Tuherm

RELATIONSHIP OF BIRCH (*BETULA* SP.) PLYWOOD BENDING
PROPERTIES DETERMINED ACCORDING TO THE EUROPEAN
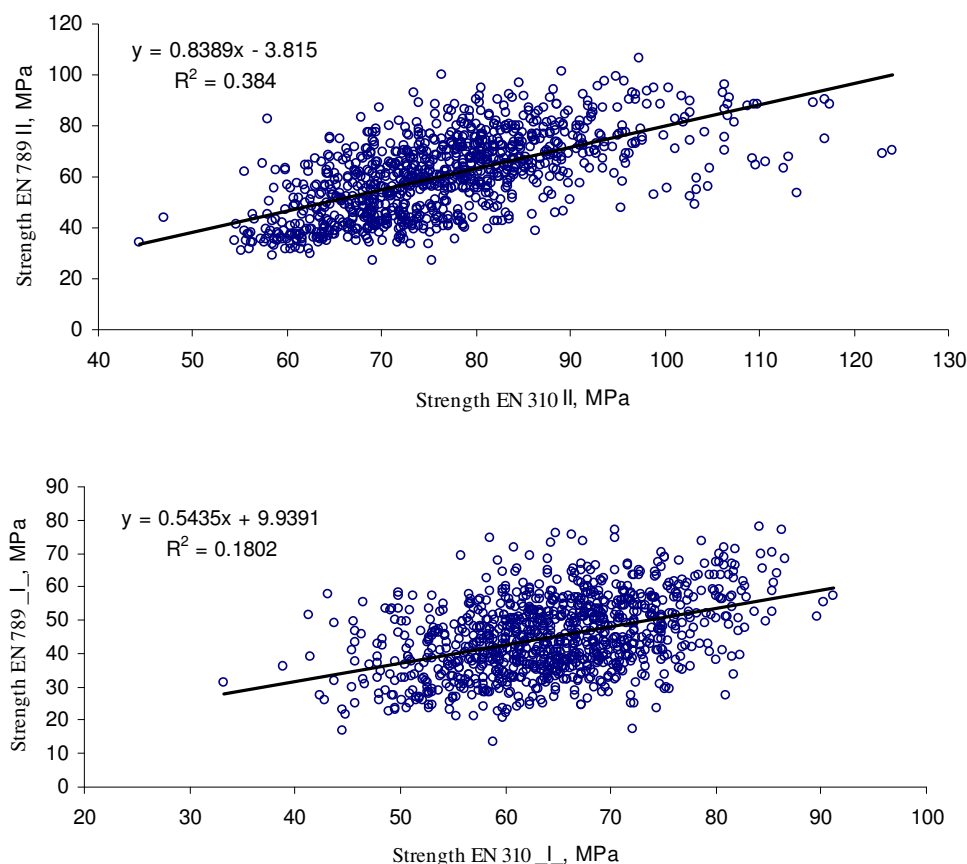STANDARDS EN 789 AND EN 310

Figure 2. Relations of EN 789 and EN 310 strength results

(‖ – surface veneer grain direction parallel to longitude; _|_ – surface veneer grain direction perpendicular to longitude).

maximum load are different. According to EN 789, the maximum load zone is 300 by 300 mm and that means that some defect influence on the results is much higher than in the test method according to EN 310.

These both factors give more variety to the test results.

Figures 4 and 5 clearly show that the ratio of EN 789/EN 310 changes depending on plywood thickness. There are no significant differences between plywood glued with PF and MUF resin glue (Figures 4 and 5). (surface veneer grain direction parallel to longitude; □ – plywood glued with MUF resin glue; ◊ – plywood glued with PF resin glue). (surface veneer grain direction perpendicular to longitude; □ – plywood glued with MUF resin glue; ◊ – plywood glued with PF resin glue).

In Figure 6 the average ratio of EN 789/EN 310 depending on surface veneer grain direction to longitude is shown. Significant differences between the ratios of strength, due to the samples

surface grain direction, were found. The ratios of strength for samples with perpendicular grain direction are on average 10% less than ratios of samples with parallel grain direction to longitude.

The regression equations are presented in Table 3.

The regression equations can be used for determination of characteristic values of bending properties for birch plywood, but further investigation is necessary for evaluation of conformity of these characteristic values. Necessary investigation for evaluation other alternative ways for determination of characteristic values of bending properties and to compare it's with reference method (tests results according to EN 789).

Many manufacturers would like to earn alternative way (easy and cheap) for determination of characteristic values, not only bending, but also other mechanical properties.

Kaspars Zudrags, Henn Tuherm

RELATIONSHIP OF BIRCH (*BETULA* SP.) PLYWOOD BENDING
PROPERTIES DETERMINED ACCORDING TO THE EUROPEAN
STANDARDS EN 789 AND EN 310
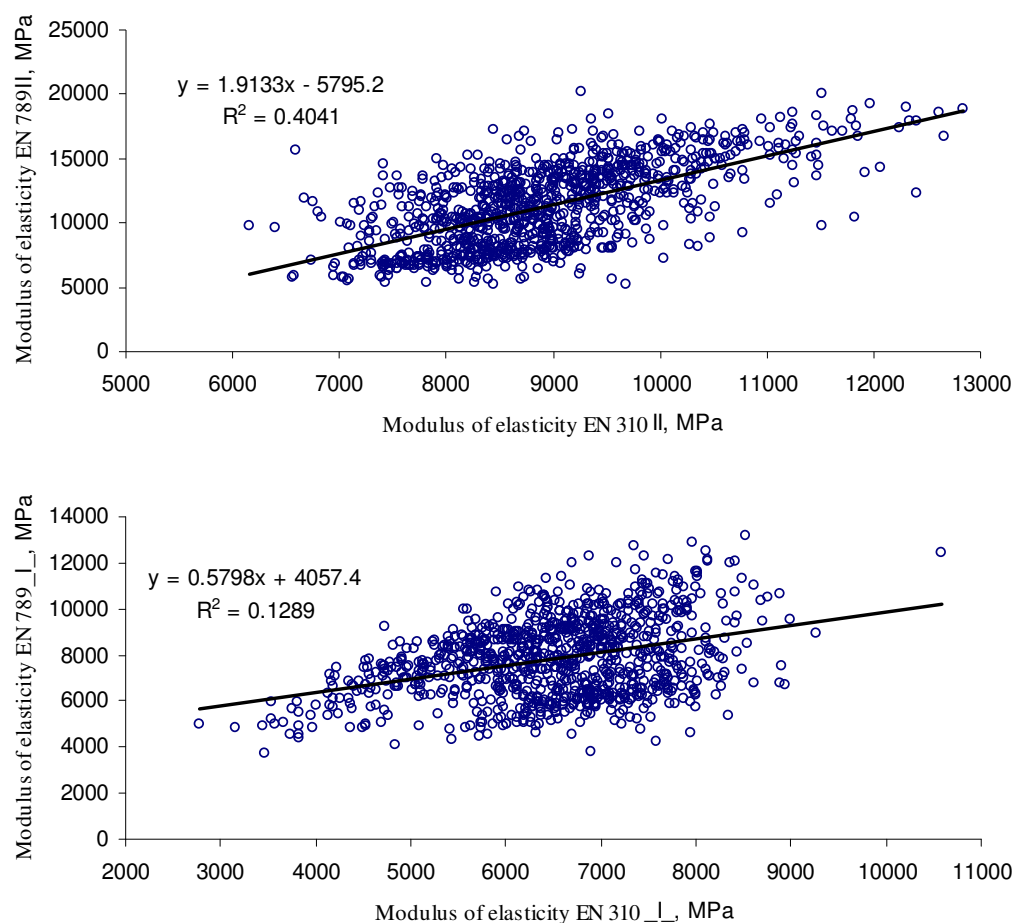

Figure 3. Relations of EN 789 and EN 310 modulus of elasticity results

(‖ – surface veneer grain direction parallel to longitude; _⏌_ – surface veneer grain direction perpendicular to longitude).
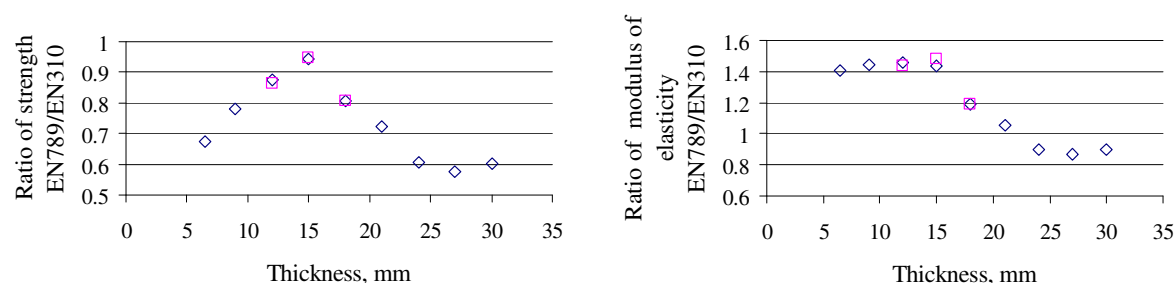

Figure 4. Ratio of strength EN 789/EN 310.

(surface veneer grain direction parallel to longitude; □ - plywood glued with MUF resin glue; ◇ - plywood glued with PF resin glue).

Kaspars Zudrags, Henn Tuherm

RELATIONSHIP OF BIRCH (*BETULA* SP.) PLYWOOD BENDING
PROPERTIES DETERMINED ACCORDING TO THE EUROPEAN
STANDARDS EN 789 AND EN 310
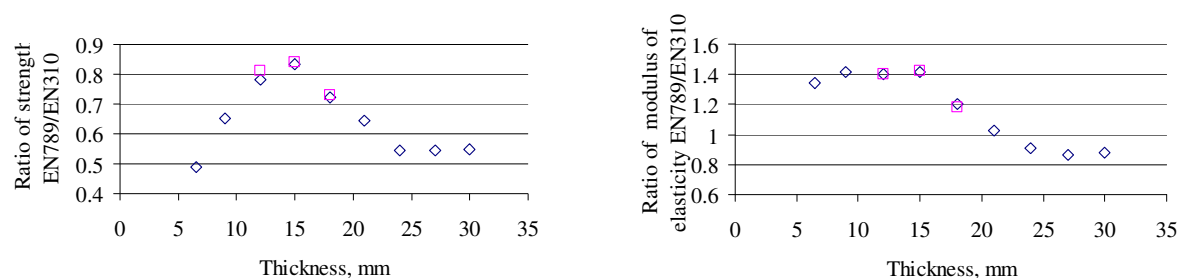
Figure 5. Ratio of modulus of elasticity EN 789/EN 310.

(surface veneer grain direction perpendicular to longitude; □ - plywood glued with MUF resin glue; ◇ - plywood glued with PF resin glue).
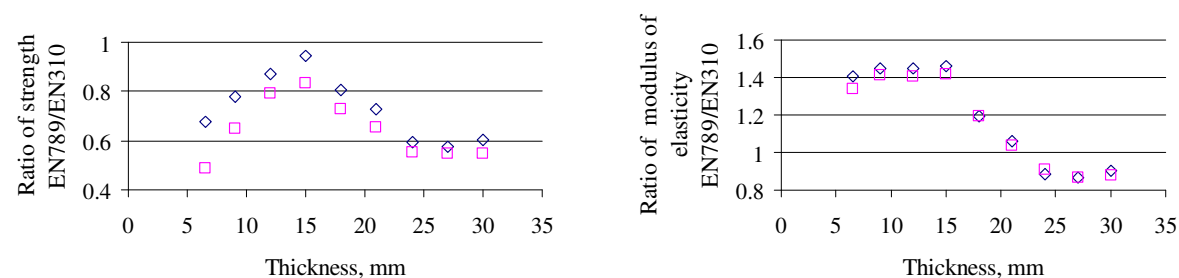
Figure 6. Ratio of strength and modulus of elasticity EN 789/EN 310

(□ – surface veneer grain direction perpendicular to longitude; ◇ – surface veneer grain direction parallel to longitude).

Table 3

Regression equations

Nominal thickness, mm	Strength ‖$^{◇}$	Modulus of elasticity ‖	Strength _‖_ $^{□}$	Modulus of elasticity _‖_
6.5	$a = 11.2 + 0.56b$	$a = 3314 + 1.1b$	$a = 6.3 + 0.37b$	$a = 1993 + 0.87b$
9.0	$a = 20.0 + 0.56b$	$a = 3432 + 1.1b$	$a = 17.7 + 0.37b$	$a = 3001 + 0.87b$
12.0	$a = 25.5 + 0.56b$	$a = 3253 + 1.1b$	$a = 27.9 + 0.37b$	$a = 3340 + 0.87b$
15.0	$a = 30.6 + 0.56b$	$a = 3229 + 1.1b$	$a = 30.3 + 0.37b$	$a = 3594 + 0.87b$
18.0	$a = 18.7 + 0.56b$	$a = 838 + 1.1b$	$a = 23.2 + 0.37b$	$a = 2156 + 0.87b$
21.0	$a = 12.2 + 0.56b$	$a = -376 + 1.1b$	$a = 18.5 + 0.37b$	$a = 1104 + 0.87b$
24.0	$a = 2.4 + 0.56b$	$a = -1901 + 1.1b$	$a = 11.2 + 0.37b$	$a = 232 + 0.87b$
27.0	$a = 1.2 + 0.56b$	$a = -1986 + 1.1b$	$a = 10.8 + 0.37b$	$a = -64 + 0.87b$
30.0	$a = 3.1 + 0.56b$	$a = -1661 + 1.1b$	$a = 11.3 + 0.37b$	$a = 11 + 0.87b$

$^{◇}$‖ – surface veneer grain direction parallel to longitude; $^{□}$ _‖_ – surface veneer grain direction perpendicular to longitude; b – test result according to EN 310; a – appropriate EN 789 test result.

Kaspars Zudrags, Henn Tuherm

RELATIONSHIP OF BIRCH (*BETULA* SP.) PLYWOOD BENDING
PROPERTIES DETERMINED ACCORDING TO THE EUROPEAN
STANDARDS EN 789 AND EN 310

Conclusions

1. The correlation between EN 789 and EN 310 test results are significant, varying from week to medium.

2. Significant differences between ratios of EN 789/EN 310 due to the plywood thickness were found.

3. Due to the dependency ratio from plywood thickness, the appliance of one equation to calculate bending characteristic values from EN 310 test results for all thickness range is not correct. The conservative equation can be used for the calculation of characteristic values.

4. No significant differences were found between the ratios of EN 789/EN 310 of birch plywood glued with PF and MUF resin glues.

5. Further investigation is necessary for comparison of different alternative methods in order to evaluate the best alternative method for determination of characteristic values of wood-based panels.

References

1. Council Directive 89/106/EEC of 21 December 1988 on the approximation of laws, regulations and administrative provisions of the Member States relating to construction products; Official Journal of the European Communities No L 040 p. 11, February 1989, 12-26 p.

2. EN 13986:2004 'Wood-based panels for use in construction – Characteristics, evaluation of conformity and marking', European Committee for Standardization, 2004, 57 p.

3. EN 310:1993 'Wood-based panels – Determination of modulus of elasticity in bending and of bending strength', European Committee for Standardization, 1993, 8 p.

4. EN 789:2004 'Timber structures – Test methods – Determination of mechanical properties of wood based panels', European Committee for Standardization, 2004, 32 p.

5. EN 1058:1995 'Wood-based panels – Determination of characteristic values of mechanical properties and density', European Committee for Standardization, 1995, 8 p.

6. EN 12369-1:2001 'Wood-based panels - Characteristic values for structural design - Part 1: OSB, particleboards and fibreboards', European Committee for Standardization, 2001, 15 p.

7. EN 12369-2:2004 'Wood-based panels - Characteristic values for structural design - Part 2: Plywood', European Committee for Standardization, 2004, 11 p.

THE *LICHENOINDICATIVE* EVALUTION OF OAK WOODLAND KEY HABITATS

Inga Straupe[1], *Jānis Donis*[2]
[1]Latvia University of Agriculture
E-mail: inga.straupe@llu.lv
[2]Latvian State Forest Research Institute 'Silava'
E-mail: donis@silava.lv

Abstract

This article presents the description of oak woodland key habitats and their importance in the maintaining of biodiversity as well as a necessity of management and monitoring. The lichens *Lichenes* and its percental cover features have been described. The exposition of lichen species depending on the cardinal points have been analysed. The article presents the characteristics of ecological indicators of lichens in the objects. The lichenoindicative evaluation and comparison of oak woodland key habitats in Latvia have been carried out.

Keywords: lichens epiphytes, oak woodland key habitats, giant trees, management of woodland habitats.

Introduction

Oak (*Quercus robur* L.) is a common broadleaved tree species in Europe which spread into Latvia 6000 years ago and in some regions it made up to 40% of forests. 1500 years ago broadleaved – spruce forests prevailed over the whole territory of Latvia. However, the demand for wood, the suitability of the land to cultivation and uncongenial climate changes were the reasons why the number of oaks was decreased. As a result, in the present structure of forests in Kurzeme and Zemgale only a few oak stands remain. In Vidzeme oaks can be found growing among other trees (Priedītis, 1999; Strods et al., 1999). Giant oak trees are biologically old and huge growing solitary or in forests. They have a wide-spread crown. They serve as a substratum and habitat for many rare and threatened species of epiphytic lichen, insect and fungi species that live in the wood of trees. A part of these species are used as a woodland key habitat indicator species (IS) and habitat specialist species (SBS). The presence of IS and SBS is a sign that determines the woodland key habitat (WKH) status for the tree (Ek et al., 2002; Bērmanis, Ek, 2003). According to the conditions of growing and developing conditions, the trees can be divided into the trees growing in the shade and those growing in an open landscape, for instance, on agricultural lands. In order to provide a habitat for an oak related SBS, different management techniques have to be used to giant trees growing in different conditions. The origin of the tree is evaluated according to the history of the land use in the respective location (the age and the structure of the surrounding stand), tree structure (the shape of a crown and branches, the depth of cracks in the bark) and the species of epiphyte on the tree (Johansson, 2005; Johannesson, Ek, 2005). A typical feature of the trees that had previously been growing in a shade (in a forest stand) is a gap disturbance dynamics – as a natural type of a natural disturbance. They do not need management or as an alternative to cutting the girdling of those trees which are intergrown into the crown of the oak. The broadleaved trees which had initially grown in a more open landscape, for instance, in a forest meadow or on pastures, as well as the living organisms which are found on them, are adapted to brighter light. It is believed that in the course of evolution they have been formed by big herbivores (bisons *Bison bonasus* L., wild horses *Equus ferus ferus* Boddaert, aurochs or urus *Bos taurus* L.) which, due to their natural habits (gnawing, grazing) have maintained a partly open landscape (Vera, 2000). On the whole, in open and partially open habitats the number and diversity of species connected with giant oaks is higher. Such trees need to be carefully and gradually released from the shade. That should be done in the same course of time as it took the shade to be formed. The older the tree and the longer it had grown under such conditions, the more sensitive it is to changes (Read, 2000; Johansson, 2005). In order to successfully preserve the characteristic species of

the later stage of the tree development in the habitat, it is necessary to have the trees of the same species of different ages around. Maintaining and carrying out management activities, the future giant trees have to be chosen (Ek et al., 2002; Johansson, 2005).

In the inventory of natural woodland habitats lichen is one of the group of organisms which is used to evaluate the biological diversity and forest continuity (Ek et al., 2002; Znotiņa, 2003). Lichen is an organism whose development and growth depends on phytocenotic and ecological conditions in the stand (Sõmermaa, 1972). In the last decades considerable attention has been paid to the research of interdependence of lichen diversity and forest management (Nash, Wirth, 1988; Sillett, Goslin, 1999; Van Herk, 1999; McCune, 2000; Will-Wolf et al., 2002) which has a direct influence on the lichen epiphyte communities and their development (McCune, 2000; Will-Wolf et al., 2002; Lõhmus, 2005). Lichen monitoring is especially important for evaluating the environmental changes, especially in relation to natural habitats that play a great role in preservation of biological diversity (Piterāns, Žeiviniece, 2000; Donis et al., 2004; Bērmanis, 2006).

The aim of the research is to describe and evaluate the woodland key habitats – giant oak trees from the lichoindicative point of view. In order to reach the goal, the following objectives have been set:

1. Lichens and the analysis of its cover in percentage in oak woodland key habitats;
2. The description and analysis of dependence of lichen exposition on cardinal points;
3. The description of lichen ecological indicators.

Materials and Methods

In order to carry out the lichenoindicative analysis in oak woodland key habitats, nine research sites were chosen in 2005 in Latvia (Table 1). Seven - eight sample plots were made depending on the number of giant oak trees (Donis et al., 2004). In total 70 oaks were measured. The age of oaks according to the inventory data is within the limits of 126 (in site 1) to 228 years (in site 6). The age of the forest stands according to the inventory data is shown in Table 1.

The record of lichens on oak trees is made clockwise (N – E – S – W), using the line method

Table 1

The description of the research sites

Site code	State Head Forestry (SHF)	State Forestry (SF)	Compartment/ sub-compartment	Stand composition, age	Forest type
1	Sēlija	Viesīte	364/ 13	$3E_{32}4E_{27}2Oz_{32}1Oz_{126}$	Oxalidosa
2	Aizkraukle	Nereta	396/ 9	$5A3B1E_{87}1Oz_{182} + P_{96}$ II st. $10E_{77}+Ba_{71}$	Myrtilloso-polytrichosa Oxalidosa
3	Zemgale	Biksti	15/ 7, 9	$5P3B2E_{84}$ $6P3E1Oz_{134}$	Hylocomiosa Oxalidosa
4	Limbaži	Katvari	266/ 2	$5E_{105}2E_{125}2A_{95}1Oz_{145} + Os_{92}$	Oxalidosa
5	Sēlija	Jēkabpils	13/ 17	$4A4B2E_{97}+ A_{91}$ $10E$ IIst.$_{76}+ Oz_{200}$	Aegopodiosa
6	Ziemeļ kurzeme	Aizupe	208/ 15	$5B2A1Oz1E_{48} 1E_{68}+ Oz_{228} Bl_{43}$	Oxalidosa
7	Ziemeļ kurzeme	Andumi	334/ 5, 6, 8	$7B1A1E1Oz_{77}$ $10E + Oz_{102}$ $7B2Oz1E_{87}+A_{82}+ Oz_{157}$	Hylocomiosa Oxalidosa
8	Ziemeļ vidzeme	Strenči	507/ 15, 16	$9P1E_{188}+Oz_{182}$ IIst. $8E_{98}2E_{52},$ $4Oz2P1E_{148} 2A1B_{78} +E_{162}$ II st.	Myrtilloso-sphagnosa Myrtilloso-polytrichosa
9	Kuldīga	Rudbārži	317/ 14	$5E1P2B_{68} 1E1P_{83} +B_{77}+Oz_{167}$	Hylocomiosa Oxalidosa

at two heights – 0.5 m and 1.5 m above the root collar. A uniform methodology for collecting and preparing the data for further processing has been used – to characterize a tree stand, sample stands of 500 m² were made around sample trees, in which the diameters of the trees of the 1st and 2nd floor were measured at breast height (DBH), also the total basal area G_{tot}, as well as G for separate species (Donis et al., 2004; Straupe, Donis, 2006). The conspectus of lichens in Latvia is used for the classification of lichen species (Piterāns, 2001). The mutual comparison of objects has been done by using Mann – Whitney and Kruskal – Wallis tests (Paura, Arhipova, 2002; Arhipova, Bāliņa, 2003). To determine and analyze the exposition of lichen species depending on the cardinal points the computer programme AXIS 1.1. (PISCES Conservation Ltd.) has been used (Fisher, 1993; Straupe, Donis, 2006). In all the research sites, using lichen species on tree trunks, the ecological evaluation has been performed, using the following seven indicators: light, temperature, continentality, moisture, reaction, amount of nutrients and toxicotolerance (Wirth, 1992).

Results and Discussion

The analysis of lichens and its percentile coverage in oak woodland key habitats.

28 lichen species, belonging to 23 genera were found on oak trees in the research sites (Piterāns, 2001) (Table 2). The epiphyte lichens stated in the research sites are morphologically divided in the following way: crustose lichens – 21, foliose lichens - 4 and fruticose lichens – 3 species. Five indicator species and three habitat specialist species of woodland key habitats, as well as five specially protected species, have been found on oaks. From the five especially protected species three species need to have microreserves (Ek et al., 2002; Bojāre et al., 2006). Indicator species and habitat specialist species of woodland key habitats have been found on 8 sites: the biggest number: 5 species (3 IS and 2 SBS) – on site 6, 4 species (3 IS un 1 SBS) – on site 7, and in the remaining sites – 1 to 3 species. WKH IS and SBS have not been found only on one - site 1.

The number of lichen species in objects in total and on the trunk at the different heights is shown in Table 3. The biggest number of species in total (11 species) has been found on two research sites: 1 and 2. The smallest number of species in total is on site 3 (4 species), in the remaining sites 7 – 8 species have been found. On all the sites the crustose lichen species *Lepraria incana* (L.) Ach. is present, constituting a significant proportion of

coverage in percentage at the both heights 0.5 m and 1.5 m – correspondingly on average 28% and 39%, and 11 species are rarely found - only on one site. Only 4 species have been found at a certain height on the oak tree: *Peltigera praetextata* (Florke ex Sommerf.) Zopf, *Sclerophora amabilis* (Tibell) Tibell, *Arthothelium ruanum* A. Massal. Körb. – at the height of 0.5 m and *Dimerella pineti* (Ach.) Vezda – at the height of 1.5 m. Most species at heights of 0.5 m and 1.5 m have been found on the site 1 (at each height 10 species), the smallest number of species at the height of 0.5 m – on site 7 (3 species), but 1.5 m – on site 3 (3 species). On most sites (6 sites) the greatest diversity of species was found on the trunk at the height of 1.5 m, but on 2 sites - the number of species is identical at both heights (Table 3). The proportion of lichens of different morphological groups at different heights on trunks is similar: 19 crustose and 3 fruticose lichen species (at both heights), but foliose lichen correspondingly - 4 and 3 species. The composition of lichens on the trunk is more homogenuous than on the base of the trunk (Sõmermaa, 1972), but it could differ on old trees because with the age the physical properties of the bark (water absorbtion capacity and texture) become more similar (Sõmermaa, 1972; Uliczka, Angelstam, 1999; Lõhmus, 2005).

Using the Mann – Whitney test it has been stated that the coverage in percentage of lichens differs significantly according to the height (p-value = 0 < α = 0.05). The average coverage in percentage of lichens at the height of 0.5 m is 36%, but at 1.5 m – 52%. The biggest coverage is usually typical for the lower part of the tree trunk (Sõmermaa, 1972), but in the case of oak trees it can be attributed to the presence of moss on the base of the trunk and to mechanical damages of the bark (fallen off bark, cracks) which reduce the possible coverage with lichen. Using the Kruskal – Wallis test it has been stated that there are substantial differences among the research sites with regard to the coverage in percentage of lichens at the height of 1.5 m (p-value = 0.084 < α = 0.1). The smallest coverage in percentage is on site 9 (37%), but the biggest – on site 8 (67%). Supposedly, the differences in lichens coverage in percentage at the height of 1.5 m on certain sites can be attributed to the local differences of these research sites.

Description and analysis of the dependence of lichen exposition on the cardinal points.

The vertical exposition of lichen on cardinal points is determined by the ecological situation (light, moisture) and physical-chemical properties

Table 2

The lichen species found in oak woodland key habitats

No.	Lichen species	Abbreviations used in data analysis	Morphological group	Status IS, SBS, SPS * MIK **
1	*Acrocordia gemmata* (Ach.) A. Massal.	Acge	K	IS
2	*Arthonia byssacea* (Weigel) Almq.	Arby	K	SBS, **
3	*Arthonia spadicea* Leight.	Arsp	K	IS, *
4	*Arthonia vinosa* Leight.	Arvi	K	IS, *
5	*Arthothelium ruanum* A. Massal. Körb.	Arru	K	-
6	*Buellia punctata* (Hoffm.) A. Massal.	Bupu	K	-
7	*Chaenotheca phaeocephala* (Turner) Th. Fr	Chph	K	SBS, **
8	*Chrysothrix candelaris* (L.) J. R. Laundon	Chca	K	-
9	*Cladonia coniocraea* (Flörke) Spreng.	Clco	Kr	-
10	*Dimerella pineti* (Ach.) Vezda	Dipi	K	-
11	*Evernia prunastri* (L.) Ach.	Evpr	Kr	-
12	*Graphis scripta* (L.) Ach.	Grsc	K	IS
13	*Hypogymnia physodes* (L.) Nyl.	Hyp	L	-
14	*Lecanactis abietina* (Ach.) Körb.	Leab	K	IS
15	*Lecanora carpinea* (L.) Vain.	Leca	K	-
16	*Lecidella euphorea* (Flörke) Hertel.	Leeu	K	-
17	*Lepraria incana* (L.) Ach.	Lepr	K	-
18	*Melanelia glabratula* (Lamy) Essl.	Megl	L	-
19	*Opegrapha varia* Pers.	Opva	K	-
20	*Parmelia sulcata* Taylor	Parm	L	-
21	*Peltigera praetextata* (Florke ex Sommerf.) Zopf	Pepr	L	-
22	*Pertusaria albescens* (Huds.) M. Choisy & Werner	Peal	K	-
23	*Pertusaria amara* (Ach.) Nyl.	Peam	K	-
24	*Pertusaria coccodes* (Ach.) Nyl.	Peco	K	-
25	*Pertusaria flavida* (DC.) J. R. Laundon	Pefl	K	-
26	*Phlyctis argena* (Spreng.) Flot	Phar	K	-
27	*Ramalina farinacea* (L.) Ach.	Rafa	Kr	-
28	*Sclerophora amabilis* (Tibell) Tibell	Scle	K	SBS, **

Designations: K – crustose, L - foliose, Kr – fruticose lichens; SPS – especially protected species; MIK – especially protected species, for which microreserves should be created.

(the age of the tree, the texture of the bark surface and the presence of nutrients) (Sõmermaa, 1972; Znotiņa, 2003). The number and the exposition of lichen species depending on the cardinal points on the trunk at the height of 0.5 m and 1.5 m on the research sites are shown in Table 3.

At the height of 0.5 m more species can be found on the S and SE side (in 6 sites), but at the height of 1.5 m - on the N and NW side (in 7 sites). At the base better moisture conditions are provided for lichens in addition, at the height of 0.5 m most trees had mosses which compete with lichens for a definite place and moisture, which could be an additional factor explaining the location of lichens on the S and SE side. Higher up on the trunk the lighting is better, but the amount of moisture decreases. Therefore, most species occupy N and NW side. There are data available that the specifics of substratum correspond to definite ecological conditions. Thus, approximately in 60% of cases the lichen community is determined by the substratum factor and in 40% of cases by microclimate (Sõmermaa, 1972; Uliczka, Angelstam, 1999; Lõhmus, 2005).

The mean values of expositions of lichen species depending on the cardinal points are shown in Fig. 2. WKH indicator species
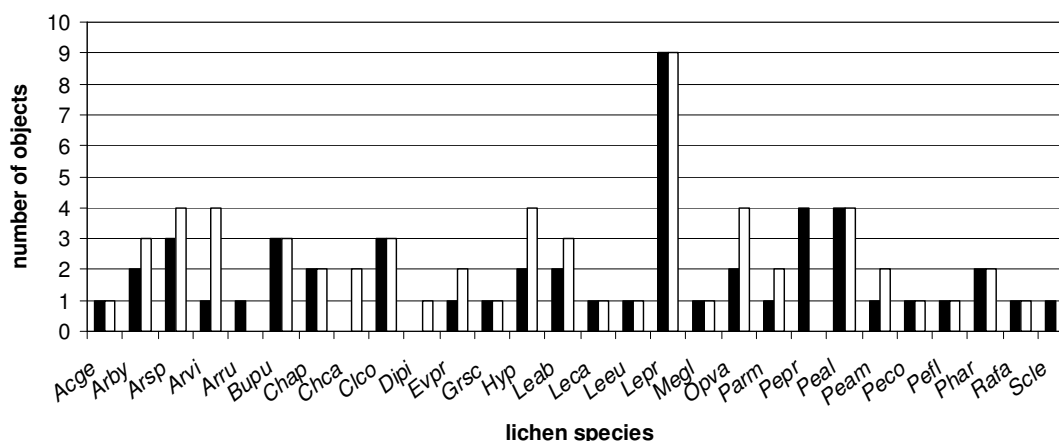
191

Figure 1. The occurrence of lichen species at the height of 0.5 m and 1.5 m on the research sites (□ − 0.5 m,
■ − 1.5 m).

Abbreviations: in Table 2.

Arthonia spadicea Leight., *Arthonia vinosa* Leight., *Lecanactis abietina* and a habitat specialist species *Arthonia byssacea* (Weigel) Almq. that occur on several sites have been analysed. IS *Arthonia spadicea* on oak trees is found at both heights (on the site 7 only at the height of 1.5 m), the mean value at the height of 0.5 is on the SW side, but at the height of 1.5 m - on the NW side. IS *Arthonia vinosa* on the oak trees is found mainly at the height of 1.5 m (on site 9 at both heights). On different sites it occupies different exposition niches depending on the cardinal points, but the mean value at the height of 0.5 m is on the S side, but at the height of 1.5 m − on the E side. IS *Lecanactis abietina*, which usually occurs on spruces and indicates high content of moisture and long-lasting

tree continuity is mostly found at both heights (on the site 7 only at the height of 1.5 m). The mean value at the height of 0.5 m is on the SE side, but at the height of 1.5 m − on the S side. SBS *Arthonia byssacea* on different sites and at different heights occupy different exposition niches depending on the cardinal points. On the site 7 it is found only at the height of 1.5 m, but on the sites with a smaller basal area − also at the height of 0.5 m, respectively the mean value at the height of 0.5 m is on the E side, but at 1.5 m − on the SW side.

The description of lichen ecological indicators.

The description of stand basal area and lichen ecological indicators on research sites is shown in Table 4. The evaluation of research sites is

Table 3

**The number and the exposition of lichen species depending on the cardinal points on the
trunk at the height of 0.5 m and 1.5 m on the research sites**

Site code	Number of species						
	In Total	Height 0.5 m			Height 1.5 m		
		In total	Z, ZR	D, DA	In total	Z, ZR	D, DA
1	11	10	2	8	10	4	6
2	11	7	0	7	9	5	4
3	4	4	2	2	3	3	0
4	8	6	1	5	7	3	4
5	8	5	2	3	6	4	2
6	8	7	1	6	8	5	3
7	7	3	1	2	7	5	2
8	8	5	3	2	5	3	2
9	8	5	3	2	7	4	3

Fig. 2. The mean values of expositions of lichen species depending on the cardinal points at the height 0.5 and 1.5.

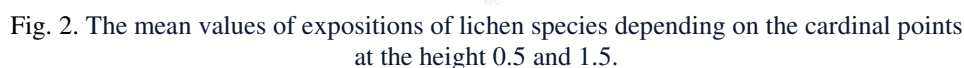Designations: - OZ05Arby, - OZ15Arby, -Oz05Arsp, - Oz15Arsp, - Oz05Arvi, - Oz15Arvi, - Oz05Leab, - Oz15Leab.

Figure 2. The mean values of expositions of lichen species depending on the cardinal points at the height 0.5 and 1.5.

Abbreviations of lichen species used in data analysis in Table 2.

Table 4

The description of a stand basal area and lichen ecological indicators in research sites

Indicators	Site codes								
	1	2	3	4	5	6	7	8	9
Basal area G ($m^2\ ha^{-1}$)	26.90	35.10	40.90	44.30	44.90	47.90	47.00	48.00	37.90
Light	5.91	5.10	5.00	5.50	4.14	3.63	3.57	4.29	4.13
Temperature	5.00	5.00	5.25	5.33	5.67	5.38	5.43	5.33	5.33
Continentality	5.82	4.80	4.75	4.90	4.71	3.50	3.86	4.57	4.75
Moisture	3.20	3.89	4.25	3.75	4.17	4.38	4.57	4.17	4.00
pH	4.27	3.60	5.00	4.50	4.29	3.38	3.71	4.00	3.63
The nutrients	3.18	2.80	3.75	3.13	2.71	2.50	2.86	2.71	2.50
Toksicotolerance	6.70	6.38	5.00	5.71	5.20	4.86	6.00	5.40	5.86

done in accordance with lichen communities and the means of values of lichen ecological indicators (Wirth, 1992).

According to the results the stand basal area correlates with the following ecological indicators: light, temperature and moisture, but the interconnection among continentality, reaction, amount of nutrients and toxicotolerance

is not found. In sample plots with higher stand basal area more shade-tolerant lichen species (relative lighting 5 – 10 %) and higher moisture are found. Using the values of the indicator continentality it is possible to divide research sites into 2 groups: the group which is located in SW, S, SE part of Latvia (higher means of values of continentality) and the group which is located in NW, NE part of Latvia (lower means of values of continentality; site 6 and 7 is affected by the near location of the Baltic sea, but site 8 – by location on the banks of Gauja). There is no explanation for high mean of values of continentality of site 4. The reaction of substratum–bark is rather acid on all the sites (pH 4.1 – 4.8) and there is a medium amount of minerals on the bark which is characteristic of the bark of oaks. The highest value of the reaction of substratum–bark (pH 4.9 – 5.6) and bigger amount of nutrients are on site 3; it could be explained by the site location near Jaunakmene cement plant in Lithuania and influence of its emissions. The pH value of oak giant trees is not different because with the age the physical properties of the bark become more similar. The values of indicator of toxicotolerance show the sensitivity of lichen species to air pollution (Wirth, 1992). The highest total value of toxicotolerance is established on site 1, which depends on site location at the edge of the forest by the roadside and the community of lichen species without rare species and WKH's IS and SBS. The lowest value of toxicotolerance is established on site 6, where the biggest number of WKH's IS and SBS is found (in total 5 species).

Conclusions

1. On oak trees in the research sites 28 lichen species, belonging to 23 genera were found. Five indicator species and three habitat specialist species of woodland key habitats, as well as five especially protected species have been found on oaks. The largest number of species in total – 11 species have been found on two research sites: 1 and 2. The fewest number of species in total is on site 3 (four species), on the remaining sites seven – eight species have been found. On all the sites the crustose lichen species *Lepraria incana* (L.) Ach. is present.

2. The diversity of lichen species and the lichen cover in percentage is smaller at the trunk height of 0.5 m than at the trunk height of 1.5 m; it can be attributed to the physical properties of the bark which are similar with respect of age, the presence of moss on the base of the trunk and to mechanical damages of the bark (fallen off bark, cracks). There are substantial differences among the research sites with regard to the coverage in percentage of lichens at the height of 1.5 m (the smallest coverage in percentage is on site 9 – 37%, but the biggest – on site 8 – 67%). Supposedly, the diferences in lichens coverage in percentage at the height of 1.5 m on certain sites can be attributed to the local differences of these research sites.

3. At the height of 0.5 m more species can be found on S and SE side, but at the height of 1.5 m on N and NW side, and this can be attributed to differences of moisture at different heights, as well as the competition between lichens and mosses on the base of the trunk.

4. The stand basal area of oak woodland key habitats correlates with following ecological indicators: light, temperature and moisture, but interconnection among continentality, reaction, amount of nutrients and toxicotolerance is not found. The highest value of toxicotolerance is established on site 1, which depends on site location on the edge of forest near the road and the community of lichen species without rare, WKH's IS and SBS. The lowest value of toxicotolerance is established on site 6, where the biggest number of WKH's IS and SBS is found (in total 5 species).

References

1. Arhipova I., Bāliņa S. (2003) Statistika ekonomikā. (Statistics in Economy) Riga: Datorzinību centrs, 352 p. (in Latvian).
2. Bērmanis R. (2006) Dabisko meža biotopu apsaimniekošana Latvijā (The Management of Natural Woodland Habitats in Latvia) In: Baltijas Koks, 2 (70), pp. 46-48. (in Latvian).
3. Bērmanis R., Ek T. (2003) Inventory of Woodland Key Habitats in Latvian State Forests. Final Report 1997 – 2002, Riga, 75 p.
4. Bojāre D., Gailis J., Kabucis I., Kalniņš M., Lārmanis V., Petriņš A., Priednieks J., Rudzīte M., Vilka I. (2006) Sugu un biotopu aizsardzība mežā (Species and Habitats Protection in Woodland) Dabas aizsardzības pārvalde, Riga, 96 p. (in Latvian).

5. Donis J., Bambe B., Barševskis A., Meiere D., Pilāte D., Piterāns A., Straupe I. (2004) Dabisko meža biotopu monitoringa metodikas izstrāde un aprobācija (The Elaboration and Approbation of the Methods of the Monitoring of the Natural Woodland Habitats) Salaspils, 70 p. (in Latvian).

6. Ek T., Suško U., Auziņš R. (2002) Mežaudžu atslēgas biotopu inventarizācija (Inventory of Woodland Key Habitats) Riga, 76 p. (in Latvian).

7. Fisher N.I. (1993) Statistical Analysis of Circular Data. Cambridge University Press, 277 p.

8. Johannesson J., Ek T. (2005) Multi-purpose Management of Oak Habitats. Sweden, Norköping. 101 p.

9. Johansson T. (2005) Dabisko meža biotopu apsaimniekošanas vadlīnijas (The Guidelines of Management of Woodland Key Habitats) Riga, 36 p. (in Latvian).

10. Lõhmus P. (2005) Forest Lichens and Their Substrata in Estonia. Dissertationes Biologicae Universitatis Tartuensis 107. 31 p.

11. McCune B. (2000) Lichen Communities as Indicators of Forest Health. The Bryologist 103, p. 353-356.

12. Nash T.H.III, Wirth V. (1988) Lichens, Bryophytes and Air Quality. Bibliotheca Lichenologica 30, J.Cramer in der Gebruder Borntraeger Verlagsbuchhandlung, Berlin-Stuttgart. 297 p.

13. Paura L., Arhipova I. (2002) Neparametriskās metodes. SPSS datorprogramma. (Non-parametric Methods. Computer Programme SPSS) Jelgava, LLU, LKC, 148 p. (in Latvian).

14. Piterāns A. (2001) Latvijas ķērpju konspekts. (The Conspectus of Lichens in Latvia) In: Latvijas veģetācija, 3. Riga, pp. 5–46. (in Latvian).

15. Piterāns A. Žeiviniece A. (2000) Lichens in the Reserves and Other Important Woods of Eastern Latvia. - Folia Cryptogamica Estonia, 37, pp. 79-84.

16. Priedītis N. (1999) Latvijas mežs: daba un daudzveidība (The Forest in Latvia: Nature and Diversity) Rīga, WWF, 209 p. (in Latvian).

17. Read H. (2000) Veteran Trees: a Guide to Good Management. Peterborough, English Nature, Countryside Agency and English Heritage, 131 p.

18. Sillett S.C., Goslin M.N. (1999) Distribution of Epiphytic Macrolichens in Relation to Remnant Trees in a Multiple-age Douglas-fir Forest. – Canadian Journal of Forest Research, 29, pp. 1204-1215.

19. Sõmermaa A. (1972) Ecology of Epiphytic Lichens in Main Estonian Forest Types. Tartu, 117 p.

20. Straupe I., Donis J. (2006) The Lichenoindicative Evaluation of Pine Natural Woodland Habitats. International Scientific Conference Proceedings. Jelgava, pp. 276 – 283.

21. Strods H., Zunde M., Mugurēvičs Ē., Mugurēvičs A., Liepiņa Dz., Dumpe L. (1999) Latvijas mežu vēsture (The History of Forests in Latvia) Riga, 364 p. (in Latvian).

22. Uliczka H., Angelstam P. (1999) Occurence of Epiphytic Macrolichens in Relation to Tree Species and Age in Managed Boreal Forest. Ecography 22: Copenhagen, pp. 396-405

23. Van Herk C.M. (1999) Mapping of Amonia Pollution with Epiphytic Lichens in the Netherlands. - Lichenologist, 31(1): 9-20.

24. Vera F.W.M. (2000) Grazing Ecology and Forest History. CABI Publishing, 528 p.

25. Will-Wolf S., Esseen P.-A., Neitlich P. (2002) Monitoring biodiversity and ecosystem function: forests. In: Monitoring with Lichens-Monitoring Lichens. Nimis P.L., Scheidegger C., Wolseley P.A. (eds.), pp. 203-222.

26. Wirth W. (1992) Zeigerwerte von Flecten. In: Ellenberg H. et al. Zeigerwerte von Pflanzen in Mitteleuropa. Scripta geobotanica 18. (Aufl.) Verlag Erch. Goetze, pp. 215 – 237.

27. Znotiņa V. (2003) Epiphytic Bryophytes and Lichens in Boreal and Northern Temperate Forests. Proceedings of Latvian Academy of Sciences, Vol. 57, No.1/2 (624/625), pp. 1-10.

LANDSCAPE ARCHITECTURE

EVALUATION CRITERIA OF PROTECTED LANDSCAPE AESTHETIC QUALITY

Daiga Zigmunde
Latvia University of Agriculture
E-mail: daiga.zigmunde@llu.lv

Abstract

The study focuses on protected landscape aesthetic quality assessment where the main problem is how to associate aesthetical and ecological approaches. High ecological quality does not often correlate with high landscape aesthetic quality, and this relationship may differ depending on specific ecosystem. The landscape aesthetic quality assessment historically developed on two approaches. One of them – expert approach which has dominated in landscape planning and management practice, and the second – perception approach which has dominated in research. In protected landscape aesthetic quality assessment traditional approaches will be revised by ecology and green philosophy aspects. The study example regards important natural and protected areas around river Lielupe - from Jelgava city to Kalnciems. This is the landscape with high heritage, natural, biological values and it is also living, recreation place for people. Therefore, cooperation between aesthetic and ecological approaches in landscape assessment is needed. The outdoor investigations were carried out in autumn 2006. There were photographs and video materials on the first stage of investigation. In the second part aesthetic quality of views was analyzed with expert approach. There were three main groups of evaluation criteria of protected landscape aesthetic quality. These covered design and compositional outlines – features, their quality and relationship among these features. The results showed that not all criteria are suitable and effective for evaluation of protected landscape aesthetic quality because of restriction of specific ecological conditions.

Keywords: landscape aesthetics, protected area, landscape preference, evaluation criteria, aesthetic quality.

Introduction

The Significance of Visual Aspects

The visual aspect is just one landscape quality among many others. We perceive the landscape and our surrounding environment through the use of our senses. Sight interacts with other senses, such as hearing, smell and touch, but it is considered to be the most important, contributing to 80% of our impression of our surroundings. However, since most people base their experience of their environment primarily on their visual senses it is an important quality for people (Figure 1.) (Ode, 2003; Ziemeļniece, 1998;

Яргина, 1991).

Within the field of landscape aesthetics there are various theoretical approaches that explain people's reactions to and preferences for landscape. However, taking visual aspects into account in the landscape management and planning is not sufficient in creating well-liked landscapes. It is also about providing means of discussing and analyzing the existing landscape, as well as methods for evaluating changes caused by natural processes or management and planning actions. Approaches for analyzing and describing the landscape based on its aesthetic quality have been of interest in landscape research, with several
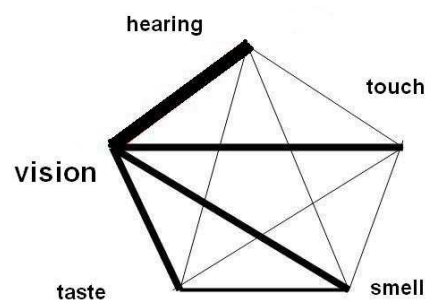

Figure 1. Intensity of perception.

approaches presented (Ode, 2003).

Aesthetic Quality Assessment

In order to take visual aspects into account there is a need to have tools and approaches for analyzing and describing theem. Over the last half – century landscape quality assessment is regarded from two different approaches. One of them is an expert or design approach which is used mostly in landscape planning and management practice (Bells and Nikodemus, 2000; Briņķis and Buka, 2001; Buka and Volrats, 1987; Kundziņš, 2004; Leymarie, 2001). This approach describes the visual component in landscape through the use of visual concepts that describes the spatial pattern of the landscape, and often uses visibility analysis of different land cover for evaluation of changes in the visual quality of the landscape (Ode, 2003). The second one is the perception – based approach, and it has been developed and used mainly in applied environmental perception and landscape assessment research (Bells and Nikodemus, 2000; Ellis and Ficek, 2001; Kaltenborn and Bjerke, 2002; Koole and Van den Berg, 2006; Melluma and Leinerte, 1992; Ode, 2003). Both approaches share the basic conception of landscape quality in which biophysical features of the landscape and human perception and experience are essential interacting components. Landscape quality arises from the relationship between properties of the landscape and the effects of those properties on human viewers. The expert and the perception – based approaches differ in how relevant features of the landscape are represented, and importance of the contribution of the human viewer in determining landscape quality levels (Daniel, 2001).

The subjective and objective approaches differ significantly in their rational for explaining and evaluating landscape visual quality. However, they are similar in that they evaluate the same landscape, with the same patterns found within, using the same type of the main medium for perception – the vision. Both the subjective and objective approaches could contribute to the development of concepts for describing visual quality (Ode, 2003).

The Expert or Design (objective) Approach

The objective approach focuses on the physical appearance of the landscape. The expert or design approach has its foundation in design theories, linking the description of landscape with terms developed in the aesthetic philosophy and art, and later transferred to a landscape context.

The aim of the approach has been to provide a language to describe the landscape with regards to aesthetic qualities, mainly in relation to design, planning and assessment. By this approach the biophysical features of the landscape (mountains, lakes, trees, etc.) are translated into formal features (e.g. form, line, texture, color) and relationships among these features (e.g. variety, unity, harmony). Then, following prescribed rules and guidelines, areas are ranked from low to high quality. At a deeper level it might be argued that the formal design parameters on which the assessment of landscape aesthetic quality is based are derived from classical or historical analyses or theories of human aesthetic perception and evaluations. Within the expert or design approach several concepts exist to explain the visual quality, both with regards to the physical attributes of elements but also their interrelationship (Ode, 2003; Daniel, 2001; Kundziņš, 2004).

The Perception – based (subjective) Approach

The perception – based approach embraces subjective philosophical point of view. For the subjective approach the focus is on the provision of psychological explanation to preferences and hence focusing on the responses (Ode, 2003). This approach treats biophysical features of the landscape as stimuli that evoke aesthetically relevant psychological responses through relatively direct sensory – perceptual processes, for example, legibility, mystery, safety etc. Perception-based methods clearly emphasize the human viewer side of the landscape quality interaction. Various survey methods are applied to obtain measures of perceived landscape aesthetic quality. Indices of perceived landscape quality are based on choices, ratings of landscapes provided by samples of actual or potential human viewers. Different views of landscape usually represented by photographs (Daniel, 2001).

Aesthetics and Ecology

Our society is becoming more and more urbanized. Urbanization is not only affecting the urbanized areas, urban processes exert an influence on the surrounding landscape. These urban processes cause different spatial pattern in the landscapes as compared to the unaffected rural area. The process of urbanization has lead to a decrease in available green spaces within the city and hence put pressure on the existing natural territories near the cities. Natural protected areas near cities is an important component of people's everyday environment, both as an attractive environment to visit as well as being a part of the

surrounding landscape. Green areas have been proven to have positive effects on people's health and reduce stress level.

Visual aspect is a feature that is significant for most people experience of the landscape and an important parameter of the naturally protected areas which are located near people's living, working and recreational areas and can be strongly influenced by urban processes. Through its location near the urban landscape it is a natural territory that people experience on a daily basis, making the visual appeal of this territory important. Management and planning for visual aspects in these territories provide one important approach for creating enjoyable environments and is also means for attracting people to recreation, education and contact with nature (Ode, 2003; Tyrväinen et al., 2003).

The Ecological Aesthetic links aesthetics with ethics and sustainability. At its base, it relates to the moral consideration for aesthetic. This approach is emphasizes the role of preconception and knowledge, particularly in relation to the ecosystem sustainability, and the need for the understanding of what is perceived as being good for the creation of an ecologically healthy landscape. The ecological aesthetic provides a link between ecology and aesthetics where our aesthetic experience is linked to our ethical values. It has placed focus on ecologically stable landscapes, stressing the appreciation of naturalness (Ode, 2003; Chenoweth, 1990; Thompson, 1999).

The aim of the study

Evaluation criteria of landscape aesthetic quality created by using expert or design approach are objective and clearly understandable. Therefore they have been used in study example. The aim of the study has been to explore which of those evaluation criteria of landscape aesthetic quality are appropriate for protected landscape assessment, and their role in landscape quality changes.

Materials and Methods

Object of the Study

The study example surveys important natural and protected areas around the river Lielupe - from Jelgava city to Kalnciems (Figure 2.). Lielupe is the second biggest river in Latvia. It is one hundred nineteen kilometers long and has two hundred fifty tributaries. There are different
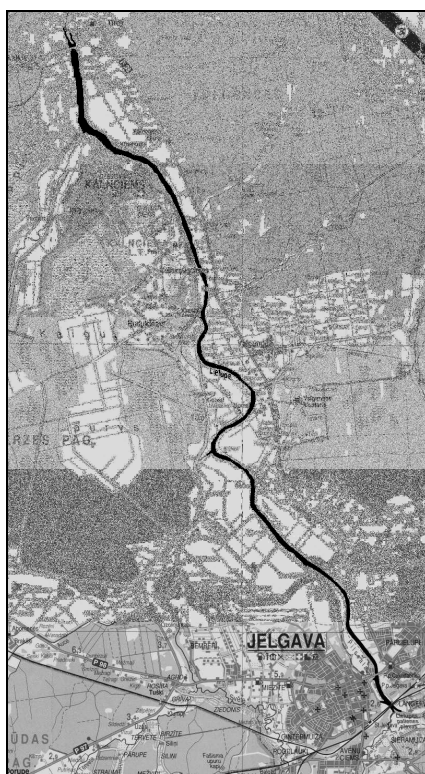

Figure 2. Location of study area of river Lielupe.

Figure 3. Characteristic natural landscape features – trees.

protected and also cultural areas near river in area from Jelgava to Kalnciems. These are landscapes with high heritage, natural, biological values and also living, recreation place for people. There is one important restricted area – ornithological reserve which is located in Jelgava city and may be accessible place for people ecological education and recreation. Other interesting areas for people are bangs of river with wild natural landscape (Žukova, 2001). There are a lot of possible activities connected with fishing, swimming and other recreational resources.

Methods

The outdoor investigations were carried out in autumn 2006, and two main methods to collect data were used. First, the photographs with a digital camera were taken in different weather conditions – sunny, cloudy and rainy days, and broad daylight. Second, the video material from the same places as photographs was taking. It was a help to sense more of sensations in landscape, such as sounds, feel of whole surrounding, weather conditions.

The role of the human viewer is acknowledged at one level by the importance of viewpoints, locations the viewers see the landscape. Therefore, all the photographs were taken from places accessible and visible to general public for a better and more complete analysis of the site and views (Daniel, 2001; Ziemeļniece, 1998). These were views from the main traffic and smaller roads, recreation routs used by tourists, fishermen and swimmers.

From 300 photos, 20 most typical slides for the landscape aesthetic quality assessment were chosen. The criteria for preference were quality aspects of the photographs: contrast, darkness, lightness, colors, absence of the sunlight and smudgy defects; typicality or representation of

area; and specific elements or actions represented on slides (Gracia Perez, 2002; Rodiek and Fried, 2004; Kaltenborn and Bjerke, 2002; Koole and Van den Berg, 2006).

Expert Questionnaire

Two experts – landscape planning professionals - analyzed selected photographs in auditorium. The expert or design approach was used in aesthetic quality analyzing process of the landscapes represented in views. There were three main groups of evaluation criteria of protected landscape aesthetic quality. These covered design and compositional outlines.

First group was the presence of characteristic or non-characteristic landscape features. The characteristic features in protected areas are natural elements (Figure 3): trees, bushes, meadows, water features and others. Non-characteristic features are man-made elements – buildings, communication constructions and others (Figure 4.).

The second criteria group was quality of landscape features. These were translating into formal design parameters which assumed to be universal indicators of landscape quality from classical models of human perception and aesthetic judgment (Daniel, 2001; Hehl-Lange, 2001). The parameters were analyzed by composition outlines: form, color, texture, scale, temporal and spatial movement. These qualities are more marketable in the natural protected areas than urban areas because of domination of natural features (Figure 5.). These are more changeable in temporal and spatial scale than man-made structures in urban areas (Kundziņš, 2004).

The third criteria group was relationships among landscape features and unity with surrounding landscape. These were rhythm,
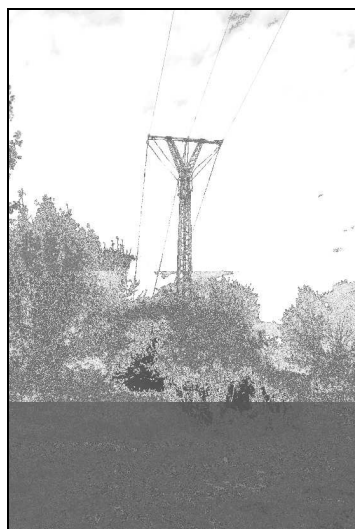
Figure 4. Non characteristic natural landscape feature - communication construction.

proportion (Figure 6.), symmetry, harmony (Figure 7.), arrangement in space (e.g. foreground, background etc.).

Results and Discussion

Evaluation criteria

In first group of evaluation criteria - presence of characteristic or non characteristic landscape features – results showed that landscape aesthetic quality was more influenced by:

- From characteristic landscape features – Lielupe River together with small water elements in surrounding landscape (Figure 6.). This was specified as positive element in the protected landscape. Either, most of characteristic landscape features were detected as positive in aesthetics.

- From non-characteristic landscape features – communication structures (mainly – high – tension electricity transmission) (Figure 4.). These and often different other man-made elements (e.g. post soviet architectural buildings, roads, etc.) were negative aspects in the landscape.

In the second group - quality of landscape features – results were mostly positive because of dominance of natural elements in the landscape. Natural elements (Figure 3.), such as trees, bushes, terrain, etc., have great diversity in all of their parameters – color, form, texture and others. That positively affects evaluation level of protected landscape aesthetic quality.

The third criteria group was the most controversial, because of non-correlation in many episodes between aesthetic and ecology in

Figure 5. Parameters of landscape features – texture and color.

Figure 6. Relationships among landscape features – criterion - proportion.

Figure 7. Relationships among landscape features – criterion - harmony.

Figure 8. Controversy between aesthetic (low) and ecology (high biodiversity).

aspect of relationship among landscape features. Harmony was positive criterion in assessment theory of aesthetic quality, but in many cases from ecological point of view more appropriate level of harmony was chaos which is the lowest rating of this criterion. Especially it covered territories with high biodiversity (decaying trees and branches, overgrow of vegetation, etc.) (Figure 8). Similar experience was observed with criteria – rhythm and symmetry which in higher evaluation level were rarely finned in relationship among protected landscape features. These were more appropriate for urban landscapes.

Some Recommendations for Future Prospects

Developed further it becomes possible to compare sites and analyze changes over time with regards to visual quality, and hence be an important complement to other types of indicator data used (ecological and recreational).

Conclusions

It is important to include ecological criteria such as increase of biodiversity and naturalness next to landscape's aesthetic quality as a criterion for environmental planning and management. It has become more substantial in protected landscape planning and management where aesthetics should be distinguished from ecological values.

However, there is an extra need for further investigation of the linkage between the aesthetic and ecological aspects and their attributes in order to identify the most significant parameters which can be used in creating evaluation criteria of protected landscape aesthetic quality.

References

1. Bells S., Nikodemus O. (2000) Rokasgrāmata meža ainavas plānošanai un dizainam (Forest Landscape Planning Handbook), Rīga, Valsts Meža dienests, 76 p. (in Latvian).
2. Briņķis J., Buka O. (2001) Teritoriālā plānošana un pilsētbūvniecība (Territorial Planning), Rīga, TU, 219 p. (in Latvian).
3. Buka O., Volrāts U. (1987) Pilsētbūvniecība (Urban Planning), R: Zvaigzne, 251 p. (in Latvian).
4. Chenoweth R.E., Gobster P.H. (1990) The Nature and Ecology of Aesthetic Experiences in the Landscape. Landscape Journal, 1, pp. 1-9.
5. Daniel T.C. (2001) Whither Scenic Beauty? Visual Landscape Quality Assessment in 21st Century. Landscape and Urban Planning, 54, pp. 267-281.
6. Gracia Perez J.D. (2002) Ascertaining Landscape Perceptions and Preferences with Pair-wise Photographs: Planning Rural Tourism in Extremadura, Spain. Landscape Research, 3, pp. 297-308.
7. Ellis L., Ficek C. (2001) Color Preferences According to Gender and Sexual Orientation. Personality and Individual Differences, 31, pp. 1375-1379.
8. Hehl-Lange S. (2001) Structural Elements of the Visual Landscape and their Ecological Functions. Landscape and Urban Planning, 54, pp. 105-113.
9. Kaltenborn B.P., Bjerke T. (2002) Associations Between Environmental Value Orientations and Landscape Preferences. Landscape and Urban Planning, 59, pp. 1-11.
10. Koole S.L., Van den Berg A.E. (2006) New Wilderness in the Netherlands: An Investigation of Visual Preferences for Nature Development Landscapes. Landscape and Urban Planning, 78, pp. 362-372.
11. Kundziņš M. (2004) Dabas formu estētika (Aesthetics of Forms in Nature), Rīga, SIA Madris, 168 p. (in Latvian).
12. Leymarie F.F. (2001) Art and Visual Perception by Rudolph Arnheim. USA, pp. 10 , http://www.lems.brown.edu/vision/people/leymarie/Refs/VisualArt/Arnheim/ArtVisualPercept.pdf, 22.03.2007.
13. Melluma A., Leinerte M. (1992) Ainava un cilvēks (Landscape and Man), Rīga, Avots, 175 p. (in Latvian).
14. Ode Å. (2003) Visual Aspects in Urban Woodland Management and Planning. Doctor's dissertation, Alnarp
15. Rodiek S.D., Fried J.T. (2004) Access to the Outdoors: Using Photographic Comparison to Assess Preferences of Assisted Living Residents. Landscape and Urban Planning, 73, pp. 184-199.
16. Thompson I.H. (1999) Ecology, Community and Delight, E&FN Spon, London, UK, 188 p.
17. Tyrväinen L., Silvennoinen H., Kolehmainen O. (2003) Ecological and Aesthetic Values in Urban Forest Management. Urban Forestry & Urban Greening, 1, pp. 135-149.

18. Ziemeļniece A. (1998) Estētiskā kvalitāte ainaviskajā telpā (Aesthetical Quality in Landscape Space), Jelgava, Latvia University of Agriculture, 98 p. (in Latvian).

19. Žukova Z. (2001) Latvijas zili zaļā rota (Blue Green Adornment of Latvia), Rīga, Jumava, 330 p. (in Latvian).

20. Яргина З.Н. (1991) Эстетика города (Aesthetics of City), Maskava, Стройиздат, 367 с. (in Russian).

WATER MANAGEMENT

INVESTIGATIONS OF THE APPLICATION OF MINERAL FILTERS FOR WASTEWATER TREATMENT ON A FARMSTEAD

Zenonas Strusevičius, Sigita Marija Strusevičienė

Water Management Institute of Lithuania University of Agriculture

E-mail: zenonas@water.omnitel.net

Abstract

Highly polluted wastewater is formed on private farms. The wastewater contains N_{total} and P_{total} concentrations up to 150 mg l^{-1} and 30 mg l^{-1} respectively, which is 2-3 times higher than that contained in domestic wastewater.

During the biological treatment of wastewater the removal of organic pollutants (BOD_5- biochemical oxygen demand, and SS – suspended solids) is about 96% and the treatment efficiency satisfies the environment protection standards. However, the removal of biogenic pollutants is only 55%, thus the residual pollution with biogenic substances exceeds the maximum allowable rate according to N_{total} and P_{total} for wastewater released into the environment.

Currently, different natural and artificial powdery mineral materials (zeolite, filtralite, etc.) containing metals and carbon compounds are transported into Lithuania. Such materials could be used as N_{total} and P_{total} adsorbing filters.

In respect of the filter load with pollutants, biologically pre-treated wastewater treatment efficiency of N_{total} and P_{total} was determined to be from 50 to 91% and from 49 to 90% respectively.

Having filtrated the wastewater through a filter containing 50% of zeolite and 50% of filtralite, N_{total} and P_{total} removal efficiency was fluctuating from 28 to 60% and from 23 to 70% respectively.

Having made the investigations with different loads of minerals, it was determined that N removal is more efficient in the zeolite mineral filter, while P removal is more efficient in the filtralite filter. In order to reach the best results of biogenic pollution removal, both mineral mixtures should be used for the load of the filter.

Keywords: wastewater, biogenic matter, filtralite, zeolite.

Introduction

In dairy farms during the washing process of the equipment and milk refrigerators, highly polluted wastewater is formed containing N_{total} and P_{total} concentration several times higher than that contained in domestic wastewater. As the experience has shown, during the biological treatment of wastewater it is impossible to reduce the initial N_{total} and P_{total} concentrations (15-30 mg l^{-1} and 100-150 mg l^{-1} respectively) to the their allowable rates from the environment protection point of view (4.0 mg l^{-1} and 30 mg l^{-1} respectively) (Dauknys and Matuzevičius, 2000).

In 2000-2003, we carried out the investigations and determined that wastewater pollution index according to BOD_5 was from 800 to 900, and the ratio BOD_5/P_{total} was 30-36. When treating biologically the wastewater from a dairy farm with high initial pollution coefficient and insufficient ratio BOD_5/P_{total}, phosphorus concentration in pre-treated wastewater reaches 12.6 mg l^{-1} (Strusevicius and Strusevicienė, 2003).

Currently, researchers are trying to discover the methods of P removal from biologically treated wastewater before their release into the environment. P- adsorption methods are most popular and most often used (Kinga et al., 2003).

Some of the authors (Johansson, 1998; Lookman et al., 1994) have made experiments with substances in order to discover a medium ensuring a long-term P-removal process. The scientists have used different methods to calculate the operating age of the filters. Other authors have been trying to define the relation between the properties of mineral matter and P removal. Special boxes have been constructed for the investigations: a small part of the filters of horizontal flow has been taken where P removal processes and kinetics have been modelled.

In 2002, we made the investigative laboratory experiments trying to use calcite macadam (CA) produced in Lithuania (Akmenė district) containing more than 54% of Ca, Al and Fe compounds that are able to adsorb phosphorus. As the study results have shown, when wastewater is filtered through the CA filter, P adsorption is rather slow. About 90% of phosphorus are removed during 5-day filtration period. Such a long retention of wastewater in the CA filter is not acceptable from the technological point of view.

Currently, different natural and artificial powdery mineral materials (zeolite, filtralite, etc.) containing metals and carbon compounds are imported into Lithuania. Such materials could be

used as N_{total} and P_{total} adsorbing filters.

The objective of the work was to estimate N_{total} and P_{total} removal efficiency from biologically treated wastewater when the wastewater is filtered through different mineral filters.

Materials and Methods

The study object was arranged on A. Visockas farm (Kirdonys village, Biržai district). Here the wastewater forms in a living house of 7 people (domestic wastewater) and on a dairy farm (100 units of milking cows and 50 units of small domestic animals). The farm has the Alfa-Laval milking line and a 2.0 m^3 refrigerator with automatic washing systems arranged. During the 24 hours, the amount of domestic wastewater forms 0.7-1.2 m^3, the amount of wastewater from washing the premises and equipment forms 0.2-0.7 m^3 (0.9-1.9 m^3 in all). The highest wastewater discharges have been determined during the washing of premises (0.9 l s^{-1}). The duration of wastewater flow during a day was determined to be from 2.32 to 3.18 hour.

Wastewater treatment facilities were arranged on this farm (a multi-chamber septic + constructed wetlands) even in 1998, according to the technology of Water Management Institute of Lithuanian University of Agriculture.

After the biological treatment process, the wastewater is filtering into the soil. In June 2004, an experimental mineral filter was constructed nearby the wastewater treatment facilities for N and P removal from biologically pre-treated wastewater (Fig. 1).

The efficiency of nutrient removal from wastewater was investigated having taken wastewater samples from all wastewater treatment stages: before treatment, after primary treatment in a multi-chamber septic tank, after biological treatment (i.e. from wastewater supplied into a new experimental mineral filter), and after filtration through a mineral filter.

During the study period, with the help of a valve the flow of wastewater into the mineral filter was changed, which gave possibility to model the efficiency of nutrient removal under different loads of the filter. The volume of the filter media was 0.4 m^3.

The investigations of nutrient removal from wastewater have been carried out in two stages. In the first stage (June-September 2004) the investigations in the zeolite filter (CE) were performed within a period of four months. After this stage of investigations, 50% of zeolite were removed from the filter, and the filter was filled up with filtralite (FLP) instead. The investigations with a two-layer filter load were started on the 4th of October and lasted during the year 2005. Wastewater samples for the investigations were taken every month.

Zeolite (CE) is natural mineral from Sokirnica Pool in Ukraine. It belongs to aluminium silicates containing about 70-75% of clinoptilot. The empirical formula of clinoptilot is M_e [(AlO$_2$)(SiO$_2$)y]zH$_2$O (M_e metal, y and z – coefficients). Aluminium and silicon oxides make up about 85% of the mineral, calcium, potassium, magnesium, iron and other microelements make up about 15%. Due to higher ion changing ability (1.5 mg-ekv g^{-1}), this mineral is often used as a sorbent for gas and air filtration. There is sufficient data about the usage of this mineral in forage additives.

Filtralite (FLP) is a product of course clay particles created especially for the adsorption of phosphorus. Clay particles were burnt in a special rotating furnace at the temperature of 1200 °C (Zhu et al., 1998). At such temperature the density of burning clay highly increases. Volume mass reaches 600-800 kg m^{-3}, and filtralite composes small particles of 0-4-mm diameter. In such a way the same amount of filtralite is distributed over the whole surface area, which ensures rather sufficient removal process of the pollutants. This mineral is produced and mostly used in Norway. Currently, the company 'Optiroc'
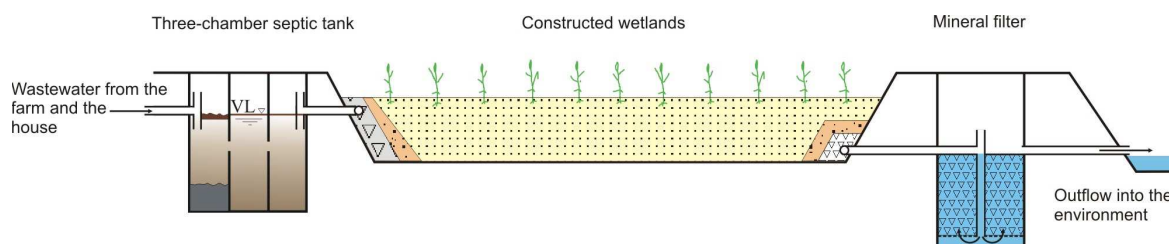

Figure 1. Technological scheme of industrial- domestic wastewater treatment on a dairy farm.

has emerged into other European countries, such as Sweden, Estonia, and Spain.

Composition of both minerals used for wastewater filtration are presented in Table 1.

During the filtration through the mineral filter, nutrient pollutants are removed at the end of the chemical reaction and biological processes. P and N join metals and form insoluble salts, such as Ca $(NO_3)_2$, $Ca_3(PO_4)_2$, Ca_4H $(PO_4)_3$, etc. (Strusevičius, 1996; Dauknys and Matuzevičius, 2000).

As the Czech researcher Kadlec has determined, N removal is limited by the anaerobic processes prevailing in the environment (Kadlec and Knight., 1996).

The main physical characteristics of minerals are given in Table 2.

Wastewater samples were taken from different wastewater treatment stages. The samples were investigated in the Chemical Analysis Laboratory of the Water Management Institute of Lithuanian University of Agriculture certified by the Environment Ministry of the Republic of Lithuania. The following indices have been determined:

- pH – by a potentiometric method using a glass electrode;
- BOD_5 – by a titrometric method (Vincler);
- suspended solids (SS) – by a gravimetric method, having filtered the substance through a mid-thickness filter;

- N_{total}– by a titrometric way, having burnt the material (Kjeldal method);
- N-NH_4– by a spectrometric method;
- N-NO_2 – by a spectrometric method;
- P_{total} – photo colorimetric method, having burnt the substance;
- PO_4-P – by a colorimetric method, with ammonia molybdate and ascorbic acid;
- COD_{Cr}– by an oxidation method, with potassium bichromate and sulphur acid.

Having determined the wastewater discharges and pollutants concentrations contained in wastewater inflowing the filter, the loads of the mineral filter with A pollutants ($g\ m^{-3}\ d^{-1}$) were calculated. The pollutants treatment efficiency E (%) was calculated according to the following formula:

$$E = \frac{C_0 - C_e}{C_0} \cdot 100, \qquad (1)$$

where C_0 – pollution concentration in wastewater flowing into the filter, mg l^{-1};

C_e – pollution concentration in wastewater, flowing out of the filter, mg l^{-1}.

The data of investigations and calculations was analyzed with the help of correlation analysis.

Results and Discussion

During the whole study period, wastewater for the laboratory analysis was taken 10 times from different treatment stages ($n = 10$).

Table 1

Chemical composition of filtralite (FLP) and zeolite (CE)

Chemical Components	Measure unit	Filtralite (FLP)	Zeolite (CE)
CaO	%	30.0	2.1
SiO_2	%	62.0	71.5
Al_2O_3	%	18.0	13.1
FeO	%	7.0	0.9
MgO	%	3.0	1.07
K_2O	%	4.0	2.5
Na_2O	%	2.0	2.5
P_2O_5	%	-	0.033
C	%	0.02	-
As	mg kg^{-1}	0.75	15.0
Cd	mg kg^{-1}	<0.4	-
Cr	mg kg^{-1}	8.9	-
Cu	mg kg^{-1}	5890.0	200.0
Hg	mg kg^{-1}	<0.015	-
Ni	mg kg	9.3	-
Pb	mg kg	<4.0	20.0

Table 2

Physical characteristics of minerals FLP and CE

Mineral	Diameter of d_{10} particles, mm	Diameter of d_{60} particles, mm	CU (d_{60}/d_{10})	Porosity, P%	Bulk density, kg m^{-3}	Specific area, m^{-1}
FLP	0.3	2.13	7.1	65.0	580.0	51000.0
CE	2.89	4.33	1.49	43.6	1232.0	770.0

Systemized and statistically processed data of wastewater composition in different treatment stages is presented in Table 3. As it can be seen, before the treatment process the wastewater is highly polluted with organic matter as with nutrients and is distinct for slightly acid or nearly neutral reaction (pH – 6.8 ± 0.34). According to the concentrations of organic matter and suspended solids, biologically pre-treated wastewater (Table 3, column 4) satisfies the maximum allowable concentrations for wastewater outflow into the environment (Aplinkosaugos reikalavimai .... 2001): BOD_5 – 30.0 mg l^{-1} O_2, SS – 35.0 mg l^{-1}.

However, after the biological treatment, the wastewater still contains large amounts of biogenic pollutants (N_{total} – 34.4 mg l^{-1}, P_{total} – 11.9 mg l^{-1}).

The investigations of biological treatment of wastewater in a zeolite filter were started on the 4th of June 2004. Different discharges of wastewater supplied into the zeolite filter resulted in a different load of the filter with biogenic pollutants. Changing the wastewater discharge from 0.2 to 1.9 m^3 d^{-1}, the load of the filter according to nitrogen was fluctuating from 14.0 to 140.0 g m^{-3} d^{-1}, whereas according to phosphorus -from 6.5 to 75.0 g m^{-3} d^{-1}.

During the second stage of the investigations (filter load was 50% CE and 50% FLP), different pollution loads of the filter were investigated as well. Having changed the discharges of wastewater supplied into the filter from 0.3 to 1.8 m^3 d^{-1}, the load of the filter according to N_{total} and P_{total} was changing from 28.0 to 117 g m^{-3} d^{-1} and from 14.2 to 50.0 g m^{-3} d^{-1} respectively.

The dependencies of N_{total} and P_{total} removal efficiency on the load of filters with pollutants are presented in Figures 2 and 3.

As Figures 2 and 3 show, the removal of biogenic pollutants in the zeolite filter depended on its pollution load. The highest loads of the filter with nitrogen (110.0-140.0 g m^{-3} d^{-1}) and phosphorus (55.0-75.0 g $m^{-3}d^{-1}$) were determined when the whole amount of wastewater had been supplied into the zeolite filter at the rate of 1.6-1.9 m^3 d^{-1}. Under such loads of the filter, N_{total} and P_{total} removal efficiency was about 50% and 49% respectively. Having investigated the lowest loads (A) of the filter with N and P (A_N- 14.0-16.0 g m^{-3} d^{-1} and A_P–13.0–22.0 g m^{-3} d^{-1}, wastewater discharge - 0.2-0.3 m^3 d^{-1}), the removal efficiency of N and P was determined to be 91% and 90% respectively. During the filtration of wastewater through a two-mineral filter, rather good N_{total} and P_{total}

Table 3

Fluctuation of pollutants concentration during the biological treatment of wastewater

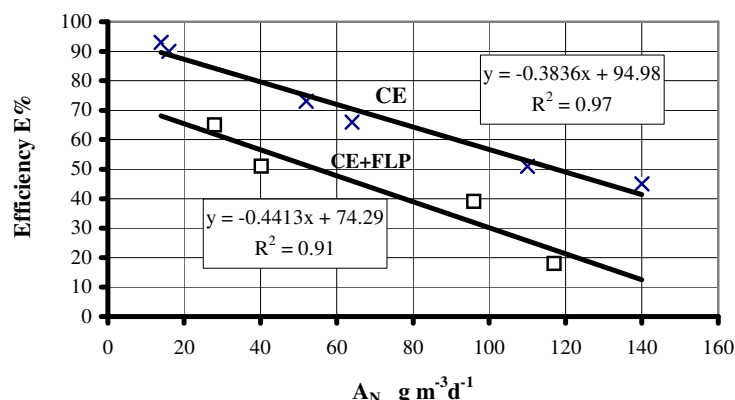| Pollutants	Measure unit	Wastewater before treatment ($n = 10$)	Wastewater after biological treatment ($n = 10$)
pH	-	6.8±0.34	7.4±0.27
BOD_5,	mg $l^{-1}O^{-2}$	631.0±195.0	28.6±8.3
COD_{Cr}	mg $l^{-1}O^{-2}$	1388.0±406.0	61.6±19.2
N_{total}	mg l^{-1}	106.9±19.3	34.4±9.6
$N-NO_2$	mg l^{-1}	1.04±0.63	0.22±0.08
$N-NH_4$	mg l^{-1}	88.2±14.4	28.4±7.1
P_{total}	mg l^{-1}	26.4±3.8	11.9±2.9
$P-PO_4$	mg l^{-1}	18.8±3.2	7.8±1.7
SS	mg l^{-1}	518.0±173.0	22.3±9.1

Figure 2. Dependence of N_{total} removal efficiency on the load of mineral filter.

removal efficiency is achieved. When the filter load of N_{total} and P_{total} is 28.0-40.3 g m^{-3} d^{-1} and 6.5-8.1 g m^{-3} d^{-1} respectively, N_{total} and P_{total} removal efficiency reaches about 60% and 70% respectively. Having investigated the lowest loads (A) of the filter with N and P (A_N– 95.0-118.0 g m^{-3} d^{-1} and A_P– 55.0-75.0 g m^{-3} d^{-1}) the removal efficiency of N and P was determined to be 28% and 23% respectively. The graphs given in Figures 2 and 3 may be used for the calculation of the parameters of filters. If there is any data about N_{total} and P_{total} concentrations contained in wastewater, it can be calculated how many per cents of those substances are to be removed in order to satisfy the normative requirements for wastewater released into the environment. Having calculated the treatment

efficiency of necessary biogenic pollutants, the exact load with nutrients can be determined. Having obtained the pollutants concentrations contained in wastewater and the filter load with pollutants, the filter volume according to N (W_N) and P (W_P) can be calculated. Higher volume of the calculated ones according N_{total} and P_{total} is accepted. The calculation is made according to the following formulas (Z. Strusevičius):

$$W_n = \frac{C_N \cdot Q}{A_N}, \qquad (2)$$

$$W_p = \frac{C_P \cdot Q}{A_P}, \qquad (3)$$

where C_N and C_P – concentration of biogenic pollutants N_{total} and P_{total} contained in wastewater supplied into the mineral filter, g m^{-3};
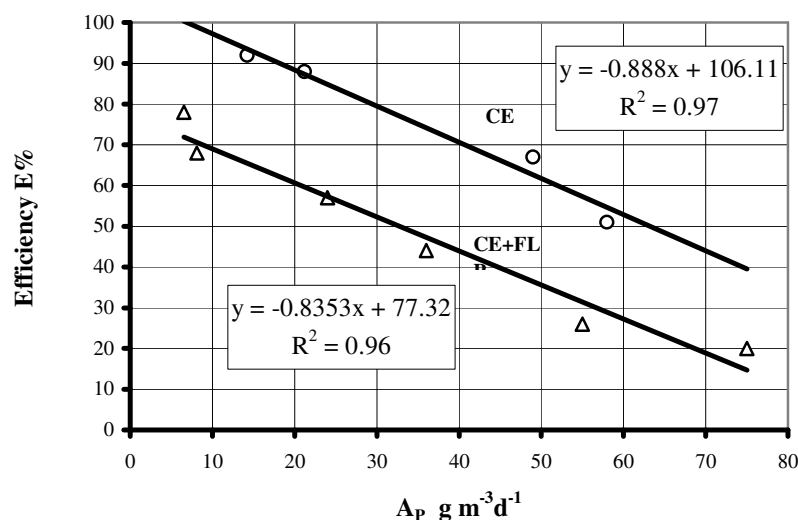

Figure 3. Dependence of P_{total} removal efficiency on the load of mineral filters.

A_N and A_P – specific filter load with biogenic pollutants N_{total} and P_{total}, g m^{-3} d^{-1};

Q – discharge of wastewater, m^3 d^{-1}.

Conclusions

Highly polluted wastewater is formed on private farms. The wastewater contains N_{total} and P_{total} concentrations up to 150 mg l^{-1} and 30 mg l^{-1} respectively, which is 2-3 times higher than that contained in domestic wastewater.

During the biological treatment of wastewater the removal of organic pollutants (BOD$_5$ and SS) is about 96%, and the treatment efficiency satisfies the environment protection norms. However, the removal of biogenic pollutants is only 55%, thus the residual pollution with biogenic substances exceeds the maximum allowable rate according to N_{total} and P_{total} for wastewater released into the environment.

In respect of the filter load with pollutants, biologically pre-treated wastewater treatment efficiency of N_{total} and P_{total} was determined to be from 50 to 91% and from 49 to 90% respectively.

Having filtrated the wastewater through a filter containing 50% of zeolite and 50% of filtralite, N_{total} and P_{total} removal efficiency was fluctuating from 28 to 60% and from 23 to 70% respectively.

Having made the investigations with different loads of minerals, it was determined that N removal is more efficient in the zeolite mineral filter, while P removal is more efficient in the filtralite filter. In order to reach the best results of biogenic pollution removal, both mineral mixtures should be used for the load of the filter.

References

1. Aplinkosaugos reikalavimai nuotėkoms tvarkyti. (2001) (Environmental requirements for wastewater handling). Žin., 10 05, Nr. 87-3054, pp. 22-29. (in Lithuanian).
2. Dauknys R., Matuzevičius A. (2000) Veiksnių, turinčių įtakos biologiniam fosforo šalinimui iš nuotekų, eksperimentiniai tyrimai. (Experimental investigations of factors affecting the biological P-removal from watewater). Aplinkos inžinerija. 8(3), pp. 156-167 (in Lithuanian).
3. Johansson L. (1998) Phosphorus sorption to filter substrates – Potential benefits for onsite wastewater treatment, In Departament of Civil and Environmental Engineering, Royal Institute of Technology. Kungl Tekniska Högskolan, Stockholm, pp. 78-83.
4. Kadlec R.H.; Knight R.L. (1996) Treatment Wetlands. Lewis Publishers, CRC, New York, 893 p.
5. Kinga A., Suliman F.R.D., Jessen P.D., Heistad A. (2003) Phosphorus sorption by Filtralite-P – small scale box experiment. In: Mander U., Voble Ch., Poom A (eds): Constructed and Riverine Wetlands for Optimal Control of Wastewater at Catchment Scale. Conference FP RTD PRIMROSE. Tartu, pp. 53-58.
6. Lookman R., Jansen K., Merckx R., Vlassak K. (1996) Relationship between soil properties and phosohate saturation parameters. A transect study in Northern Belgium. Geoderma 69, pp. 265-274.
7. Strusevičius Z. (1996) Nuotekų, atliekų ir mėšlo tvarkymas žemės ūkyje (Treatment of wastewater, wastes and manure in agriculture). Vilainiai, 156 p. (in Lithuanian).
8. Strusevicius Z., Strusevicienè S.M. (2003) Investigation phosphorus removal in wastewater treatment facilities on dairy farm. Water management engineering, 2003, 23(45), pp. 5-13.
9. Zhu T.M., Jenssen P.D., Maehlum T., Krogstad T. (1998) Phosphorus sorption and chemical characteristics of lightweight aggregates (LWA)-potential filter media in treatment wetlands. Water Sci.Technol. 35(5), pp. 103-108.

PECULIARITIES OF NITROGEN COMPOUNDS REMOVAL FROM WASTEWATER IN CONSTRUCTED WETLANDS

Zenonas Strusevičius[1], *Valerijus Gasiūnas*[2], *Sigita Marija Strusevičienė*[2]
[1] Lithuanian University of Agriculture
E-mail: zenonas@water.omnitel.net
[2] Water Management Institute of Lithuanian University of Agriculture
E-mail: v.gasiunas@water.omnitel.net

Abstract

The objective of the present studies has been to estimate peculiarities of nitrogen removal in constructed wetlands of different construction. In limited companies (LTD) 'Pastogė' and 'Nikola', constructed wetlands of vertical flow (VFCW) are arranged, while limited company (LTD) 'Agaras' has two-stage constructed wetlands of horizontal flow (HFCW). In all the objects the supplied wastewater is after primary treatment.

Having compared the efficiency of ammonium and nitrite nitrogen removal in two types of constructed wetlands (VFCW and HFCW) it was determined that larger amounts of total nitrogen are removed in HFCW (38.1%) rather than in VFCW (24.4%). However, in VFCW smaller amounts of ammonium and nitrite nitrogen are discharged with wastewater.

No significant effect of the fluctuations of ambient temperature on the removal of ammonium and nitrite nitrogen was observed in HFCW (difference in average values of cold and warm periods was 3-8%).

A rather reliable relation ($R^2 = 0.738$) was determined between ammonium nitrogen concentrations in wastewater outflow and HFCW load according to total nitrogen, however, ammonium nitrogen amounts in treated wastewater (when filter load according to total nitrogen is 0.3 to 4.6 g m^{-2} d^{-1}) exceeded the maximum allowable concentration (MAC) and were fluctuating from 6 to 32 mg l^{-1}.

Keywords: ammonium, constructed wetlands, nitrites, nitrogen, wastewater treatment.

Introduction

When calculating parameters of wastewater treatment facilities, the focus has been on the removal efficiency of organic matter – biochemical oxygen demand (BOD), suspended solids (SS), and biogenic N_{total} and P_{total} pollutants so far. Having evaluated scientifically the biologically treated wastewater outflow into open water bodies and its negative impact on aquatic fauna, the requirements of ammonium (N-NH$_4$) and nitrite nitrogen (N-NO$_2$) outflow with wastewater into open water bodies were restricted. Since 2002, Lithuania has transferred the basic regulations of this directive into the state's normative documents (Aplinkosaugos reikalavimai..., 2001). After those regulations came into power, additional requirements were set for wastewater treatment facilities. According to those requirements, nitrogen compounds concentration in treated wastewater outflow into open water bodies should not exceed the determined rates: N_{total} – 30.0 mg l^{-1}, ammonium nitrogen (N-NH$_4$) – 5.0 mg l^{-1}, and nitrite nitrogen (N-NO$_2$) – 0.3 mg l^{-1}.

Ammonium (NH$_4$) entering a water body with wastewater is dissociated and becomes ammonia NH$_3$ $\leftrightarrow$ NH$_4^+$.
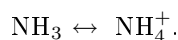
Ammonium is a particularly toxic chemical compound. Even small amounts of this element (0.0125-3.0 mg l^{-1}) contained in water are cankerous for most species of fish of cold and warm waters (Gross et al., 2003).

Intermediate products of ammonium oxidation process – nitrites (NO$_2$) – are detrimental even in relatively small concentrations (over 1.0 mg l^{-1}). For example, lethal N-NO$_2$ concentration for a rainbow trout (*Oncorhynchus mykiss*) is 1.8 mg l^{-1} after 24 hours of retention (Hagopian and Riley, 1998).

When treating wastewater biologically, during the ammonification reactions organic nitrogen N_{org} decomposes into ammonium, which in the ambience of oxygen is dissolved into nitrites and later into nitrates.

In Lithuania, the investigations of biological treatment of wastewater in constructed wetlands of different construction were started in 1994, while in other countries they were started in 1980. Recently, in Lithuania, vertical flow constructed wetlands (VFCW) as well as horizontal flow constructed wetlands (HFCW) have become popular (Strusevičienė and Strusevičius, 1994). Those wastewater treatment technologies are

less expensive from the investment as well as exploitation point of view.

Constructed wetlands of subsurface horizontal flow (HFCW) have more advantages, because in this case water is not exposed to the air during the treatment process, and energy losses during evaporation and convection are least. Therefore such filters are more suitable in winter. As the results of the studies carried out in Norway show, efficient functioning of HFCW does not depend on the climatic conditions. When wastewater flows under the ground surface, the problem of heat insulation topical in countries of cold climate is solved more easily. Moreover, filters with subsurface filtration are more attractive from the aesthetic point of view (Reddy and D'Angelo, 1994).

In HFCW, wastewater from the inflow zone is flowing in a horizontal direction through the filter body (roots of uliginous plants, rhizomes and soil) where the wastewater is treated. The functioning principle of VFCW is similar to that of HFCW, except that in VFCW wastewater is distributed at the filter surface and then filter through a 0.6-1.0 m thick sand layer vertically downwards into the collection pipes.

HFCW are widely studied in the whole world. As it is noted, such filters are particularly efficient in the removal of organic pollutants. Treatment efficiency according to BOD_7 reaches 80-98%. Nitrogen and phosphorus removal efficiency is 40-90% (Vymazal, 2001; Schierup et al., 1990; Mander and Mauring, 1997; Cooper, 1999; Kadlec and Knight, 1996).

Biological N removal processes in constructed wetlands have no significant effect on the environment. During those processes biological N compounds are transferred into N_2 gas.

First, organic N is mineralized and transferred into ammonium (NH_4) during the degradation processes of invertebrates and microbes. Then aerobic chemosynthetic nitrifying bacteria use NH_4 as a source of energy and thus produce the final product – nitrates (NO_3) (Focht and Chang, 1975). Finally, during the denitrification process (i.e., heterotrophic respiration process), NO_3, as a final acceptor of electrons, is transferred into N_2 gas.

The main ways of nitrogen removal in constructed wetlands include the mineralization of organic N, evaporation of ammonia, assimilation into the biomass, ammonium absorption into the filter background, and nitrification-denitrification processes (Reddy and D'Angelo., 1994; Kadlec and Knight, 1996). Those processes may be expressed as follows:

$$N_{org} \leftrightarrow N\text{-}NH_4 \rightarrow N\text{-}NO_3 \rightarrow NO_2 \rightarrow N_2O, N_2 \,.$$
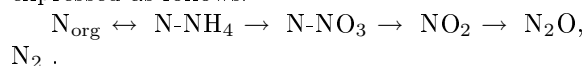
ammonification / nitrification / denitrification

From all those ways, nitrification and denitrification in anaerobic-aerobic ambience of the filter background are considered as the principle ways of nitrogen removal (Reddy and D'Angelo, 1994). Nitrogen removal with the help of vegetation and biomass or its transformation into ammonium makes up 1-34% of all removed N_{total}, while during the denitrification up to 60-95% of all N_{total} are removed (Stengel et al., 1987; Cooke, 1994).

P.F.Cooper (1999) has distinguished the following advantages and disadvantages of HFCW and VFCW systems: HFCW is more suitable for denitrification rather than for nitrification due to restricted oxygen transport abilities, whereas in VFCW, oxygen transport abilities are higher therefore nitrification processes are more

Table 1

Characteristics of constructed wetlands

Name of the object	Model of constructed wetlands	Study period	Output of wastewater treatment facilities, $m^3\ d^{-1}$	Area of constructed wetlands, m^2	Hydraulic load of filters during the study period, $m\ d^{-1}$ (min-max) $m\ d^{-1}$	Filtration coefficient of constructed wetlands, $m\ d^{-1}$
LTD 'Pastogė'	VFCW	2004 06-2006 06	4.5	250.0	0.0040–0.0970	35.5±5.9
LTD 'Nikola'	VFCW	2004 08-2006 06	5.0	300.0	0.0047–0.1000	30.6±6.1
LTD 'Agaras'	HFCW	2004 06-2006 06	100.0	1600.0	0.0096–0.0700	21.5±4.3

Table 2

Average and standard deviation of the indices of wastewater before treatment in the filters within the study period

Name of the object	mg O_2 l^{-1}	Indices, mg l^{-1}					
	BOD_7	Suspended solids (SS)	N_{total}	$N\text{-}NH_4$	$N\text{-}NO_2$	$N\text{-}NO_3$	P_{total}
LTD 'Pastogė'	91.0±26.0	78.0±20.0	93.2±16.7	79.1±14.3	0.029±0.007	0.41±0.09	12.9±4.3
LTD 'Nikola'	151.2±98.2	133.4±67.0	143.0±23.0	129.6±21.0	0.021±0.009	0.32±0.04	15.6±5.1
LTD 'Agaras'	98.6±36.4	104.0±23.0	62.3±26.0	51.0±22.0	0.030±0.010	1.10±0.76	8.9±1.7

intensive.

The objective of the work was to evaluate the efficiency of ammonium and nitrite removal from wastewater when treating it in constructed wetlands of horizontal and vertical flow.

Materials and Methods

The material of the studies carried out in experimental objects 'Pastogė', 'Nikola' and LTD 'Agaras' was used in the present research. In 'Pastogė'and 'Nikola', VFCW are arranged, while LTD 'Agaras' has two-stage HFCW. The main technical data of the experimental objects is presented in Table 1.

In all the objects wastewater is supplied into filters after primary treatment. Average indices and standard deviation of wastewater inflow into the filters are presented in Table 2.

In all the objects wastewater discharge by water meter was measured every day,and wastewater samples were taken once a month. Laboratory analysis of wastewater was made in the Chemical Analysis Laboratory of the Water Management Institute of Lithuanian University of Agriculture applying the methods certified in the European Union. Analysis of variance and regression analysis was used for the mathematical processing of data

Results and Discussion

Figures 1 and 2 present the fluctuations in total nitrogen inflow and outflow from filters as well as the changes in ammonium and nitrite nitrogen outflow from filters in the constructed wetlands of vertical flow within the study period. In LTD 'Pastogė', N_{total} concentration in wastewater inflow was fluctuating from 40 to 150 mg l^{-1}, whereas in wastewater outflow (after treatment) - from 30 to 110 mg l^{-1}. Average treatment efficiency is 24.4%. Ammonium
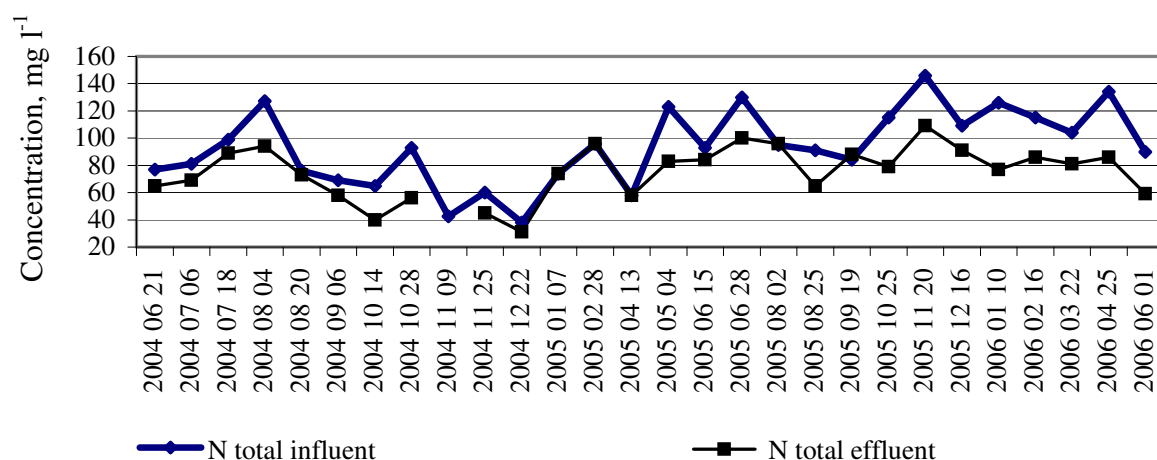

Figure 1. Pollution of wastewater inflow and outflow from the constructed wetlands according to total nitrogen during the study period in LTD 'Pastogė'.
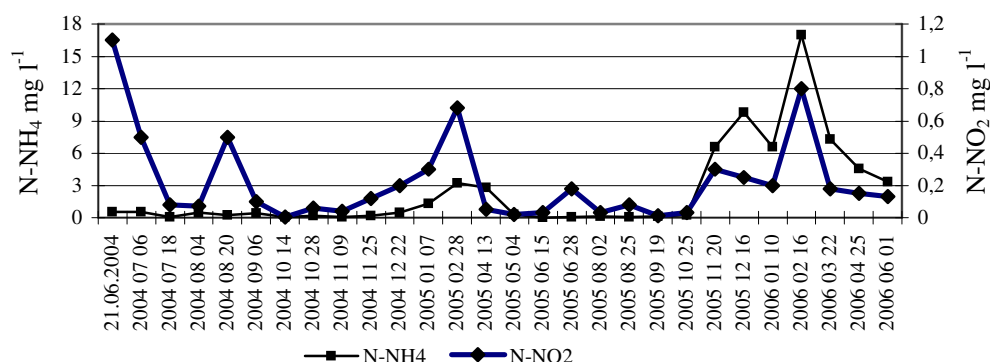
Figure 2. Pollution of wastewater outflow from the constructed wetlands according to ammonium and nitrite nitrogen within the study period in LTD 'Pastogė'.

nitrogen concentration in wastewater outflow was fluctuating from 0.1 to 17.5 mg l^{-1}, but nitrite nitrogen concentration - from 0.01 to 1.15 mg l^{-1}. The changes an ammonium and nitrite nitrogen concentrations are of a seasonal nature. During the warm period of the year (May-October), the lowest concentrations of those pollutants were observed: ammonium nitrogen - 0.4-7.5 mg l^{-1}, and nitrite nitrogen - 0.01-0.15 mg l^{-1}.

During the cold period of the year (November-April), concentrations of those pollutants were highest – ammonium nitrogen concentrations were fluctuating from 4.5 to 17.5 mg l^{-1}, and nitrite nitrogen concentrations were changing from 0.1 to 1.15 mg l^{-1}. Nitrite nitrogen amount contained in wastewater after treatment depends on the season, however, its average amount does not exceed 0.3 mg l^{-1}.

Similar fluctuations of those pollutants were observed in wastewater studied in the other object

– LTD 'Nikola' (Figs 3 and 4).

The changes in total nitrogen, ammonium and nitrite nitrogen in LTD 'Agaras' are presented in Figure 5. In this filter the effect of ambient temperature on N removal was insignificant. Having compared ammonium and nitrite concentrations in cold and warm periods of the year, 3-8% differences of the average values of the periods were determined. However, those differences are considered as insignificant. In this object, N_{total} amount in wastewater inflow was fluctuating from 30.0 to 98.0 mg l^{-1}, but in wastewater outflow (after treatment) it was changing from 12.0 to 36.0 mg l^{-1} (average N_{total} removal efficiency was 38.1%).

During the whole study period, ammonium nitrogen concentrations were fluctuating from 2.2 to 18.5 mg l^{-1}, but nitrite nitrogen concentrations were changing within the range of 0.15 to 1.4 mg l^{-1}.
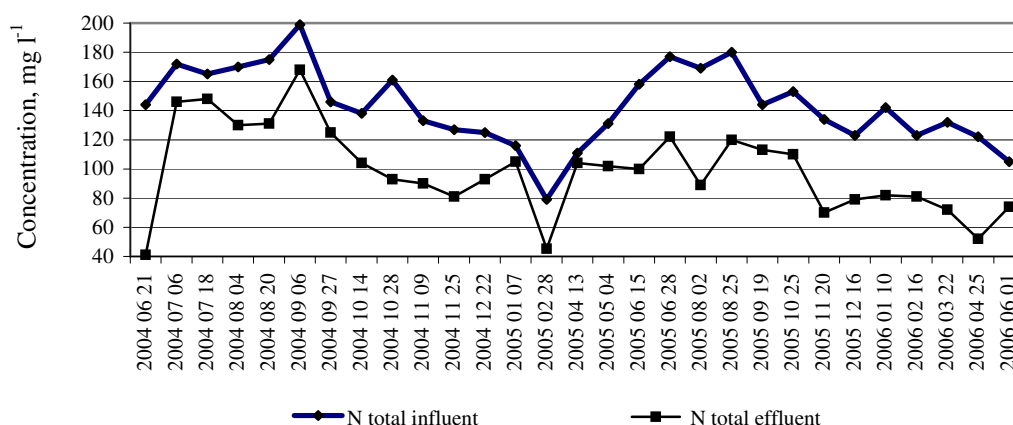

Figure 3. Pollution of wastewater inflow and outflow from the constructed wetlands according to total nitrogen within the study period in LTD 'Nikola'.
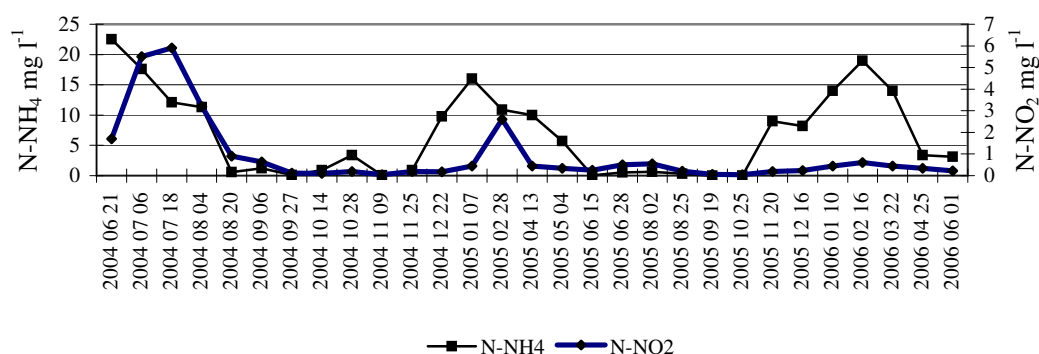
213

Figure 4. Pollution of wastewater outflow from the constructed wetlands according to ammonium and nitrite nitrogen within the study period in LTD 'Nikola'.

Comparison of ammonium and nitrite nitrogen concentrations in wastewater after treatment in both filters shows that wastewater outflow from HFCW contains higher concentrations of those elements than wastewater outflow from VFCW, although N_{total} removal efficiency is better in HFCW rather than in VFCW.

Figures 6 and 7 present the dependences of ammonium amount in wastewater after treatment in VFCW on the load of filter according to N_{total} in warm and cold periods of the year.

As it is seen, maximum allowable concentration (MAC, 5.0 mg l^{-1}) of N-NH$_4$ contained in wastewater after treatment in the warm period of the year is observed when filter load according to N_{total} is 2.1 g m^{-2} d^{-1}, while in the cold period of the year it appears when the load of all the studied filters according to N_{total} is

from 0.45 to 3.46 g m^{-2} d^{-1}. Ammonium amount does not exceed MAC.

This data shows that if the constructed wetlands are going to operate only in the warm period of the year (i.e., in objects of seasonal activity), then it is not necessary to do the calculations of filter parameters according to ammonium nitrogen removal efficiency.

Figure 8 presents the dependence of ammonium nitrogen amount in wastewater after treatment in HFCW on the filter load according to N_{total}. During the study period, the filter load was fluctuating from 0.3 to 4.6 g m^{-2} d^{-1}. When there is a large number of measurements ($n = 48$) and filter load is different, the functional dependence obtained by a regression analysis has a rather high determination coefficient ($R^2 = 0.7381$). As it is seen from Figure 8, the increasing filter load
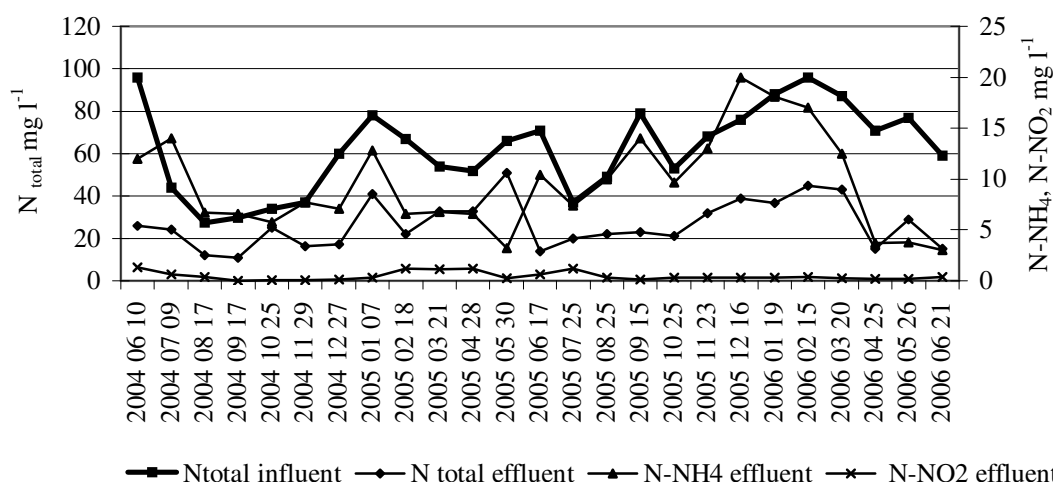

Figure 5. Pollution of wastewater inflow and outflow from the constructed wetlands according to total nitrogen and pollution of wastewater outflow according to N-NH$_4$ and N-NO$_2$ within the study period in LTD 'Agaras'.

214

Figure 6. Ammonium nitrogen concentrations in wastewater outflow from the constructed wetlands of vertical flow with respect to the load according to N_{total} during the warm period of the year (05-10 months).

according to N_{total} from 0.25 to 4.6 g m^{-2} d^{-1} determines the increasing ammonium nitrogen (N-NH$_4$) concentration from 6.0 to 32.0 mg l^{-1} in a treated wastewater. In the Czech Republic and in Denmark, studies of HFCW (Vymazal, 2002) showed that N_{total} removal efficiency is 41.6-42.9%. However, total nitrification here occurs only when N_{total} load is similar to the results obtained in the present research.

Thus, when nitrogen mineralization is performed under anoxic conditions (i.e., when there is a lack of oxygen) or under anaerobic conditions, it is possible to reach a high nitrification level and reduce the ammonium concentration in wastewater outflow in HFCW

only when filter load with nitrogen is reduced (i.e., when filter area is increased).

Table 3 presents the average pollution of wastewater outflow from different filters within the study period.

As the generalized study results show, filters of both models demonstrate a good removal efficiency of organic pollutants. Considering N_{total} removal efficiency, HFCW correspond to the environment protection requirements, however, compared to HFCW, wastewater outflow in VFCW contains less amounts of ammonium and nitrite nitrogen.
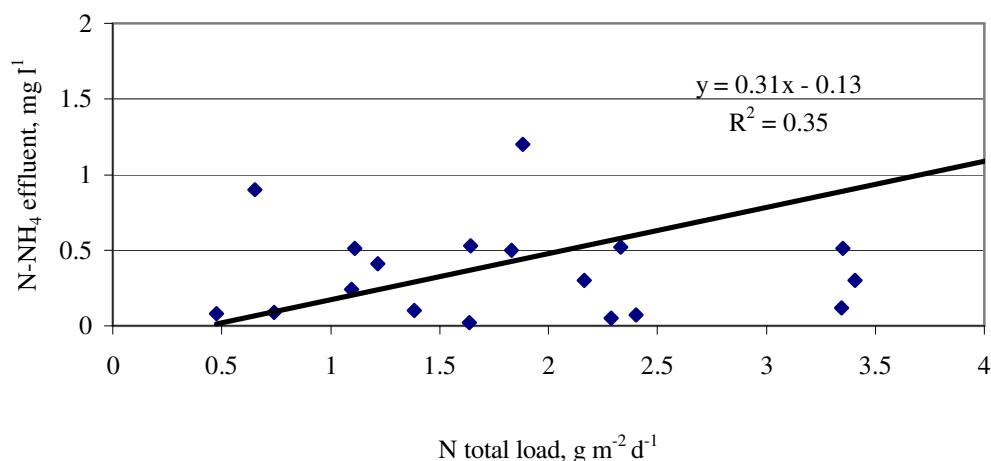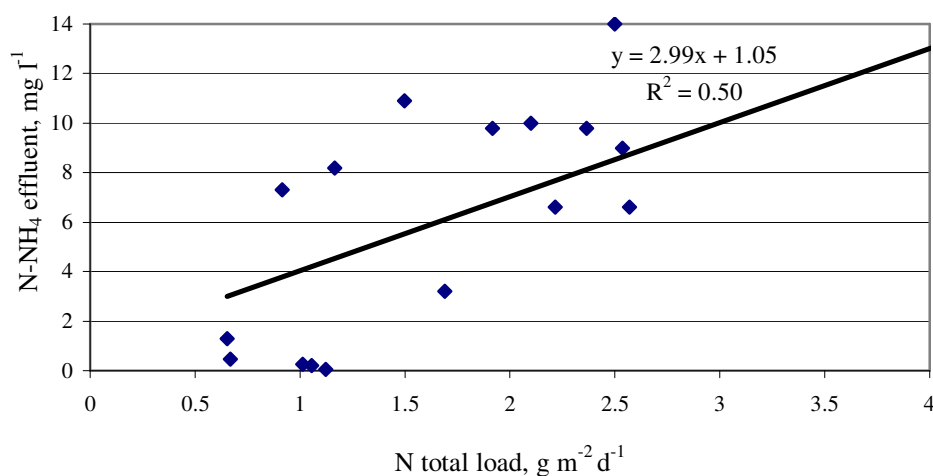

Figure 7. Ammonium nitrogen concentrations in wastewater outflow from the constructed wetlands of vertical flow with respect to the load according to N_{total} during the cold period of the year (04-11 months).
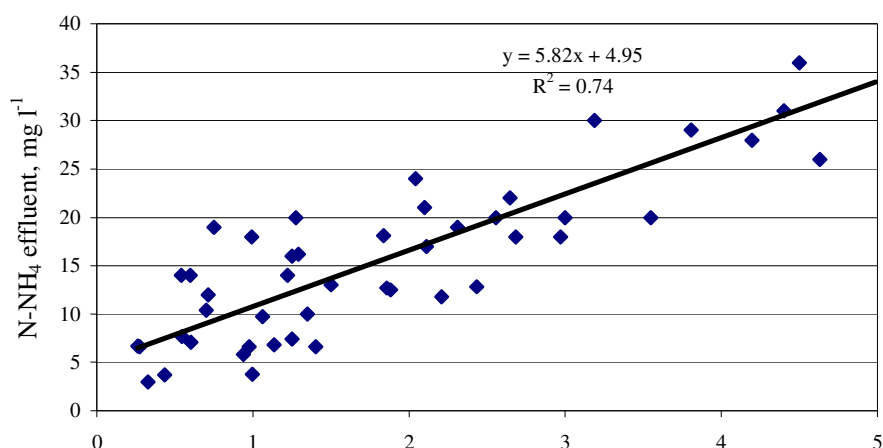
Figure 8. Ammonium nitrogen concentrations in wastewater outflow from the constructed wetlands of horizontal flow with respect to the load according to N_{total}.

Table 3

Average and standard deviation of wastewater outflow indices from different constructed wetlands

Name of the object	BOD_7, mg O_2 l^{-1}	Suspended solids, mg l^{-1}	N_{total}, mg l^{-1}	N-NH_4, mg l^{-1}	N-NO_2, mg l^{-1}	N-NO_3, mg l^{-1}	P_{total}, mg l^{-1}
LTD 'Pastogė'	6.9±3.8	9.8±4.9	75.3±12.2	2.4±0.6	0.22±0.07	71.4±11.8	6.90±3.10
LTD 'Nikola'	5.8±2.7	8.9±4.2	98.9±14.8	4.7±1.2	0.31±0.09	92.8±16.2	5.60±2.70
LTD 'Agaras'	16.8±8.8	18.4±9.7	26.6±11.8	9.5±3.8	0.46±0.13	12.7±4.6	1.66±0.24

Conclusions

Having compared ammonium and nitrite nitrogen removal efficiency from wastewater in constructed wetlands of two different models (VFCW and HFCW), it was determined that larger amounts of N_{total} are removed in HFCW (38.1%) than in VFCW (24.4%). However, compared to HFCW, wastewater outflow in VFCW contains less amounts of ammonium and nitrite nitrogen.

In VFCW, ammonium and nitrate nitrogen removal is of seasonal nature:

- during the warm period of the year (05-11 months) when filter load according to N_{total} is fluctuating from 0.45 to 3.4 m^{-2} d^{-1}, ammonium nitrogen concentrations in treated wastewater outflow were changing from 0.4 to 7.5 mg l^{-1}, while nitrite nitrogen concentrations were changing from 0.01 to 0.15 mg l^{-1};

- during the cold period of the year when filter load was fluctuating from 0.65 to 2.6 m^{-2} d^{-1}, ammonium and nitrite nitrogen concentrations in wastewater outflow were much higher - fluctuating from 4.5 to 17.5 mg l^{-1} and from 0.1 to 1.15 mg l^{-1} respectively.

No significant effect of the fluctuations of ambient temperature on the removal of ammonium and nitrite nitrogen was observed in HFCW (the difference of average values of cold and warm periods was 3-8%).

A rather reliable relation ($R^2 = 0.738$) was determined between ammonium nitrogen concentrations in wastewater outflow and in HFCW load according to total nitrogen. However, ammonium nitrogen amounts in treated wastewater (when filter load according to total nitrogen is 0.3 to 4.6 g m^{-2} d^{-1}) exceeded the maximum allowable concentration (MAC) and were fluctuating from 6 to 32 mg l^{-1}.

References

1. Aplinkosaugos reikalavimai nuotėkoms tvarkyti. (2001) (Environmental requirements for wastewater handling). Valstybės žinios, 2001 10 05, Nr. 87-3054, pp. 22-29. (in Lithuanian).
2. Cooke J.G. (1994) Nutrient transformations in a natural wetland receiving sewage effluent and the implications for waste treatment. Water Science and Technology, 29, pp. 209–217.
3. Cooper P.F. (1999) Review of the design and performance of vertical-flow and hybrid reed bed treatment systems. Water Science and Technology, 40 (3), pp. 1–9.
4. Focht D.D., Chang A.C. (1975) Nitrification and denitrification processes related to waste water treatment. Advances in Applied Microbiology., 19, pp. 153–186.
5. Gross A., Nemirovsky A.; Zilberg D. et al. (2003) Soil nitrifying enrichments as biofilter starters in intensive recirculating saline water aquaculture. Aquaculture, 23, pp. 51–62.
6. Hagopian D.S., Riley J.G. (1998) A closer look at the bacteriology of nitrification. Aquacultural Engineering, vol. 18 (4), pp. 223-244.
7. Kadlec R.H., Knight R.L. (1996) Treatment Wetlands., New York: Lewis Publishers, CRC, pp. 894.
8. Mander Ü., Mauring T. (1996) Constructed wetlands for wastewater treatment in Estonia. Water Science and Technology, 35 (5), pp. 323–330.
9. Reddy K.R., D'Angelo E.M. (1994) Soil processes regulating water quality in wetlands. In: Mitsch, W.J. (Ed.). Global Wetlands: Old World and New. Amsterdam: Elsevier, pp. 309–324.
10. Schierup H.-H., Brix H.; Lorenzen N. (1990) Wastewater treatment in constructed reed beds in Denmark—state of the art. In: Cooper P.F., Findlater B.C. (Eds.). Constructed Wetlands in Water Pollution Control, Oxford: Pergamon Press, pp. 495–504.
11. Stengel E., Carduck W., Jebsen C. (1987) Evidence for denitrification in artificial wetlands. In: Reddy K.R., Smith W. H. (Eds.). Aquatic Plants for Water Treatment and Resource Recovery. Magnolia Publishing, Orlando, FL, pp. 543–550.
12. Strusevičienė S., Strusevičius Z. (1994) Cleaning of polluted surface water. Agricultural run-off; In: Proceedings of NorthFA Seminar. Latvia, University of Agriculture.-Jordgorsk, Norway, Jelgava, Latvia, November 10–12, pp. 51–52.
13. Vymazal J. (2001) Constructed wetlands for wastewater treatment in the Czech Republic. Water Science and Technology, 44 (11-12), pp. 369–374.

IMPROVEMENT OF THE PARAMETERS OF CONSTRUCTED WETLANDS FILTER WHEN APPLYING IT FOR THE TREATMENT OF DAIRY WASTEWATER

Simanas Aškinis

Water Management Institute of Lithuanian University of Agriculture
E-mail: s.askinis@takas.lt

Abstract

The objective of the studies was to evaluate the suitability of sand reed filter for the treatment of wastewater from milk collection post and on the basis of the studies performed to determine the minimal length of filtration path in order to reach the normative wastewater treatment level.

In 2003, in Padargupiai village (Ariogala municipality, Raseiniai district) experimental treatment facilities for wastewater from milk collection post were constructed. As the pollution of such wastewater after pre-treatment (primary treatment) is 2 times higher than that of domestic wastewater, the filtration path in constructed wetlands was made 2 times longer (up to 10 m long). On the basis of the study results the dependence equations were made, with the help of which the amounts of the main pollutants contained in wastewater of milk collection posts were calculated, after the wastewater is filtered through the sand layer of different length. As calculations have shown, the treatment of wastewater from milk collection posts until the allowable rates depends on the constructed wetlands with the length of the filtration path of 7 m. The removal of organic pollutants, total nitrogen and total phosphorus from wastewater flowing through such media are 97.2%, 68.7%, and 91% respectively.

The studies performed allowed to improve the calculations of the necessary area of constructed wetlands in order to reach the normative treatment level of wastewater from milk collection posts according to the index biochemical oxygen demand (BOD_5).

Keywords: constructed wetlands, filtration path, treatment efficiency.

Introduction

Large milk processing companies in different districts of the country create a network of posts where milk is collected from farmers and then cooled. In such posts particularly polluted wastewater is formed, because the possibility of pollution of such wastewater with milk biochemical oxygen demand (BOD_5) – 100000-120000 mg O_2l^{-1}) is very high. Therefore the pollution of wastewater from milk collection posts directly depends on milk losses and used water amount. Those indices basically depend on the level of technologies and work culture. As the experience shows, the largest losses occur due to offhanded removal of milk from auto-tanks and refrigerating tanks and reach 0.26 kg of BOD per ton (Strusevičius, 1996). The highest wastewater pollution with organic pollutants according to BOD_5 was determined to be when washing auto-tanks where up to 10 l of milk (1565-2130 mg O_2l^{-1}) remain; the least pollution with organic pollutants was observed when washing the premises and refrigerating tanks (617-826 mg O_2l^{-1}).

In 2001, wastewater pollution investigations were carried out in three milk collection posts:

Pabaiskas (2.0 t d^{-1} collected) and Vaivadiškis (2.5 t d^{-1} collected) in Ukmergė district, and Ariogala (120 t d^{-1} collected) in Raseiniai district. Wastewater pollution here reached 580, 270, and 1400 mg O_2l^{-1} respectively. The low wastewater pollution in Vaivadiškis milk collection post was observed because a modern milk refrigerator with automatic washing program is arranged here. In Ariogala milk collection post, a 5 times higher wastewater pollution is due to the large number of washed auto-tanks (30 units). The wastewater of such high pollution first of all is to be treated by using chemical substances. Currently, the primary treatment of heavily polluted wastewater (BOD_5 1200-6000 mg O_2l^{-1}) from meat processing companies is performed by the hydration and carbonization method (Strusevičius and Strusevičiene, 2001; Strusevičienė and Strusevičius, 2004; Strusevičienė et al., 2002) or with the help of coagulant 'Zetag 8660'. The mixture of those substances is also used for the primary treatment of wastewater from slaughterhouses (Strusevičienė and Strusevičius, 2006). Applying those methods, wastewater from meat processing companies are treated up to 50%. Therefore those methods were selected for the primary treatment of wastewater from milk

processing companies as well.

After clarification in the sedimentation tank, wastewater is further treated biologically in constructed wetlands. As the studies of the treatment of domestic wastewater in such filters have shown, the wastewater treatment level corresponds to all the approved requirements. The length of wastewater filtration path here is usually 5 m. Such length is enough to ensure the removal of 86-96% of organic matter and 57-89% of biogenic compounds from domestic wastewater during complex physical and biological processes. In order to reach the normative wastewater treatment level, the reaction constant in calculations is taken to be 0.06 (Strusevičienė et al., 1997).

The objective of the studies was to evaluate the suitability of sand reed filter for the treatment of wastewater from milk collection post and on the basis of the studies performed to determine the minimal length of filtration path in order to reach the normative wastewater treatment level.

Materials and Methods

The studies were carried out in the treatment facilities of wastewater from a milk collection post arranged in Padargupiai village (Ariogala municipality, Raseiniai district) within the period of 2003-2005. The technological scheme of the treatment facilities is presented in Figure 1. The designed amount of wastewater was 5 m^3 d^{-1}, but later increased up to 12.5 m^3 d^{-1} as a result of the development of the production. The wastewater is discharged from the company through two sewerage collectors into a well-type pump-house, from which the wastewater is further supplied into the aeration-flocculation device (useful volume 8 m^3) through a pressure line. In the reaction chamber of the device the wastewater is treated with chemicals and air mixture. Further it is supplied into the sedimentation chamber (useful volume 8 m^3). Above the reaction chamber

a dosage device of chemicals is arranged. In 2003-2004, quicklime (Ca O) was supplied into the reaction chamber for the coagulation of pollutants (1 kg of quicklime for 1 m^3 of wastewater). In 2005, quicklime was replaced by the coagulant 'Zetag 8660' (4 g of coagulant for 1 m^3 of wastewater). Compared to quicklime, this coagulant has some exploitation advantages: its dosage is not complicated (dissolved in water (40 g for 1 l) the coagulant is dripped from the vessel with a tap into the wastewater), and thus less amount of sediment are formed in the sedimentation tank. Wastewater is clarified in the sedimentation tank; as a result, sludge starts accumulating here. The useful volume of the sedimentation tank (7.5 m^3) is calculated to contain the amount of sludge accumulated within a period of 3-4 months with enough space for flocculus to settle. From the sedimentation tank the wastewater is supplied into 2 successively connected sand reed filters. The size of both filters is 200 m^2 each. Coarse particle sand was used for the arrangement of constructed wetlands. After the treatment in the facilities, wastewater is discharged into the drainage channel.

Wastewater samples for chemical analysis were taken once per two months from the following places: before treatment – from the pump-house; after pre-treatment in the physical-chemical treatment device – from the outflow from chemical reaction chamber; after clarification in the settler – from the wastewater distribution well of the first sand reed filter; after 5 m filtration through sand media – from the wastewater distribution well of the second sand reed filter; after 10 m filtration through sand – from the control well.

Wastewater analysis was made in the certified Chemical Analysis Laboratory of Water Management Institute of Lithuanian University of Agriculture, applying the unified methods (Unifikuoti..., 1994). The following indices were
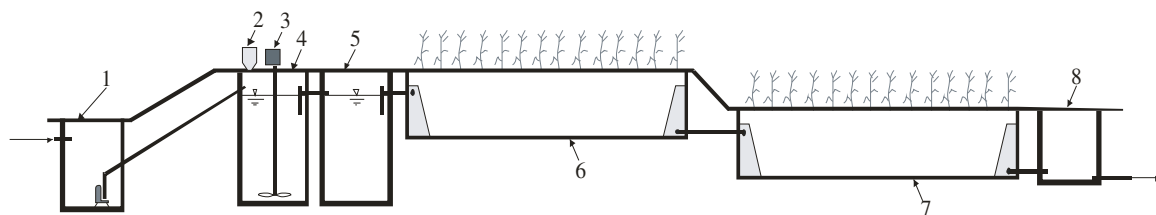

Figure 1. Technological scheme of constructed wetlands: 1 – wastewater pumphouse, 2 – dosing device of chemical reagent matter; 3 – ejectoric wastewater mixer; 4 – chamber of chemical reaction; 5 – settler; 6 – the first sand reed filter; 7 – the second sand reed filter; 8 – control well.

determined: BOD_5, pH, total nitrogen, total phosphorus, suspended solids, and fat.

Matematical and statistical analysis of test study results was performed with the help of standard computer programs. To determine the interrelations, 'Excel' program was used.

An operating time meter of the pump was arranged in wastewater treatment facilities. Considering the discharge of the pump, the amount of wastewater inflow into the treatment facilities was calculated.

Results and Discussion

The wastewater forming in milk collection posts, is particularly heavily polluted. Its pollution is fluctuating from 369 to 1388 mg $O_2 l^{-1}$ and is changing within a day and not during separate periods. This depends on the collected amount of milk and the amount of water used for washing auto-tanks and refrigerators. When treating such heavily polluted wastewater in constructed wetlands, first of all the primary treatment is to be carried out. For this purpose, chemical treatment method was selected. In 2003-2004, quicklime (Ca O) was supplied into the reaction chamber for the coagulation of pollutants. In the milk collection post about 90% of wastewater is formed within the period of 5 hours, therefore it is important to use chemical matter that would ensure as short duration of wastewater treatment process as possible. Thus, since 2005, quicklime was replaced by the coagulant 'Zetag 8660'. Compared to quicklime, this coagulant has certain exploitation advantages: its dosage is not complicated (dissolved in water it is dripped from the vessel with a tap into the wastewater), and less amounts of sediments are formed in the settler. Using this coagulant, the efficiency of wastewater treatment, under laboratory conditions reached 70%. Similar efficiency was obtained when using quicklime. Under the industrial conditions, after the primary treatment the amount of BOD_5 contained in wastewater decreased by 27.2%, the amount of

suspended solids was reduced by 48.1%, and the amounts of total nitrogen and total phosphorus decreased by 15.8% and 27.0% respectively. This depended on the air temperature regime, sometimes - on inexact dosage of chemicals; too small space of the reaction chamber for 2.5 times increased the amount of wastewater, and the capacity of sedimentation tank.

The main pollution indices of wastewater forming in the treatment facilities and pre-treated with chemical substances (minimal value – maximum value / average value) are presented in Table 1.

As wastewater of milk collection posts is heavily polluted (BOD_5 is up to 1400 mg l^{-1}), a two-stage sand reed filter was constructed in the second stage of the treatment process. The studies have shown that sand reed filters are quite suitable for the treatment of such kind of wastewater. Wastewater treatment in such filters is good just after the arrangement of the filters: according to BOD_5, wastewater outflow contained 24.3 mg $O_2 l^{-1}$ of organic pollutants, 2.4 mg l^{-1} of total nitrogen, 0.2 mg l^{-1} of total phosphorus. After the primary treatment, wastewater from milk collection post is still twice as much polluted as domestic wastewater. For the treatment of such wastewater, sand reed filters were used for the first time in Lithuania. Due to the lack of experience, the length of the filtration path was selected to be 10 m. As the investigation results have shown, 5-m long filtration through sand is insufficient for wastewater treatment until the allowable rates, although even 88.5% of organic pollutants are removed. Nevertheless, in most cases the pollution of wastewater does not satisfy the environment protection requirements (average pollution according to BOD_5 is 60 mg $O_2 l^{-1}$), wastewater is of blackish color and becomes clear only after certain period of time. When the filtration path is 10 m, wastewater according to BOD_5 is treated to 4 mg $O_2 l^{-1}$, and even the highest pollution of wastewater outflow reaches only 10 mg $O_2 l^{-1}$. The removal of biogenic pollutants from wastewater is also

Table 1

The main chemical indices of wastewater from milk collection post (mg l^{-1})

Studied wastewater	BOD_5	pH	N_{total}	P_{total}	SS	Fat
Before treatment	369–1388	6.0–7.6	17.7–82.0	3.7–11.0	291–944	176–364
	821	6.9	38.0	6.3	534	252
After primary treatment	103–926	6.4–10.7	6.6–58.0	0.6–9.1	103–496	76–184
	521	7.5	32.0	4.6	277	178
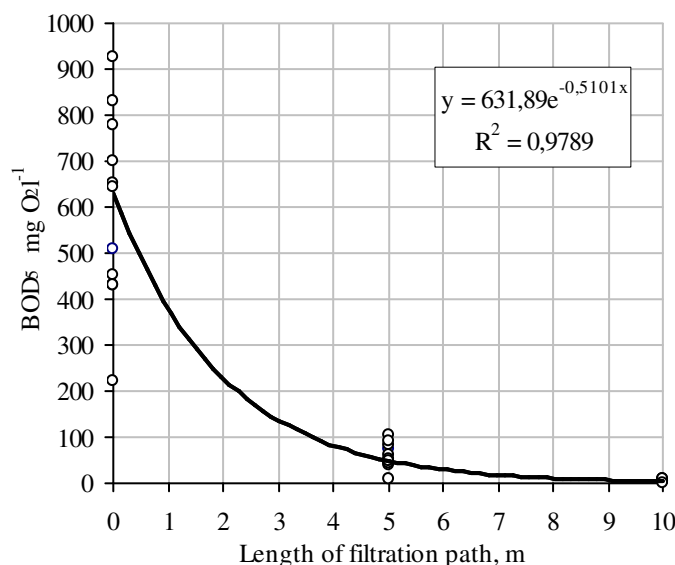
Figure 2. Dependence of the removal of organic pollutants on the length of filtration path ($p < 0.05$).

good in constructed wetlands: the amounts of total nitrogen and total phosphorus decreased by 82% and 97% respectively. Total nitrogen amount contained in wastewater outflow from the first sand reed filter never exceeded the allowable rate, while its concentration in wastewater outflow from the second filter reached 12.8 mg l^{-1}. The filtration path may be reduced so that the pollution of wastewater outflow would be close to the allowable rate but would not exceed it. Shorter filtration path would ensure lower expenses on the construction of wastewater treatment facilities. In order to calculate the pollution of wastewater at any point of the filtration path, the dependence of the removal of

the main pollutants on the length of filtration path was evaluated (Figs. 2 - 5).

With the help of the dependence equations obtained, the amounts of the main pollutants contained in wastewater of milk collection posts after filtration through the sand layer of different length was calculated. Calculation results are presented in Table 2.

As it is seen in Table 2, a 10 m long filtration path is not necessary for wastewater pretreatment until the allowable rate. In order to reach the normative wastewater treatment, the length of the filtration path may be reduced to 7 m. In such constructed wetlands, the average treatment level according to BOD_5 would be
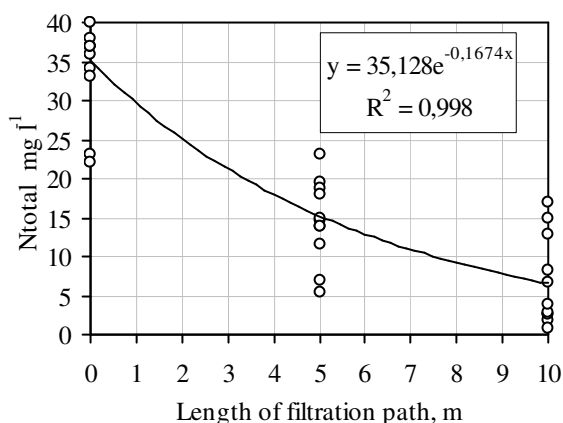
Figure 3. Dependence of the removal of total nitrogen on the length of filtration path ($p < 0.05$).
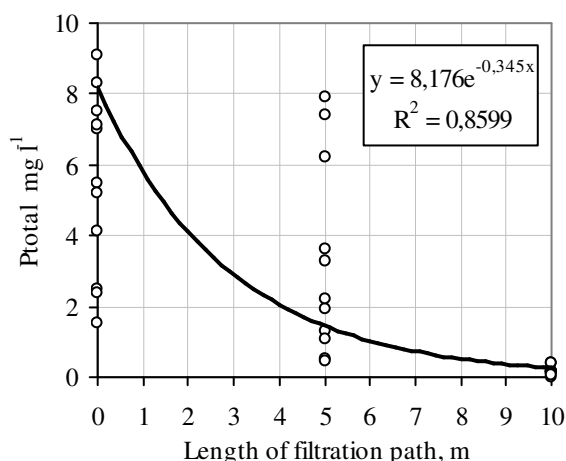
Figure 4. Dependence of the removal of total phosphorus on the length of filtration path ($p < 0.05$).

18 mg $O_2 l^{-1}$, treatment efficiency would reach 97.2%, and the removal of total nitrogen and total phosphorus would be 68.7% and 91.0% respectively. The amount of suspended solids would still exceed the allowable rate by 7.4 mg l^{-1}. During further investigations in 2006, it was observed that using the coagulant 'Zetag 8660' the average amount of suspended solids contained in wastewater outflow from the filter decreased by 56.5% and reached 10.0 mg l^{-1}. Therefore having reduced the length of the filter to 7 m, there is no danger for the amount of suspended solids to be exceeded.

To ensure normal wastewater treatment in constructed wetlands, its active reaction is particularly of great importance. Optimal medium for biological processes is when pH of wastewater reaches 7-8. When quicklime was used for wastewater pre-treatment (primary treatment), there were certain dosage problems, therefore with the fluctuations of quicklime amount its pH was changing from 6.8 to 10.7. When the alkalinity of wastewater is so high, even nitrate bacteria are inanimate.

When using the coagulant 'Zetag 8660', pH of wastewater after filtration through a 5-m deep sand layer is 7.4, but through a 10-m deep sand layer - 7.6. No stronger influence of the reduced length of sand reed filter to 7 m on the active reaction was observed, because the active reaction
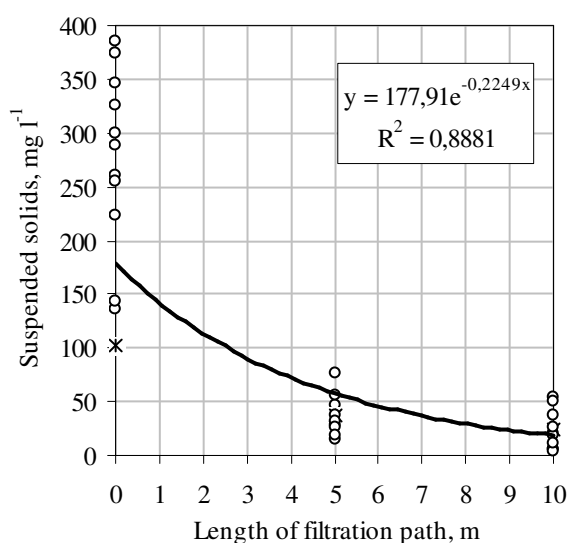
Figure 5. Dependence of the removal of suspended solids on the length of filtration path.

Purification level of wastewater in milk collection post in respect of the length of filtration path

Index, mg l^{-1}	Length of filtration path, m										
	0	1	2	3	4	5	6	7	8	9	10
BOD$_5$	632	381	229	138	83	60	30	18	11	7	4
N$_{total}$	35.1	29.8	25.2	21.3	18.1	15.3	13.0	11.0	9.3	7.9	6.7
P$_{total}$	8.18	5.80	4.12	2.92	2.08	1.47	1.05	0.74	0.53	0.37	0.27
SS	177.9	142.3	113.9	90.8	73.0	58.2	46.6	37.4	29.7	23.8	19.0

is optimal.

The necessary area of constructed wetlands for the treatment of domestic wastewater is calculated by the following formula in respect of BOD$_5$ (Strusevičienė et al., 1997):

$$A = \frac{Q(\ln C_0 - \ln C_v)}{K_r} \qquad (1)$$

where

A – necessary surface area of the filter, m^2;
Q – wastewater discharge, m^3 d^{-1};
C_0 – BOD$_7$ of wastewater inflow, mg l^{-1};
C_v – normative BOD$_7$ after the treatment, mg l^{-1};
K_r – reaction constant.

When calculating the area of the filter, the reaction constant of domestic wastewater is taken to be 0.06. As the investigations have shown, it is impossible to use this constant for the calculation of the area of constructed wetlands where the treatment of wastewater from milk collection post is performed. The calculated area of constructed wetlands was obtained to be larger than the needed one (the calculated - 400 m^2, the necessary - 280 m^2). According to the experimental sand reed filter, it was calculated that $K_r = 0.12$.

Considering that the pollution of pre-treated wastewater is reduced by one third, the areas of sand reed filters in respect of the wastewater discharge and its pollution with organic pollutants according to BOD$_5$ was calculated with the help of formula 1. The calculation results are presented in Table 3.

Under the laboratory conditions, the efficiency of primary wastewater treatment is much higher. However, milk collection posts are located in rural territories and, as the long-term experience has shown, the equipment is operated insufficiently. Therefore, in calculations, the pollution according to BOD$_5$ was taken to be reduced by one third within the first stage of treatment process.

As it is seen in Table 3, the constructed wetlands used for the treatment of wastewater from milk collection posts require larger areas of land. However, as it was mentioned above, such milk collection posts are located in rural areas where the land is not expensive. The expansion of such posts is promoted by positive characteristics (e.g., simplicity of the operation) and local materials used for construction. Such posts fully meet the hygienic and environment protection requirements, therefore the perspectives of the

Dependence of the area of sand reed filter (m^2) on the discharge and pollution of wastewater of the milk collection post according to BOD$_5$

BOD$_5$ of wastewater, mg O$_2$l^{-1}	Wastewater discharge, m^3 d^{-1}											
	1	2	3	4	5	6	7	8	9	10	11	12
1000	27.3	54.6	82.0	109.3	136.6	164.0	191.3	218.6	246.0	273.3	300.6	328.0
900	26.4	52.8	79.2	105.6	132.0	158.5	184.9	211.3	237.8	264.2	290.6	317.0
800	25.5	51.0	76.5	102.0	127.5	153.0	178.5	204.0	229.5	255.0	280.5	306.0
700	24.3	48.6	72.8	97.2	121.4	145.8	170.0	194.3	218.6	242.6	267.2	291.5
600	23.1	46.2	69.2	92.3	115.4	138.5	161.6	184.6	207.7	230.1	253.9	277.0
500	21.4	42.8	64.2	85.6	107.1	128.5	150.0	171.3	192.8	213.8	235.6	257.0
400	19.8	39.5	59.3	79.0	98.8	118.5	138.3	158.0	177.8	197.5	217.3	237.0

usage of such constructed wetlands are promising.

Conclusions

1. Treatment of wastewater from milk collection posts until the allowable rates is ensured by the constructed wetlands, the length of the filtration path of which is 7 m. After the filtration through such sand medium, wastewater is released of 97.2% of organic pollutants, 68.7% of total nitrogen, and 91.0% of total phosphorus.

2. When calculating the necessary area of the constructed wetlands needed to reach the normative treatment level of wastewater from milk collection posts according to BOD_5, the reaction constant is to be equal to 0.12.

References

1. Strusevičiene S.M., Strusevičius Z., Gasiunas V. (1997) Ūkininkų sodybų nuotekų valymas smėlio ir nendrių filtruose (Treatment of wastewater from private farmsteads in constructed wetlands). Vandens ūkio inžinerija, 3 (25), pp. 133–143.(in Lituanian).
2. Strusevičienė S.M., Strusevičius Z., Radzevičius A. (2002) Hidratacijos ir karbonizacijos metodo taikymas maisto pramonės nuotekoms valyti (Application of hydratation and carbonization method for the treatment of wastewater from food industry). Vandens ūkio inžinerija, 21(43), pp. 13–20. (in Lituanian).
3. Strusevičienė S.M., Strusevičius Z. (2004) Gyvulių skerdyklos nuotekų valymo efektyvumo tyrimai (Investigations on treatment efficiency of wastewater from cattle slaughterhouse). Vandens ūkio inžinerija, 26(46), pp. 5–11. (in Lituanian).
4. Strusevičienė S.M., Strusevičius Z. (2006) Investigations on the removal of biogenic pollutants from wastewater produced in cattle slaughterhouse. Water Management engineering, 3(6), pp. 38–43.
5. Strusevičius Z., Strusevičienė S. (2001) Pirminio nuotekų valymo mėsos perdirbimo įmonėje tyrimai (Investigations of primary treatment of wastewater in meat processing company). Vandens ūkio inžinerija, 16 (38), pp. 76–84. (in Lituanian).
6. Strusevičius Z. (1996) Nuotekų, atliekų ir mėšlo tvarkymas žemės ūkyje (Handling of Effluents, Wastes and Manure in Agriculture). Vilainiai, 1996 pp. 77-78. (in Lituanian).
7. Unifikuoti nuotekų ir paviršinio vandens kokybės tyrimų metodai. D.1. (Unified study methods of wastewater and surface water quality. D.1). (1994) Vilnius: AAM leidybos biuras, pp. 223. (in Lituanian).

MAINTENANCE PECULIARITIES OF POLDER SYSTEMS IN LITHUANIA DURING THE LAST DECADE

Nijolė Bastienė, Valentinas Šaulys
Water Management Institute of the Lithuanian University of Agriculture
E-mail: vegelyte@delfi.lt

Abstract

Basing on the economic, ecological and social points of view, the polder systems in the Nemunas lowland are considered as unique, requiring a great deal of annual state subsidies. According to the land-improvement programme, during the period of 2006-2008, Lithuanian polder system are planned to be yearly granted 2.15 million euros from the State budget, whereas the local administration of Silute district, which is exploiting the polders of the Lower Nemunas - more than half of the sum (63%).

The article includes the analysis of exploitation expenses and statistical estimation of the Lower Nemunas' polders during the period of 1996-2006 as well as the investigation of the funds distribution on routine repairs, reconstruction and maintenance work. The average annual expenses on the pump stations, dikes, ditches and roads during the research period were determined. The analysis of the previous decade's expenses shows that the statistical average of the expenditure on the polder systems of Silute district amounts to 0.68±0.13 million euros a year. The yearly renovation of polders depreciation should be obviously awarded a grant of the amount not less than 0.72 million euros.

Keywords: polder systems, maintenance expenses, state subsidies.

Introduction

Rehabilitation of the inherited polder systems and their employment for the future needs have proved to be one of the main goals of European countries around the region of the Baltic Sea. In Dutch where more than 2500 km of dikes have been constructed to protect the polders against floods, a maintenance decision model has been developed for the optimization of the cost–optimal dike repairs (Speijker et al., 2000). Van Overloop (2006) analyzed the water management peculiarities of polders in the Netherlands and presented a control method to avoid drainage problems. Since 1996, the experts from Lithuania and Germany had been cooperatively working on the development of a sustainable rehabilitation concept for the polder systems on the rivers Older and Nemunas (Quast and Lukianas, 1999). They concluded that the future agricultural employment of the polders requires special socio-economic conceptions based on practice and scientifically proved rehabilitation solutions.

In Lithuania, polder systems cover the area of 50972 ha. At the beginning of the year of 2005, Lithuanian's separate areas were protected from the flooding during the periods of floods by the 464.37 km of dikes. A total of 94 drainage pump stations are constantly in operation in order to remove the water out of them. Those sorts of constructions have already depreciated

approximately by 50% (the dikes – by 47%, the pump stations – by 54%) and have lost around half of the balance value. At the moment their residual value amounts to 9.2 million euros.

Approximately 82% of the polders are concentrated in the Lower Nemunas. There have been constructed two types of polder systems (summer polders and winter ones). The dikes of the length of 302 km protect the total area of 42 000 ha. The winter polders are employed to protect settlements and cultivated areas from flooding throughout the area of 10.6 thousand ha. The summer polders are usually overflowed during the time of spring floods. The flooded area varies from 30 to 55 thousand ha according to the flood intensity. In the springtime after the snow melt the flood runoff lasts approximately 30 days.

During the soviet period, the summer polders provided the development of an intensive industrial production of vitamin grass flour. After regaining its independence, Lithuania undertook the privatization of its lands. The polder land employment under the new farming conditions is gradually changing due to the reduced demand for fodder. The degradation of the polder systems in the Nemunas delta has resulted in a decreased intensity of the draining (the major part of the automatized pump stations was damaged, and the repairs of the pump stations, dikes and electricity intake have faced the shortage in payment). Progressively, denaturalization of summer polder

landscape started and the areas of the meadows were reconverted into swamps (Mališauskas and Morkunas, 2004). However, the flooded meadows have been a valuable sort of the semi–natural landscape that is expected to have been retained, leastwise in some summer polders. Therefore, the vision of water resources for the year of 2025, has intended to withdraw the part of summer polder systems from the agricultural practice (Rekomendacijos. . . , 2000).

The intensity of alterations in farming has been negligible in the winter polders during the last decade. Despite the holdings of arable lands are small (1-1.5 ha), the process of the land privatisation has been rapid here. The winter polders employment has been comparatively intensive. Therefore water-operating conditions must be applied not only to the needs of the grassland but to any sort of the plants under the cultivation. In such case, water operating conditions control is conditioned by the changes in farming and land tenure (Juškauskas and Balodis, 1999; Ascila et al., 2001).

In the year of 1992, most of the polders were integrated into the Nemunas Delta Regional Park, some areas being attributed to the territories of 'Nature 2000'. A. Dumbrauskas and P. Punys (1999) proposed that water regime control in those areas should be coordinated with the demands of the parks – the different kinds of biotops necessary for the environment might be protected and developed under the conditions of water meadows with the possibilities of limited usage.

Intensive agricultural activities in the polder systems stimulate the sedimentation and pollution processes in Curonian Lagoon. A.P. Mališauskas (2000) determined that the loads of nitrogen and phosphorus from the polders reach 5-12 and 0.5-1.0 kg ha^{-1} respectively. Therefore the attention to ecology and environment requirements must be concentrated. Thus the ecological and environmental requirements should be awarded a far greater attention.

The implementation and maintenance of the polder systems are rather expensive. Although the land in the polders is owned or leased to private farmers, cooperatives or agro-firms, its structures (the dikes, pump stations, and drainage systems) are lawfully considered to be included in the possession of the State. Irrespective of the land usage, the repairs of the damages caused by floods are yearly financed by the State funds. In spite of the constant increase of the budget subsidies of special purposive assignation for the polder exploitation, their stable functioning

cannot be ensured. Besides that, the absence of the scientifically based distribution of means has been noticed. At the moment the financing of the polder systems exploitation on the contrary to the financing of the land-improvement works is not based on the function dependence on the residual value of the constructions under their exploitation (Šaulys and Bastienė, 2004). The amount of the polder subsidies is decided by some other accidental factors. Such practice is considered to be economically inefficient. Therefore it is important to determine the ways for the decrease of the expenses on the polders drainage. In order to optimize the exploitation of the land and nature in the Nemunas delta as well as to save up the limited energetic and financial resources, the new standards of the exploitation of the polders systems are necessarily to be prepared.

The main aim of those investigations includes the analysis of the exploitation expenses on the polders during the last decade and the determination of the optimal needs of the means to support stable conditions of the hydrotechnical constructions of polders.

Materials and Methods

The area of the Lower Nemunas, constantly suffering from the regular river floods, is provided with a wide scale system of the summer and winter polders (Fig. 1). The great part of these areas is protected from the summer and autumn floods and only a minor part, including settlements (for example, Rusne) and other constructions or arable land, is under a constant protection all year round. Most polders were constructed in the years 1960-1971. The winter polder of Uostadvaris constructed in 1907 and the summer polder of the Sysa built in 1912 are considered undoubtedly as out-of-date. The most out-of-date polders, which were constructed during the prewar period, include the summer polders of the Pakalne, Minija, and Stankiskes. Some out-of-date polders have been under repairs twice. The last reconstruction of the year 1986 involved the summer polder of the Vorusne.

The water-polder area differs from some tens to some thousands of hectares. The calculation reveals that the water-area of Silute district amounts to over 25 thousand hectares. The Alka (4887 ha), Verze (3625 ha), and Sysa (3095 ha) summer polders are considered as the greatest according with the water-area of the river basin. The areas of the winter polders are far smaller, including Uostadvaris (35 ha) and Vorusne (40 ha) polders as the smallest ones. The total

length of all polder dikes amount to 213.5 km (183.5 km of summer polders and 30 km of winter polders). The Alka summer polder (27.6 km) and the Rusne winter polder (13.1 km) are undoubtedly considered to be the longest. Some dikes are only 2-3 km long, for example, the winter polders of Uostadvaris and Vorusne. Each polder is supplied by a corresponding network of ditch approaches and local roads. The Alka summer polder, which occupies the greatest area, is supplied by four effective pump stations. Three pump stations are under exploitation in the Ruguliai winter polder. As the pump stations have been under exploitation for many years, their mechanisms have been depreciated. They should be replaced by newer according to the advanced appreciation of the farming level and all economic and ecological aspects.

Grassland and pastures predominate in the polders of the Lower Nemunas. They include 84% of the total 24 232 ha area. The arable land covers 7%, but swamps include only 0.7% of the total area (Fig. 2). The Alka summer polders include the most share of the farming land - even 3327 ha as well as the greatest part of the arable land – 459 ha. The Rusne winter polders cover a sufficiently great share (third part of the total area) of the arable land. The winter polders of the Rusne, Vorusne, and Uostadvaris include the relatively greater amount of arable land than meadows, and the winter polder of Ruguliai does not have arable land at all. Grassland and pastures (88.5%) dominate in the summer polders, and arable land covers only the 6% of the total area. The investigation includes the period of 1996-2006. The expenses on the exploitation of the Lower Nemunas polders have been calculated according to the statements and estimates of the fulfilled works of the joint-stock company 'Silute polders'. The article includes the data of the Ministry of Agriculture of Lithuania and the Department of the infrastructure, land reclamation and cooperation. The reliability of the results was determined by processing them using mathematical-statistical methods, using the MS Excel 2000 Data Analysis Tool Pack. The mean of expenses was calculated at significant level $P = 0.05$.

Results and Discussion

For the purpose of the polder maintenance, a joint-stock company 'Silute polders' has been
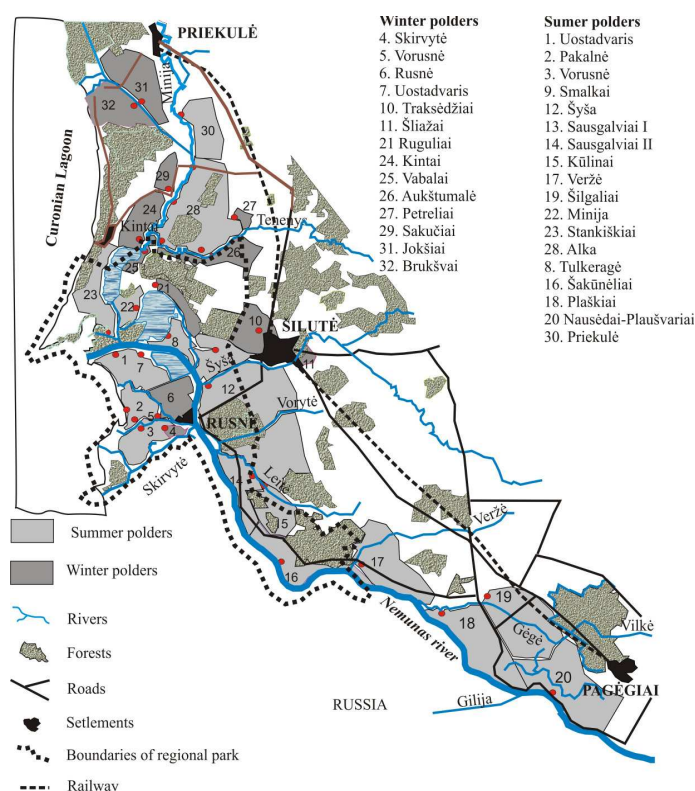

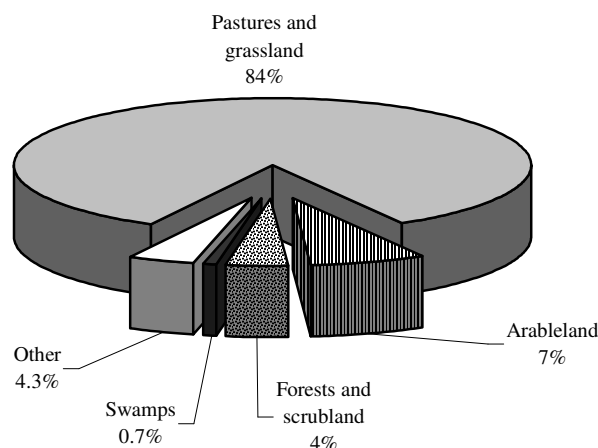Figure 1. The location of polders in the Nemunas Lowland.

Figure 2. Distribution of the land usage in Silute polders.

established. The polder area covers 30 thousand ha and is under the service of the joint-stock company. It maintains 38 pump stations.

During the last decade (1996-2006), the joint-stock company 'Silute polders' maintained the polder systems and concluded labour contracts for 7.5 million euros. The average annual expenses reach 678±134 thousand euros (the relative error of the means − 10%), varying from 345 to 1150 thousand euros depending on particular years (the coefficient of the variation − 34%). The analysis of the expenses change (Fig. 3) shows that during the period from 1996 to 1999, the expenses were gradually decreasing. In 2000 after the administrative redistribution of Lithuania's territory, the local administration of Pagegiai separated from the Silute district and took some part of the polder systems (Plaskiai, Silgaliai, and Nausedai- Plausvariai summer polders covering area of 5639 ha) at its own disposal. Some part of the financing has been redistributed as well and granted for the local administration of Pagegiai. Thus, in 2000, the State subsidies for the polder

exploitation in Silute district were decreased to 440 thousand euros, and in 2001 the district was granted only 345 thousand euros or on average 10.9 euros ha^{-1}. But the technical conditions of the polder implementation under such financing started rapidly to worsen. The granted funds were not sufficient to maintain the stability of the functioning or at least to renovate its depreciation. Thus, the State increased financing for Silute district once again and in 2003 its amount reached the sum of the year 1999, i.e., 678 thousand euros. In 2006, the total expenses of the exploitation of the polder systems increased to a very high level − up to 1.15 million euros. Thus, one hectare of the draining land requires about 36.4 euros.

The diagram of the percentage expenses distribution for various kinds of work in polder systems (Fig. 4) shows, that the repairs, reconstruction and maintenance of the pump stations demand the most share of the means (42%), the repairs, reconstruction and maintenance of the dikes require the third share
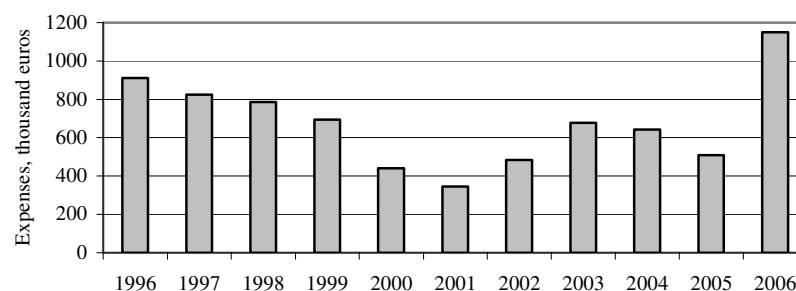

Figure 3. Dynamics of the means allocated for out the maintenance of the polders in Silute municipality during 1996-2006.
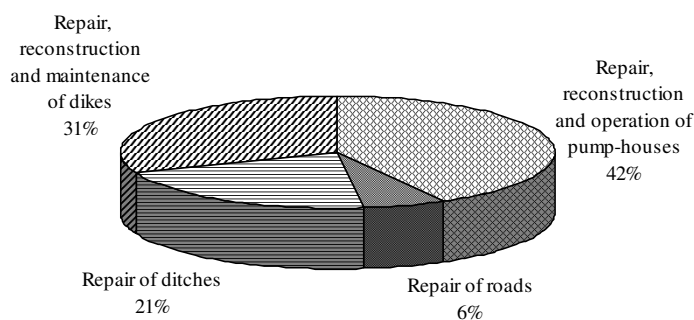
Figure 4. Common distribution of the financial allocation for 'Silute polders' in 1992-2006.

of the means (31%), the repairs of the ditches and their equipment need the fifth share of the funds (21%), and only 6% are spent on the repairs of the local roads and approaches to the pump stations.

Pump stations. During the last decade, for the maintenance of the pump stations operation (repairs, reconstruction and maintenance 262-390 thousand euros were granted, i.e., the average annual expenses reached 326±64 thousand euros. The statistical estimation shows that the calculated average of the expenses on the pump stations exploitation proves to be sufficiently exact (the data variation – 33%, the relative error of the mean – 10%). During the investigation period the pump stations were granted on average 42% of annual funds' of the sum: the least in 1999 – 29%, the most in 2003 – 76%.

Dikes. The repairs, reconstruction and maintenance of the dikes annually need about 239±88 thousand euros (the error of the mean – 18%), when includes the third part of the annual sum granted for polder funds. Due to the equally great data variation (59%), the confidence interval of the expenses average at the 95% confidence level proves to be rather

extensive, which means that the range on of the fluctuations of the dike exploitation expenses vary greatly throughout separate years (from 151 to 327 thousand euros). The dike repairs require the most share of the means (approximately 64%), reconstruction - about 20%, whereas the dike maintenance (mowing down of vegetation) are yearly provided 10–33% of the means (the average – 26%).

Fig. 5 presents statistical estimation of annual expenses on the maintenance of pump stations, dikes, ditches and local roads.

Ditches. The repairs of the polder ditches and their equipment were granted from 33 to 275 thousand euros a year. Excluding the data of the year 2002 because of its sufficient separation from the total data range, the calculated expenses on average amounted to 157±57 thousand euros. Statistically it is purposeful to exclude the two periods of the polder ditches exploitation. According to the data, during the period from 1996 to 1999, the ditches were supplied with the means 2.7 times more than during the later years - 2000–2006 (accordingly 251 and 94 thousand

Figure 5. Average annual expenses and its variation during 1996-2006.

euros), which includes 32 and 16 percents of the annual expenses.

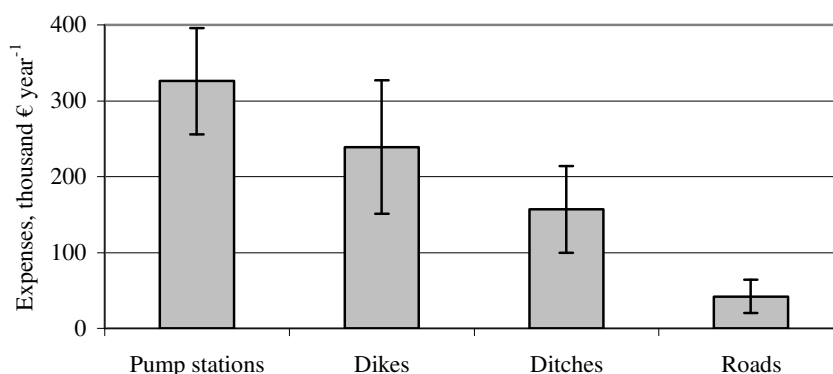*Roads.* The funds, required for the repairs of the approaches to the pump stations and local polder roads, varied from 3 to 113 thousand euros. Due to an exceptionally great expenses variation (81%), the calculated average (42±22 thousand euros) proves to include a sufficiently great (24%) error of calculation. The road repairs were granted approximately 6% of the total means amount.

The State audit report on the State budget means, spent on the land-improvement in the year 2005, indicates that the planning of the budget funds' needs for the land-improvement and the funds distribution in the State capital investment programme didn't ensure an effective funds employment. For that reason the State control of the Republic of Lithuania applied to the Ministry of Finance with a suggestion to look through the financing order of the land-improvement work (during the preparations for the ratification of the State budget and the financial rates of the local administration budgets in the year 2006) to insure a proper funds planning and their distribution according to the needs of the land-improvement work and the requirements of the Investment Law.

The land reclamation programme for the period of 2006–2008 is granting the funds for the exploitation, repairs and reconstruction of the land reclamation structures, in which the polder funds are excluded into a separate line.

The land reclamation programme provides the polder systems with 2.15 million euros a year. In spite of that, the funds are going to be redistributed for separate kinds of works during the next two years. The means for the maintenance of pump stations (in connection with the increase of energy prices) are going to be increased by 16%, and the total means for the repairs and reconstruction are going to be accordingly less by 30% and 67%. But, in fact, due to the smaller number of the pump stations under repair and reconstruction, the recalculated means for one unit will be the same. Analogically, the total means for the repairs and reconstruction of the dikes are going to increase by 42% and 54%, but calculating per 1 km of the dikes, the means for the repairs will even be less, whereas the means the reconstruction will increase by 19%.

The expenses analysis in Silute district reveals that the statistical average of the expenses on the polder systems amounts to 679 thousand euros a year. The equal division of the average expenses on the total number of stations (326 thousand euros) by all the pump station units on the operation (38 units) concludes that on average 8.6 thousand euros: a year are provided for a pump station. Due to some kind of an error of the calculation of the average being involved, it may change around the limits of 7–10 thousand euros. The calculation of the division of the average of expenses on the dike exploitation (239

Table 1

The State subsidies provided for the maintenance, repairs and reconstruction of the polder systems in 2006 – 2008

Years	Maintenance					
	Pump stations			Dikes		
	number	budget, thousand euros	thousand euros per unit	length, km	budget, thousand euros	thousand euros per km a year
2006	94	740	7.9	378	128	0.3
2007	94	857	9.1	378	128	0.3
2008	94	857	9.1	378	128	0.3
Repair						
2006	33	219	6.6	9.2	369	40.1
2007	10	67	6.7	14.0	522	37.3
2008	10	67	6.7	14.0	522	37.3
Reconstruction						
2006	3	565	188	1.55	132	85.3
2007	2	377	188	2.00	203	101.4
2008	2	377	188	2.00	203	101.4

Table 2

Depreciation of the main hydrotechnical structures in polder systems in Silute district

Hydrotechnical structures	Unit	Number	Balance value, euros	Depreciation, %	Residual value, euros	Yearly depreciation	
						%	euros
Dikes	km	221.7	6754033	46.5	3613408	1.57	106038
Pump stations	unit	38.0	4214983	49.3	2136997	2.35	99052
Ditches	km	988.3	4485013	82.4	789362	2.67	119750
Culverts	unit	922.0	1520610	67.9	488116	3.08	46835
Sluices	unit	35.0	472186	64.8	166210	3.08	14543
Bridges	unit	33.0	362727	46.7	193333	1.18	4280

thousand euros) by the total dike length (213.5 km) shows that the dikes are allocated for about 1.1 thousand euros per km a year. This average may fluctuate from 0.7 to 1.5 thousand euros per km a year. Correspondingly, the total average of the expenses (159 euros per km a year) is calculated after dividing the expenses on the ditches (157 thousand euros) by the total length of ditches (988.3 km) (the average may fluctuate from 100 to 217 euros per km a year. The fact is that the exploitation of the polder roads requires from 46 to 145 euros per km a year and the average reaches 97 euros per km a year.

To secure a stable functioning of the polder systems, they should be granted at least the minor amount of the funds required for the reconstruction of the annual depreciation. The data in Table 2 includes the depreciation and residual value of the main polder systems elements.

The calculation reveals that the equipment of the polder systems depreciates on average by 390.5 thousand euros a year. The addition of the annual exploitation expenses in the area of 14254 ha to this amount concludes that the local administration of Silute should award a grant for the polder exploitation containing the sum not less than 721 thousand euros.

The financing of polder exploitation must be based on the market economy principles and valid not so much by social as by the economic necessity. In this case not only the state but also the local administration and entities, which use the polders of the Lower Nemunas, must take some additional engagements upon themselves as well.

The funds must be differentiated not only according to the area of the polders and their equipment but to the social and economic needs as well. It is namely a district local administration that is responsible for the determination and legalization of the funds redistribution priorities.

Conclusions

1. Throughout the last decade (1996–2006) the exploitation of the polder systems in the local administration of Silute district shows that the joint-stock company 'Silute polders' had completed a 7.46 million euros worth. The average annual expenses during this period amount to 579±138 thousand euros. The repairs, reconstruction and maintenance of the pump stations need the most share of the funds (42%), the repairs, reconstruction and maintenance of the dikes need the third part of the means (31%), the fifth part (21%) are spent on the repairs of the ditches and their equipment, and only 6% are necessary for the repairs of local roads and approaches to the pump stations.

2. The analysis of the expenses in the local administration of Silute district reveals that the statistical average of the exploitation expenses on the polder systems (679 thousand euros a year) is less than that to be provided for annual renovation of equipment depreciation, i.e., 721 thousand euros a year.

3. Due to optimization of the exploitation of the lands and nature in the Nemunas delta, the polder funds should be differentiated not only according to the area of the polders and their equipment but to the social, economic and ecological needs as well.

References

1. Ascila R., Dumbrauskas A., Punys P. (2001) Hydrological aspects of Flooding of the Nemunas river delta. Transactions of LUA LIWM. 14 (36).

2. Dumbrauskas A., Punys P. (1999) Kai kurie potvynių Nemuno žemupyje aspektai (Some flooding problems in downstreem region of Nemunas river). In: Ramonas Č. (ed) Hydraulic engineering in the context of agricultural development. Proceedings of national scientific conference, LŽŪU, Kaunas, pp. 17-24 (in Lithuanian with English summary).

3. Juškauskas J., Balodis E. (1999) Nemuno žemaslėnio polderių siurblinių darbo hidrologinių ir energetinių charakteristikų pokyčiai (Changes in hydrological and energetic characteristics of pumping station performance in polders of the river Nemunas lowlands). Vandens ūkio inžinerija, 7 (29), pp. 92–101 (in Lithuanian with English summary).

4. Mališauskas A.P., Morkūnas V. (2004) Istoriniai ir hidrologiniai vandens režimo reguliavimo Nemuno žemaslėnyje aspektai (Historical and hidrological aspects of water regime regulation in the Nemunas floodplain). Vandens ūkio inžinerija. 25(45) 1, pp. 16–24 (in Lithuanian with English summary).

5. Mališauskas A.P. (2000) Vandens režimas vasaros polderiuose ir pievų naudojimas (Water regime in summer polders and use of meadows). Vandens ūkio inžinerija, 9 (31), pp. 12–18 (in Lithuanian with English summary).

6. Quast J., Lukianas A. (1999) Rehabilitation of polder system in the plains of rivers Oder/Germany and Nemunas/Lithuania for new economic conditions, changed land use practices, aims of nature protection and improved flood control. Transactions of 17 th ICID Congress. Vol. 1E. Question 49. Granada/Spain. pp. 129-142.

7. Rekomendacijos, kaip prižiūrėti ir naudoti Nemuno žemaslėnio polderius (Optimal maintenance and employment decisions for the polders of the Nemunas flood-lands) (2000). Lietuvos vandens ūkio institutas. Vilnius, 35 p. (in Lithuanian).

8. Šaulys V., Bastienė N. (2004) Regioninio melioracijos darbų finansavimo modeliavimas (The modelling of financing of land reclamation works). Vandens ūkio inžinerija, 27 (47), pp. 16-24 (in Lithuanian with English summary).

9. Speijker L.J.P., Van Noortwijk, J.M., Cooke, R.M. (2000) Optimal maintenance decisions for dikes. Probability in the Engineering and Informational Sciences, 14 (1), pp. 101 – 121.

10. Van Overloop P.J. (2006) Drainage control in water management of polders in the Netherlands. Irrigation and Drainage Systems, 20 (1), pp. 99-109.

EFFICIENCY OF SURFACE-FLOW WETLANDS FOR FINISHING TREATMENT OF WASTEWATER

Valerijus Gasiūnas
Water Management Institute of Lithuanian University of Agriculture
E-mail: v.gasiunas@water.omnitel.net

Abstract

The objective of the present studies has been to estimate wastewater treatment efficiency of surface-flow wetlands for finishing treatment of secondary effluent. The studies have been carried out within the reconstructed wastewater treatment facilities in Babenai (Kedainiai district, Lithuania), where, after the initial wastewater treatment in the septic tanks and biological ponds, a plant filter has been set for finishing the wastewater treatment. The removal efficiency of the main pollutants in the filter like BOD_5, suspended solids, total N (nitrogen), and total P (phosphorus) has become the focus of the analysis as well. Wastewater treatment efficiency analysis was done on base measurements taken in all seasons of the year within the period 2003-2006

Surface-flow wetlands are characterised by good removal efficiency of the organic pollutants. At the average load of the examined plant filter - 0.9 mg O_2 l^{-1} BOD_5 (biochemical oxygen demand), the removal efficiency reached up to 61.2%. Low winter temperatures reduce the rate of removal for BOD and the biological reactions responsible for nitrification and denitrification. During the warm period of the year, the treatment efficiency of BOD_5 was 70.8%, and during the cold one – 52.4%. However, the total N constituted up to 16.7% and 9.7% respectively. Due to the anoxic and anaerobic conditions in the filter, wastewater after the treatment on average contains 66.0% of ammonium nitrogen of the total N concentration. After a year, with the growth of plants the phosphorus removal efficiency improved and at the average load of the examined plant filter according to P 0.063 g m^{-2} d^{-1}, on average 0.018 g m^{-2} d^{-1} of the total P was removed, i.e., the removal efficiency constituted 28.6%.

Keywords: wastewater treatment, constructed wetlands, surface-flow wetlands.

Introduction

Constructed wetlands are considered as one of wastewater treatment methods containing plant and soil filters. A plant-soil filter is a certain type of wastewater treatment facilities ensuring optimal conditions for natural self - purification processes of wastewater to occur. Constructed wetlands may be designed as surface-flow wetlands (SFW). They are also known as free-water surface wetlands or plant filters.

In surface-flow wetlands the wastewater is directly 'exposed' to atmosphere. Certain filters contain a filtration body (plant roots + soil) with an isolated bottom for the protection of subsurface water from pollution. The principal filter scheme is presented in Figure 1.

Surface-flow wetlands often include a pre-settling basin and a number of compartments with a shallow water layer (0.2–0.4 m) planted up with helophytes such as *Phragmites*, *Typha* or *Scirpus* spp. (Verhoeven and Meuleman, 1999). In the USA and other countries, SFW filters are usually used in secondary and tertiary wastewater treatment stages. They may also be used for the treatment of surface runoff water from agricultural land areas (Koskiaho, 2003).

On the basis of experience in the USA, it has been established that the purification efficiency of surface-flow wetlands is high for COD (chemical oxygen demand) and BOD (90%), but substantially lower for N and P (10–15%) (Kadlec
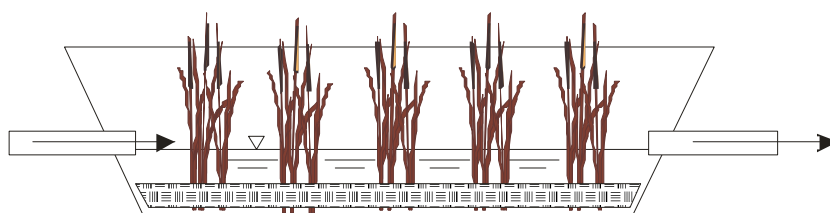

Figure 1. Principal scheme of surface-flow wetlands.

and Knight, 1996). P.S.Burgoon et al., 1999 has studied the treatment of potato processing wastewater and has determined that in surface-flow wetland 10-20% of NH_4-N was removed. However, there are some data indicating much higher treatment efficiency. In the N-data from 17 constructed surface-flow wetlands in the North American Database (Knight et al., 1992), the average N removal efficiency was 49.9% of the total Kjeldahl N and 33.9% for NH_4.

Bachand and Horne (2000) specifies that such systems are distinct for particularly high N removal efficiency that depends on the type of vegetation and air temperature. Swedish researchers also indicate the impact of air temperature (Kallner and Wittgren, 2001). In South Sweden, surface-flow wetlands have been built to treat wastewater from municipal wastewater treatment plants. Commonly, nitrogen removal has been the prime aim, though a significant removal of total P and BOD_7 has been observed. The wetlands performed satisfactorily and removed 0.7-1.5 tons of N ha^{-1} yr^{-1} with loads between 1.7 and 6.3 tons of N ha^{-1} yr^{-1}. P removal varied between 10 and 41 kg ha^{-1} yr^{-1}, and was related to differences in loads (Andersson et al., 2005).

In Lithuania, wastewater treatment in surface-flow wetlands was performed by A.Balevičius (2002). His studies were mostly focused on the development of biocenosis. Strusevičienė and Strusevičius (1994) has also investigated the application of such filters for the treatment of polluted surface water.

The objective of the studies was to estimate wastewater treatment efficiency of surface-flow wetlands for finishing treatment of secondary effluent.

Materials and Methods

For surface-flow wetland, the investigation object included the Babenai wastewater treatment facilities (Kedainiai town) that have been re-constructed from the aeration wastewater treatment plant into the natural one.

Technological scheme of wastewater treatment facilities after reconstruction is presented in Figure 2.

After the reconstruction, wastewater gets into the aero tank reconstructed into a septic tank. Further wastewater is flowing through two concrete-laid ponds. A plant filter (SFW) has been arranged for the finishing wastewater treatment. The filter was set in 2003; currently it is completely overgrown with common cattail (*Typha latifolia*). The length of the filter is 45 m, the width is 15 m. Water depth in the filter may be regulated from 0.1 to 0.8 m. Water depth is maintained to be at the depth of 10 cm in the warm period of the year and at the depth of 50 cm in winter. Due to the entrance of surplus water into the wastewater network, its discharge is fluctuating from 10 to 90 m^3 d^{-1}. The inflow and effluent water samples were taken every 2-4 weeks in different study periods (2003-2006). The water discharge was measured at the same time as well. Laboratory analysis was done considering standard Lithuanian methodologies that completely meet EU standards (Unifikuoti...1994). Regression and analysis of variance were used for the mathematical processing of 34 measurements.

Results and Discussion

The indices of wastewater supplied into the filters after the primary treatment in septic tank and biological ponds are presented in Table 1.

Correlation analysis of the study data has been done in order to determine BOD_5 concentration in the effluent with respect to the load of the filter. The dependences obtained are shown in Figure 3. Considering the given equation, possible load of the filter has been calculated in order to reach the normative treatment level of 25.0 mg O_2 l^{-1} according to BOD_5 in treatment facilities up to 2000 people equivalents (Nuotekų ..., 2006). In this case the possible load of the filter should not exceed 3.1 mg O_2 l^{-1} according to BOD_5.

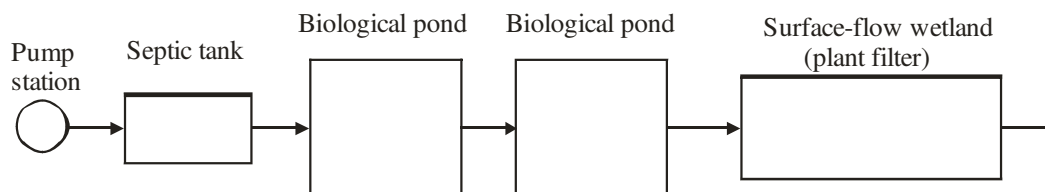The average load of the filter according to BOD_5 was 0.9 g m^{-2} d^{-1}. Having this kind

Figure 2. Technological scheme of wastewater treatment facilities after reconstruction.

Average indices of wastewater supplied into the filter

	BOD_5, mg $O_2 l^{-1}$	Total N, mg l^{-1}	Total P, mg l^{-1}	Suspended solids, mg l^{-1}
Average	19.8	30.3	2.9	19.0
Min	4.2	8.5	0.7	6.0
Max	56.0	103	6.6	40.0

of load, the wastewater treatment efficiency was analysed due to different periods of the year. During the warm period the treatment efficiency was 70.8%, and during the cold one – 52.4%. With reference to low temperatures, snow and ice, the oxygen regime became worse in the filter therefore diminishing the removal efficiency of organic pollutants. A certain BOD_5 removal analysis with respect to the load of the filter was also performed. The data of the analysis are presented in Figure 4. In order to achieve the normative level of the treatment according to BOD_5 the load of the filter cannot exceed 3.1 mg O_2 l^{-1}. Subsequently, BOD_5 removal efficiency constitutes approximately 35.0%. When the average load of the examined filter was 0.9 mg O_2 l^{-1}, BOD_5 removal efficiency reached up to 61.2% on average.

The average load of the filter according to suspended solids was 1.1 g m^{-2} d^{-1}. With respect to the given load, the average removal efficiency of suspended solids - was 55.4%. To reach the normative treatment level according to suspended solids 30 mg l^{-1}, the load of the filter might be about 9.7 g m^{-2} d^{-1}. With such a load the removal efficiency of suspended solids was 60.8%. Similar results have been received by other researchers – A.S. Slack et al. (2005) have determined it to be 64.6%.

Wastewater in the filter goes through the roots of plants therefore involving them into the process of nitrogen removal. In winter, plant vegetation stops and that is why the nitrogen removal processes are analysed due to the warm and cold periods. The average load of the filter according to the total N in different periods had little difference and was 1.2±0.82 and 1.2±0.67 g m^{-2} d^{-1} respectively. The results show that in the filter the average removal of total N is 0.116 in winter and 0.20 g m^{-2} d^{-1} in summer. According to the analysis of variance, the difference between the average is statistically unreliable (LSD – 0.14 g m^{-2} d^{-1}, $p = 0.05$). Although a statistically reliable difference has not been determined, the
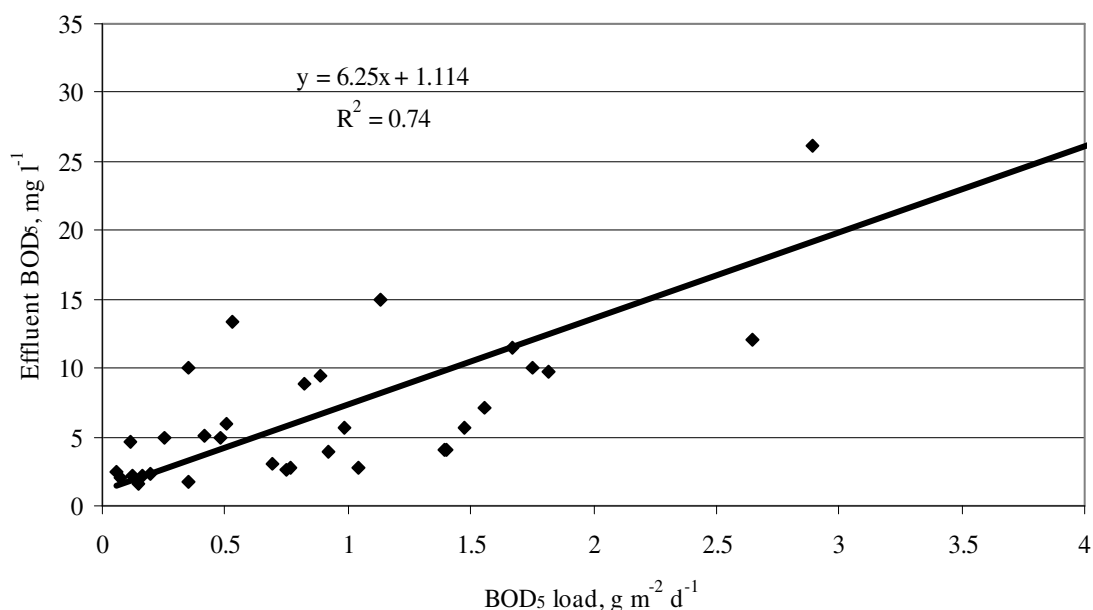
Figure 3. BOD_5 concentration in the effluent with respect to the load of the filter ($p < 0.05$).
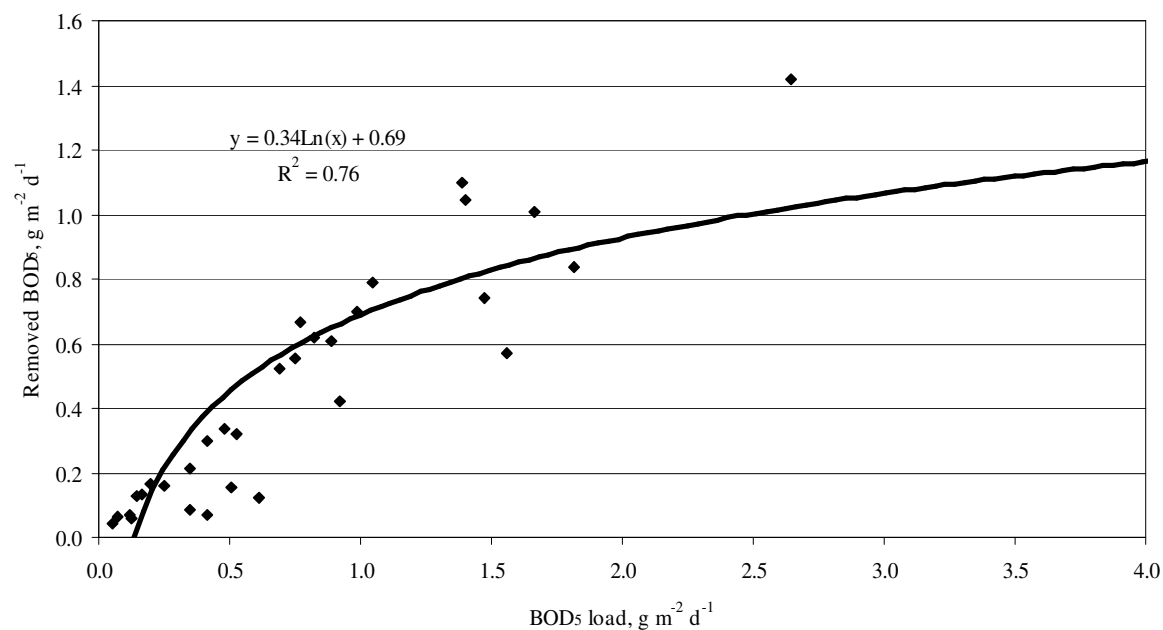
Figure 4. BOD$_5$ removal capacity of the filter with respect to the load ($p < 0.05$).

tendency of greater nitrogen removal during the warm period has been noticed. The removal efficiency of total N in warm period was 16.7 and in cold period it was 9.7%.

N contained in wastewater is of different forms and amounts. Having compared nitrogen forms

contained in the inflow and effluent water of the filter, no significant changes in their composition were observed. NH$_4$-N in the inflow water of filter constituted 67.3%, and in the effluent water constituted 66.0% of the total N concentration. This indicates that anaerobic conditions are

Figure 5. Total N concentration in the effluent with respect to the load of filter ($p < 0.05$).

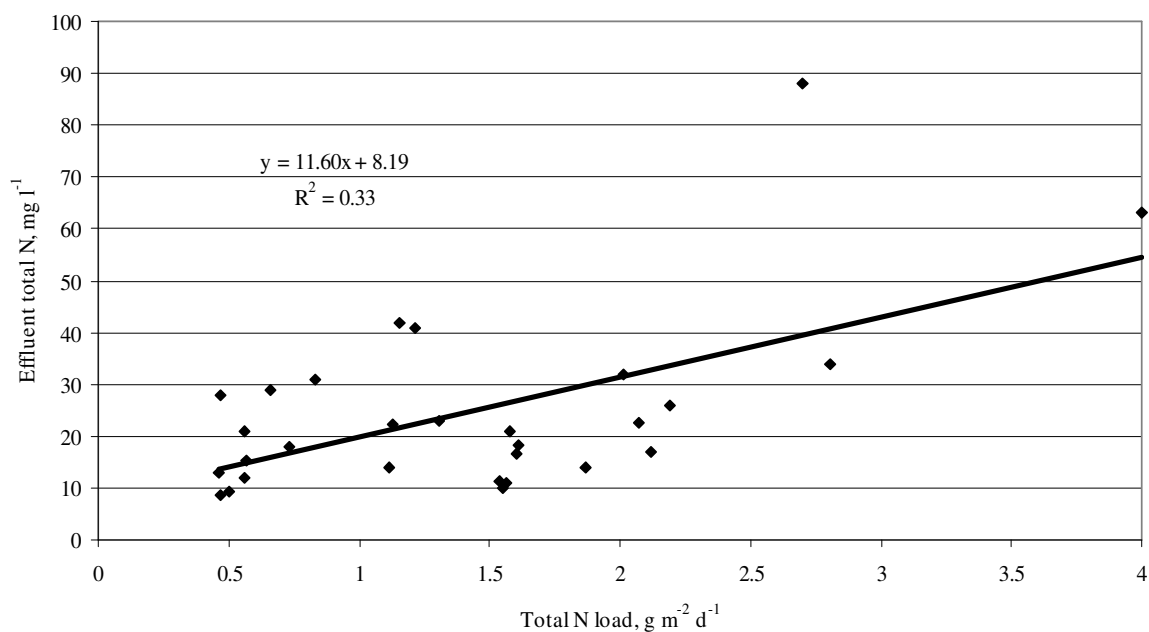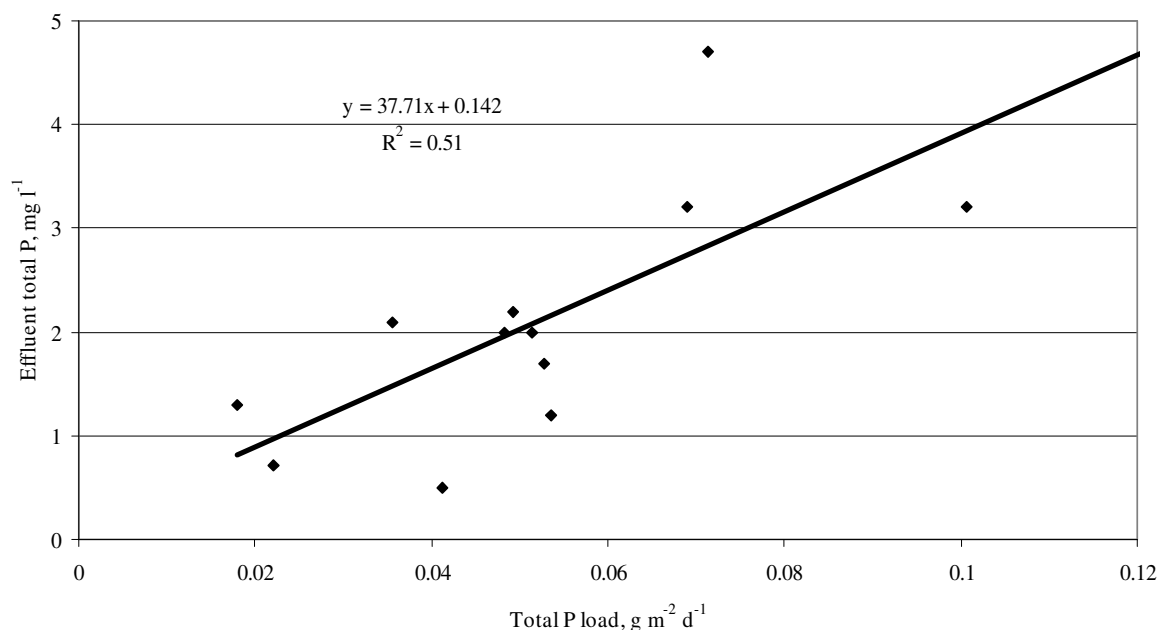Figure 6. Total P concentration in the effluent with respect to the load of filter ($p < 0.05$).

dominant in the filter.

Total N concentration contained in wastewater after the treatment depends on the load of the filter. Results of the data analysis are presented in Figure 5. The data of the studies are scattered and the coefficient of determination is not high. However, in order to anticipate the possible concentration of total N after the treatment with respect to the load, it is possible to rely on the given dependency. With reference to the maximum allowable concentration of hazardous and other controlled substances, the concentration of total N in the effluent water could not exceed 30 mg l^{-1} (Nuotekų ..., 2006). In order to satisfy a certain requirement, the load of the plant filter due to total N should not exceed 1.6-2.0 g m^{-2} d^{-1}.

The removal efficiency of total P depended on the duration of the filter operation. During the first year of the filter setting, common cattail was planted. At that time it was a rare species that ensured perfect conditions for algae vegetation. During that period the same or even greater P concentration was found in the effluent water as it was in the inflow water. The following year the plants spread well and became dense. The dark water surface resulted in poor conditions for algae vegetation. However, the efficiency of phosphorus removal got better. The average load of the filter according to the total P was 0.063 g m^{-2} d^{-1} and on average 0.018 g m^{-2} d^{-1} were

removed, i.e., the removal efficiency was 28.6%. According to recent data, the dependency of the total P concentration in the effluent water on the load was determined. The results are presented in Figure 6. With reference to the maximum allowable concentration of hazardous and other controlled substances, the concentration of total P in the effluent water could not exceed 4.0 mg l^{-1} (Nuotekų ..., 2006). In order to satisfy a certain requirement, the load of the plant filter due to total P should not exceed 0.11 g m^{-2} d^{-1}.

Conclusions

1. Surface-flow wetlands are characterised by good removal efficiency of organic pollutants. At the average load of the examined plant filter - 0.9 mg O$_2$ l^{-1} BOD$_5$ the removal efficiency reached up to 61.2%. In order to achieve the normative level of the treatment according to BOD$_5$ - 25 mg O$_2$ l^{-1}, the load of the filter cannot exceed 3.1 mg O$_2$ l^{-1}.

2. Low winter temperatures reduce the rate of removal for BOD and the biological reactions responsible for nitrification and denitrification. During the warm period of the year, the treatment efficiency according to BOD$_5$ was 70.8%, and during the cold one − 52.4%, meanwhile the total N constituted up to 16.7% and 9.7% respectively.

3. Due to the anoxic and anaerobic conditions

in the filter, wastewater after the treatment on average contains 66.0% of ammonium N of the total N concentration. In order to achieve that the concentration of the total N in the effluent water not exceeding 30 mg l^{-1}, the load of the plant filter due to total N should not exceed 1.6-2.0 g m^{-2} d^{-1}.

4. It was established that when the average load of the filter according to the total P was 0.063 g m^{-2} d^{-1}, on average 0.018 g m^{-2} d^{-1} of the total P were removed, i.e. the removal efficiency was 28.6%. When the load of the filter according to the total P is not higher than 0.11 g m^{-2} d^{-1}, it is possible to achieve that the concentration of total P in the effluent water does not exceed 4.0 mg l^{-1}.

References

1. Andersson J.L., Kallner Bastviken S., Tonderski K.S. (2005) Free water surface wetlands for wastewater treatment in Sweden: nitrogen and phosphorus removal. Water Science and Technology, 51, No 9, pp. 39-46.
2. Bachand P.A.M., Horne A.J. (2000) Denitrification in constructed free-water surface wetlands: II. Effects of vegetation and temperature. Ecological Engineering, 14, pp. 17-32.
3. Balevičius A. (2002) Makrofitų biofiltro įdiegimas ir funkcionavimo bei efektyvumo tyrimai. (The implementation and investigations of the functioning of macrophyte biofilter). Vandens ūkio inžinerija. Mokslo darbai 19(41), Kaunas-Akademija, Vilainiai, pp. 14-21. (in Lithuanian).
4. Burgoon P.S., Kadlec R.H., Henderson M. (1999) Treatment of potato processing wastewater with engineered natural systems. Water Science and Technology, 40, pp. 211-256.
5. Kadlec R.H., Knight R.L. (1996) Treatment Wetlands. Lewis Publishers, CRC, New York, pp. 894.
6. Kallner, S., Wittgren, H.B. (2001) Modelling nitrogen transformations in surface flow wastewater treatment wetlands in Sweden. Water Science and Technology, 44 (11-12), pp. 237-244.
7. Koskiaho J. (2003) Deceleration of runoff in free water surface wetlands. In: Mander Ü., Vohla C. and Poom A. (eds). International Conference Constructed and Riverine Wetlands for Optimal Control of Wastewater at Catchment Scale, Tartu, Sept. 29 - Okt. 2. 2003. Publicationes Instituti Geographici Universitatis Tartuensis, 94, pp. 117-121.
8. Knight R.L., Kadlec R.H., Reed S. (1992) Wetlands Treatment Data Base. Presented at the Water Environment Federation 65th Annual Conference Exposition, New Orleans, LA. September, 1992. AC92-009-003, pp. 25-35.
9. Nuotekų tvarkymo reglamentas (2006) (Regulation for Wastewater Treatment). Valstybės žinios, Nr. 59-2103 (in Lithuanian).
10. Strusevičienė S., Strusevičius Z. (1994) Cleaning of polluted surface water. Agricultural run-off. In: Proceedings of NorthFA seminar. Latvia University of Agriculture.- Jordgorsk, Norway, Jelgava, Latvia, 1994, November 10-12, pp. 51-52.
11. Slak A.S., Bulc T.G., Vrhovsek D. (2005) Comparison of nutrient cycling in a surface-flow constructed wetland and in a facultative pond treating secondary effluent. Water Science and Technology, 51 No 12 pp. 291–298.
12. Verhoeven J.T.A, Meuleman A.F.M. (1999) Wetlands for wastewater treatment: Opportunities and limitations. Ecological Engineering, 12, pp. 5–12.
13. Unifikuoti nuotekų ir paviršinių vandenų kokybės tyrimų metodai (1994) (Unified methods for analysis of wastewater and surface-water quality). Vilnius, pp. 224. (in Lithuanian).

DISTRIBUTION OF WOODY VEGETATION ON THE SLOPES OF REGULATED STREAMS

Oksana Survilaitė, Valentinas Šaulys

Vilnius Gediminas Technical University

E-mail: so@ap.vgtu.lt

Abstract

The paper presents the study material and analysis of the distribution of woody vegetation of regulated streams in southeast Lithuania. The studies were carried out in 110 randomly selected slope strips of regulated streams in the Neris river basin in the Baltic Highland within the period of 2005 to 2006. During the studies 32 species of woody vegetation were found, from which 14 species of trees and 18 species of bushes. In regulated streams different species of willows are most common. However their distribution on channel slopes is different. For most species of woody vegetation the conditions are most favorable in the lower and middle part of slopes. Here their density is highest (0.34 ± 0.89 and 0.73 ± 0.139 units m^{-2} respectively), the frequency is 0.56 and 0.64 respectively. As it was determined, the frequency of woody vegetation on slope strips of regulated streams is $n_a = 0.61$. On the slope the lower overgrowth limit of woody vegetation is $r_a = 1.58 \pm 0.16$ m, the upper limit is $r_v = 4.13 \pm 0.22$ m. In southeast Lithuania, in discharge network of drainage systems there are more possibilities for planning of ecological means, when trees and bushes are allowed to grow on slopes.

Keywords: regulated streams, overgrowth of slopes, woody vegetation.

Introduction

Except for protective channels (there are about 10 thousand km of them) in Lithuania there are about 53 thousand km of land reclamation channels. Most of those channels are former natural, now regulated water flows. The purpose of a drainage channel is to collect and discharge water from draining areas on time (Lamsodis, 2001). When selecting maintenance ways for water recipients of drainage systems and adapting them to natural processes occurring in channels, it is important to determine the suitability of the state of channels for the performance of functions of water recipients. The main purpose is the conductivity of the channel. Vegetation – trees, bushes, grass – reduce the conductivity of the channel (regulated stream) (Rimkus and Vaikasas, 1998). Many researchers have investigated the resistance of trees and bushes to water flow, the influence of their shadows on the development of grass vegetation, as well as the hydraulic conductivity of the channel (Rimkus et al., 2002; Šukys and Poškus, 1998). Naturally, every additional obstacle (trees, bushes and grass vegetation) increase the resistance to the flow within a flow profile and thus reduce the hydraulic conductivity. As the study results show, the hydraulic conductivity in overgrown channels is most affected by the central part of channels, and flood water is often collected in the bed; moreover, the lower strip of the channel is less overgrown

with trees, and in the zone of shadow grass vegetation is choked naturally. Higher density of trees makes more significant impact on the vegetation.

Having carried out land reclamation works, also having eliminated sprouts, bushes and other perennial vegetation from slopes, the morphological structure of landscape has changed and become less different. Natural components were replaced by many morphological anthropogenic components. When the amount of vegetation decreases in draining areas, the conditions become favorable for wind erosion, pollution of water bodies, specific changes of fauna and changes of local microclimate. The studies carried out in the Vardas stream basin in southeast Lithuania (Šileika et al., 1998) have shown that the protective belt arranged around the streams may effectively retain and remove nutrients and sediment. Trees and bushes growing on the protective belt significantly reduce nitrate concentration in water flowing from adjacent arable land plots.

Having regulated the stream, woody vegetation does not grow on its slopes. During the changes of grass vegetation in channels, woody plants start growing here. Most often these include deciduous trees and bushes. Having investigated woody vegetation in the Nevėžis Plain in Middle Lithuania (Lamsodis, 2002; Lamsodis, 1999), 32 species of woody vegetation

were observed. It was determined that the highest specific composition, frequency and density of woody vegetation is observed in channels arranged in the forest, at the outskirts or near the forest. Thus the forest and outskirts of forest are places where drainage channels are most naturalized from the dendrology point of view. In field channels single plants are prevailing. Here the lower and upper parts of channels are overgrown most intensively. In channels located near the forest, in outskirts of forest or in the forest the middle and upper parts of slopes are overgrown most intensively. This implies that the distribution of plants more depends on the forest; on slopes of field channels the distribution of vegetation more depends on different moisture conditions on the upper and lower parts of slopes. The overgrowth of channel slopes also depends on the exposition of the channel. As it was determined (Lamsodis, 1999; Survilaitė and Šaulys, 2006), field channels facing west, northwest, north and northeast tend to overgrown with vegetation more intensively.

Thus, the overgrowth process of the discharge network of drainage systems with trees has a positive impact on the environment, as well as reduces the hydraulic conductivity of the channel, which is particularly important for the principle draining function to perform. Detailed investigations about the overgrowth of channel bed and slopes with woody vegetation, its specific composition and expansion were performed in the region of intensive agriculture in the Nevėžis river basin located in the Middle Lithuania (Lamsodis, 2001; Lamsodis, 2002). Meanwhile, no any similar investigations are performed in

southeast Lithuania. The objective of this work was to investigate quantitative and qualitative peculiarities of the overgrowth of regulated streams with woody vegetation, and evaluate the future possibilities to plan the naturalization of regulated streams of southeast highlands.

Materials and Methods

The studies were carried out in the Neris river basin, in the Baltic highlands (the so-called Baltiškais mountain range) located in the south and east of Lithuania within the period of 2005 –to 2006. Form the point of soils regionalism, the territory corresponds to the districts of South and East Lithuanian Highlands, and its larger part. Soils prevailing here include sand, loam and sandy loam rock-forming soils. Widely expanded sand and sandy loam soils permeable to water absorb snow thaw and precipitation water. Due to their fast infiltration, those waters contribute to the subsurface water stock that gradually is transported to rivers during the abatement period. Annual subsurface runoff of rivers of the study area reaches $5.0 \ l \ s^{-1} \ km^{-2}$, which is nearly 10 times higher than that of rivers of Middle Lithuania ($0.5 \ l \ s^{-1} \ km^{-2}$) where soils of heavy-textured soils of low conductivity are prevailing. The region is distinct for hilly relief, large areas of eroded land and high danger of erosion. The average precipitation amount in southeast Lithuania reaches 700 mm per year. Their distribution is uneven due to the non-homogeneity of spread hills, abundance of water bodies and other reasons. The average annual air temperature is 5.7 °C, the amplitude of yearly air temperature, the index of which is
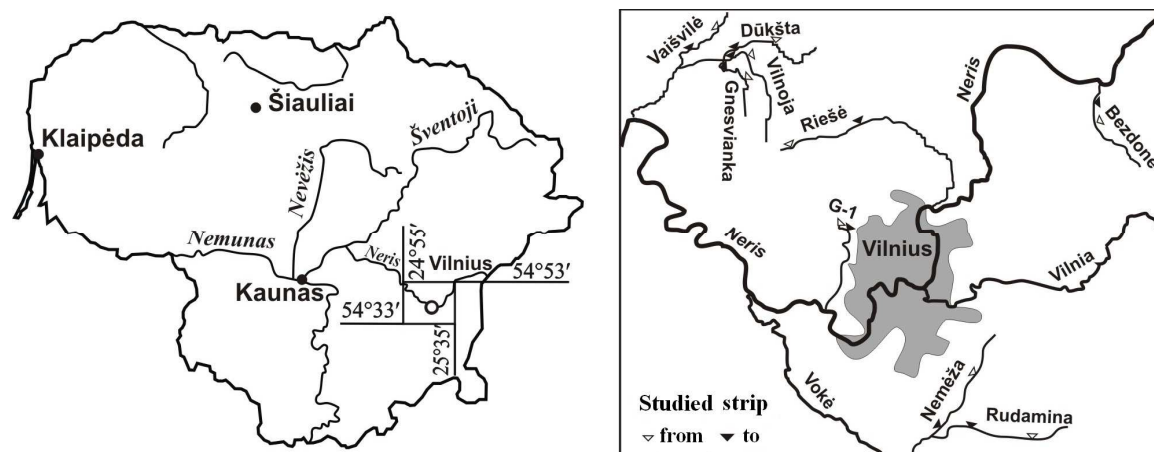

Figure 1. Location of the study area.

the difference between average temperatures of July and January, reaches 23.0-23.5 °C (Gailiušis et al., 2001). Forest density is middle in the region (about 28%). Here small forests, mostly pinewoods, fir woods, birch woods, alder woods and asp woods are prevailing without any large forest areas (Kuliešis et al., 1997). River network is sparse (on the average 0.75 km km^{-2}), because apart from rivers, the territory is drained by lakes and marshes (Baltrušaitienė et al., 1975).

The studies were carried out in strips of the following regulated streams: the Bezdonė, the Dūkšta, the Gnesvianka, G-1, the Nemėža, the Riežė, the Rudamina, the Vaišvilė and the Vilnoja. Scheme of the study area is given in Figure 1.

The length of all investigated stream strips reaches 12.7 km, the one of slope strips is 112 km. The average strip length was selected to be 10 meters. In the most representative place of the strip one profile under analysis was distinguished, where morphometric measurements of the stream bed profile were made. The lower border (r_a) of slope overgrowth with woody vegetation was determined – i.e., the distance upwards the slope, from the foot of the slope until the edge of vegetation. Also the upper border (r_v) of slope overgrowth with woody vegetation was determined – i.e., the distance upwards the slope from the foot of the slope until the edge where no vegetation is observed. The width of the overgrown strip of the slope (L_a) is expressed by the difference between overgrowth of upper and lower edges of the slope with woody vegetation.

Considering the moisture conditions for plants, the slopes of investigated strips were divided into three parts – upper, middle and lower (the foot of slope). In every part of the stream slope (habitat) the dispersion of woody vegetation was determined in respect of quantitative and qualitative characteristics of different species, communities and their whole. The habitat of woody vegetation is considered to be the stream bed profile where individual species or their communities are present.

The number of woody vegetation species (R_{sk}) in habitats (distinguishing upper, middle and lower parts of slope) was determined on the basis of the Guidebook for the recognition of Lithuanian plants (Lekavičius, 1989; Snarskis, 1968).

The frequency of separate species of woody vegetation (D) in habitats was determined as ratio of bed slopes or their sample of parts in which this spice was found (upper, middle and lower part of slope) and the number of researched bed profiles.

The density of woody vegetation (T) in habitats was determined as a total number of stems and forms (a bush of one species was considered as a unit) falling for 1 m^2 of the area of the whole bed slope as well as parts of slopes (i.e., the number of stems and forms falling for 1 m^2 of the area of upper, middle and lower part of slope).

The data of the spread of woody vegetation in the regulated stream beds was processed by the methods of mathematical statistics (was estimated mean value, standard deviation, coefficient of variation, standard error of the mean value) (Čekanavičius and Murauskas, 2000; Čekanavičius and Murauskas, 2002).

Results and Discussion

Different trees and bushes grow on the slopes of regulated streams. Having made the investigations in streams of southeast Lithuania (Fig. 1), 32 species of woody vegetation were found, from which 14 species of trees and 18 species of bushes. Within the study area the following tree species were most dominant: sallow (*Salix caprea*) observed in 25 habitats, white alder (*Alnus incana*) and black alder (*Alnus glutinosa*) observed in 22 and 16 habitats respectively. From all bushes, the most popular was grey osier (*Salix cineria*) observed even in 47 habitats.

When analyzing the overgrowth of regulated stream slopes with woody vegetation it is obvious that its distribution on channel slopes is different. For most species of woody vegetation the conditions are most favorable on the lower and middle parts of the slope. Here its frequency and density is highest (Fig. 2). Frequency of woody vegetation on the middle part of the slope and on the foot of the slope is 0.64 and 0.56 respectively. Frequency on the foot of the slope is 0.45 less. The changes of density of woody vegetation are similar in different parts of the slope. The highest density is observed on the middle part of the slope (0.73 $\pm$ 0.139 units m^{-2}) and on the foot of the slope (0.34 $\pm$ 0.089 units m^{-2}). The least density and frequency of woody vegetation are observed on the upper part of the slope.

Changeable growing conditions on the slope resulted in scarce woody vegetation due to moisture excess on the lower part of the channel slope (the most frequent spot of the contact of depression curve with the slope) (Table 1). The lower edge of the overgrowth of slope with woody vegetation is r_a = 1.58 m. In each case the variety of different conditions is expressed by a rather high variation coefficient (84%). On the
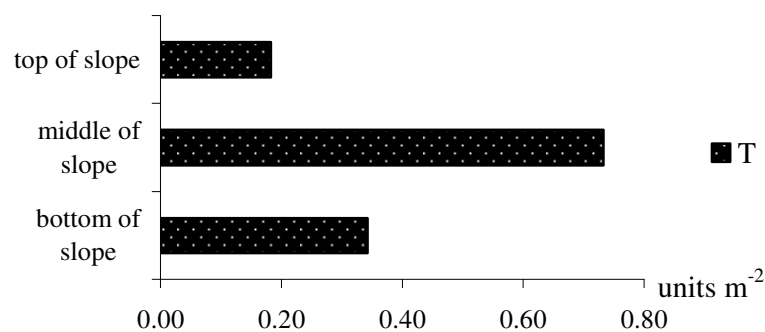
Figure 2. Distribution T of woody vegetation.
(T - density (units m^{-2})).

upper part of the channel slope (nearly always above the depression curve) the amount of woody vegetation is also less due to the lack of moisture. The upper edge of the overgrowth of slope with woody vegetation is $r_v = 4.13$ m, or 2.02 m from the upper part of the slope (variation coefficient is 43%). As the best conditions for plant growing are observed on the middle part of the slope, here woody vegetation is most abundant. In this part of the slope the width of overgrown strip is $L_a = 2.55$ m, variation coefficient is 77%.

As it was determined, the lower edge of the overgrowth of slope with woody vegetation is $r_a = 1.58$ m, which is 1.76 times more than the overgrowth of the lower edge (0.90 m) determined in the Middle Lowland of Lithuania In southeast Lithuania, sand and sandy loam soils are prevailing, and here the coefficients of channels of trapezium-shaped profile are higher (m = 2.0) than in the Middle Lowland of

Lithuania (m = 1.5) where loam and clay soils are dominant. Therefore here the water depth in the channel bed increases 1.42 times and the width of the flow increases 2.23 times until the edge of woody vegetation strip. When the hydraulic roughness and other morphometric parameters of the lower part of profile are similar, the hydraulic conductivity of regulated streams overgrown with woody vegetation is more than 2 times higher in southeast Lithuania compared to those in the Middle Lowland of Lithuania. From this point of view, in southeast Lithuania there are more possibilities to plan ecological means in the discharge network of drainage systems, allowing trees and bushes to grow on the slopes.

Different moisture demand of the species determined their different distribution on the slope (Table 2). Various trees and bushes require different amounts of water, and thus differently support the lack of moisture.

Table 1

Indices of slopes of regulated streams covered with woody vegetation

Index	slope length, L	lower overgrown limit, r_a	upper overgrown limit, r_v	width of overgrown strip, L_a
total number of strips, N	112			
number of strips when woody vegetation was discovered on slopes, n	68			
frequency of slopes covered with woody vegetation, n_a	0.61			
mean value, $\bar{x}$, m	6.15	1.58	4.13	2.55
standard deviation, S	1.60	1.32	1.78	1.95
coefficient of variation, C_V	26 %	84 %	43 %	77 %
standard error of the mean value, S_X	± 0.19	± 0.16	± 0.22	± 0.24
error of the mean value when reliability is 95%, S_{X95}	± 0.38	± 0.31	± 0.42	± 0.46

Table 2

Spread of species (frequency and density) in different parts of the slope

Species	$D \times 10^{-2}$ (frequency) ratio			T (density) $\times 10^{-2}$ units m^{-2}		
	top	middle	bottom	top	middle	bottom
Alnus glutinosa	0.00	1.82	9.09	0.00±0.000	0.11±0.111	0.79±0.402
Salix triandra	1.82	3.64	7.27	1.09±1.092	1.04±0.875	1.40±0.788
Salix fragilis	3.64	7.27	9.09	1.02±0.835	3.27±1.780	5.08±2.660
Alnus incana	3.64	20.00	18.18	0.18±0.130	4.00±1.480	3.84±1.580
Salix caprea	5.45	18.18	7.27	0.92±0.707	3.63±2.083	2.00±1.753
Salix pentandra	0.00	5.45	1.82	0.00±0.000	4.36±2.783	0.25±0.248
Tilia cordata	1.82	0.00	0.00	0.11±0.108	0.00±0.000	0.00±0.000
Quercus robur	3.64	1.82	0.00	0.46±0.405	0.08±0.081	0.00±0.000
Acer platanoides	7.27	5.45	0.00	1.07±0.821	0.64±0.415	0.00±0.000

For some species, such as black alder (Alnus glutinosa) and crack-willow (*Salix fragilis*), the most favorable growing conditions are observed on the foot of the slope. Here their frequency and density are highest (0.091, 0.0140 units m^{-2} and 0.0508 units m^{-2} respectively). For other species, such as white alder (*Alnus incana*), twig willow (*Salix pentandra*) and sallow (*Salix caprea*), more favorable conditions are found on the middle part of the slope. Oak tree (*Quercus robur*), fir tree (*Picea abies*), European wahoo (*Euonymus euripaea*), small-leave linden (*Tilia cordata*), pear-tree (*Pyrus*) and apple-tree (*Malus*) are found only on the upper part of the slope or on the protective strip. (Lamsodis, 2002) has assigned to this group common black alder (*Frangula alnus*), common filbert (*Corylus avellana*), common maple (*Acer platanoides*), cork elm (*Ulmus suberosa*) (the species are spreading towards the top of the slope). Those species, except for common filbert (*Corylus avellana*), were found very seldom, most often in the forest, therefore it is difficult to decide about their location on the slope.

Conclusions

On the slopes of regulated streams of the Baltic highlands of southeast Lithuania 32 species of woody vegetation were found, from which 14 tree species and 18 bush species. As the study results have shown, the specific composition of woody vegetation and its distribution in regulated streams depend on the place in the landscape (forest, outskirts of forest or field) and on the location on the slope. The study results have also shown that the frequency of the overgrowth of regulated stream slopes with woody vegetation is $n_a = 0.61$ (ratio). The lower and upper edges of the overgrowth of slope with woody vegetation are $r_a = 1.58 \pm 0.16m$ and $r_v = 4.13 \pm 0.22m$ respectively. The width of the slope strip overgrown with woody vegetation is $L_a = 2.55 \pm 0.24m$.

For many species of woody vegetation the most favorable growing conditions were observed on the lower and middle parts of the slope, where the frequency (D) and density (T) of vegetation are D-0.56, T-0.34 ± 0.089 units m^{-2} and D-0.63, T-0.73 ± 0.139 units m^{-2} respectively.

According to the distribution of growth on the slope of regulated streams, three types of woody vegetation of streams were distinguished, which has shown that not all species are equally adapted to the growing conditions on different parts of the slope.

References

1. Baltrušaitienė I., Jablonskis J., Lasinskas M. (1975) Pietryčių Lietuvos Hidrografija (Upės) (Hydropgrahy of South-East Lithuanian (Rivers)). Vilnius, Fizikinių-Techninių Energetikos Problemų Institutas, Lietuva, 141 p. (in Lithuanian).
2. Čekanavičius V., Murauskas G. (2000) Statistika ir jos taikymai (Statistics' aplication). 1 dalis. Vilnius, TEV, Lietuva, 240 p. (in Lithuanian).
3. Čekanavičius V., Murauskas G. (2002) Statistika ir jos taikymai (Statistics' aplication). 2 dalis. Vilnius, TEV, Lietuva, 270 p. (in Lithuanian).
4. Gailiušis B., Jablonskis J., Kovalenkovienė M. (2001) Lietuvos upės (Hidrografija ir nuotėkis)

(Lithuanian rivers. Hydrography and runoff). Kaunas, Lietuvos energetikos institutas, Lietuva, 794 p. (in Lithuanian).

5. Kuliešis A., Vaičys M., Rutkauskas A. (1997) Lietuvos miško dirvožemių ir augimviečių našumas (Yield and productivity of forest sites and soil in Lithuania). In: Švedas A., Kadžiulis L., Kairiūkštis L. (eds) Lietuvos klimato ir dirvožemio potencialo racionalaus naudojimo perspektyvos. Tarptautinė konferencija. Dotnuva-Akademija, Lietuva, pp. 67–74. (in Lithuanian).

6. Lamsodis R. (1999) Melioracijos griovių Vidurio Lietuvos lygumoje apaugimo sumedėjusia augalija kiekybinis vertinimas (Quantitative evaluation of cover of drainage channel slopes by self-growing shrubs and trees in the middle Lithuanian plane). Vandens ūkio inžinerija, 7(29), pp. 81-91. (in Lithuanian).

7. Lamsodis R. (2001) Apie prielaidas melioracijos griovių gamtinėms funkcijoms plėtoti (On preconditions for the development of natural functions of drainage channels). Vandens ūkio inžinerija, 16(38). pp. 61–67. (in Lithuanian).

8. Lamsodis R. (2002) Sumedėjusios augalijos melioracijos grioviuose rūšinė sudėtis ir paplitimas (Botanical structure and spread of woody vegetation in drainage channels). Vandens ūkio inžinerija, 20(42). pp. 31–40. (in Lithuanian).

9. Lekavičius A. (1989) Vadovas augalams pažinti (Identification of plants). Vilnius, Mokslas, Lietuva, 440 p. (in Lithuanian).

10. Rimkus A., Vaikasas S. (1998) Natūralizuojamų kanalų hidraulinio-matematinio modelio papildymas ir jo taikymas (Supplementing of hydraulic-mathematical model of canals and its application for planning of naturalization). Vandens ūkio inžinerija, 1998, 5(27). pp. 80-88. (in Lithuanian).

11. Rimkus A., Vaikasas S., Poškus V., Šaulys V. (2002) Naturalization of brooks canalized for land reclamation and their maintenance as water recipients in Lithuania. In: Killingtveit A. Nordic Association for Hydrology. XXII Nordic Hydrological Conference, Roros, pp. 389–397.

12. Snarskis P. (1968) Vadovas Lietuvos augalams pažinti (Identification of Lithuania plants). Vilnius, Lietuva, 502 p. (in Lithuanian).

13. Survilaitė O., Šaulys V. (2006) Reguliuotų upelių (griovių) apaugimo sumedėjusia augalija tyrimai Pietryčių Lietuvoje (Investigations of regulated streams covered with woody vegetation in South-East Lithuania). Vandens ūkio inžinerija, 29(49). pp. 50–56. (in Lithuanian).

14. Šileika A.S., Kutra G.J., Gaigalis K. (1998) Tree and Bush Vegetation as Buffer Zones in Lithuania. Aplinkos tyrimai, inžinerija ir vadyba, 2(7), pp. 21-34.

15. Šukys P., Poškus V. (1998) Griovių deformavimasis kaupiantis sąnašoms (Deformation of drainage channels by siltation). Vandens ūkio inžinerija, 5(27). pp. 130–141. (in Lithuanian).

TREATMENT OF DOMESTIC WASTEWATER BY NATURAL MEANS

Simanas Aškinis
Water Management Institute of Lithuanian University of Agriculture
E-mail: s.askinis@takas.lt

Abstract

On the basis of this research and the investigations of other authors (1992 – 2002), the paper presents the comparison of the treatment efficiency of domestic wastewater treatment facilities functioning by different natural means. From all the studied three natural wastewater treatment facilities, constructed wetlands are considered as most efficient for domestic wastewater treatment: here the removal of organic pollutants and biogenic compounds is 85-98% and 67-95% respectively. Biological ponds are most suitable for the treatment of domestic wastewater, the discharge and pollution of which is fluctuating within a wide range. However, such ponds do not always ensure the treatment until the allowable rates. Their treatment efficiency according to biochemical oxygen demand (BOD_5) is 49.6%. Total nitrogen amount contained in wastewater outflow from the treatment facilities with biological ponds was on the average 22.2 mg l^{-1}. The biggest problem of those ponds is rather low P removal efficiency (only 29.5%). Therefore wastewater flowing out of the ponds needs additional treatment. The usage of subsoil filtration fields is limited because their arrangement requires light soils. When arranging the distribution pipeline below the freezing zone, in many places the requirement that the pipes must be 1 m above the maximum ground water level is violated. The pipes should be arranged in places where there is no recipient for treated wastewater outflow. The load of subsoil filtration fields should not exceed 300 m^3 ha^{-1} per month.

From the economical point of view, domestic wastewater treatment facilities with flowing ponds require least expenses.

Keywords: filter, flowing ponds, subsoil filtration field.

Introduction

As the experience shows, in villages domestic wastewater may be successfully treated applying natural methods. Such methods are the basis for the functioning of bio-engineering, filtrating and soil treatment facilities (Принципы..., 1988; Николаев, 1972; Gumbricht, 1991; Haberl et al., 1995). They are distinct for high treatment efficiency and little energetic needs (only for wastewater transportation). They are not complicated; their simple operation does not require qualified staff, which is particularly important in rural areas.

In Lithuania, domestic wastewater treatment facilities functioning by natural methods are getting more popular. Treatment facilities with flowing biological ponds are arranged in Tiskūnai, Plinkaigalis, and Barkūniškis settlements in Kėdainiai district, and they are constructed in other districts as well. However, the expansion of such wastewater treatment facilities is impeded, because the problem of worse wastewater treatment quality in summer is still under the question.

Currently, subsoil filtration fields are most often used for the treatment of domestic wastewater from individual farmsteads. There is special methodology prepared for their hydraulic calculations (Проектирование..., 1987), however there is still a lack of the data about their longevity and effect on the natural environment.

From all the methods of domestic wastewater treatment, constructed wetlands are most popular. They are widely used for the treatment of domestic wastewater from settlements, industrial companies, and farmsteads. Constructed wetlands may be used for the treatment of different amounts of wastewater – from 1 to 500 m^3 a day. Recently, they have been applied for the treatment of industrial wastewater as well.

The increasing number of different domestic wastewater treatment facilities requires the evaluation of their technical and economical characteristics as well as their comparison seeking to select the most optimal ones for the conditions of Lithuania.

The objective of the work was on the basis of this research and investigations of other authors to compare the efficiency of domestic wastewater treatment facilities functioning by different natural methods, and to evaluate their applicability for the treatment of domestic wastewater from settlements with fluctuating discharge and pollution indices.

Materials and Methods

To compare the efficiency of domestic wastewater treatment by natural methods, three wastewater treatment facilities in Kėdainiai district were selected: with subsoil filtration fields in Liepų settlement, with flowing biological ponds in Tiskūnai, and with constructed wetlands in Pagiriai. In the first two objects the observations were performed by the author. To evaluate wastewater treatment efficiency in constructed wetlands, the data of the studies carried out by V. Gasiūnas, S. Strusevičienė and Z. Strusevičius was used (1996 – 2000) (Sodybų..., 2000).

The studies were carried out in settlements where sewerage network is arranged improperly and thus collects surface and drainage water. Such settlements are numerous in Lithuania. The discharge of wastewater inflow into the treatment facilities was fluctuating from 5 to 20 m^3 d^{-1} in Liepų settlement, from 2.7 to 400 m^3 d^{-1} in Tiskūnai settlement, and from 50 to 750 m^3 d^{-1} in Pagiriai settlement. Wide-range fluctuation of discharges determines wide-range fluctuation of wastewater pollution indices.

Wastewater and water samples for chemical analyses were taken once per month in all study objects. The analyses of domestic wastewater, drainage water and ground water were made in Chemical Analysis Laboratory of Water Management Institute of Lithuanian University of Agriculture. Total nitrogen (N_{total}) contained in the samples was determined by Kjeldahl method, total phosphorus (P_{total}) was determined by spectrometric method after mineralization with potassium persulphate, ammonium nitrogen (N-NH_4^+) was determined by spectrometric method with Nesler reagent, nitrate nitrogen (N-NO_3^-) was determined by spectrometric method with phenoldisulphic acid, and residual of phosphorus acid (P-PO_4^-) was determined by spectrometric method with ascorbic acid.

Mathematical and statistical analysis of test study results was performed with the help of standard computer programs. To determine the interrelations, 'Excel' program was used.

Results and Discussion

In Liepų settlement, primary wastewater treatment was performed in anaerobic filter. Further deep treatment was performed when wastewater was filtered through the subsoil. Anaerobic filter is a monolithic ferroconcrete vessel with a conical bottom filled with insoluble media with large surface area (about 100 m^2 m^{-3}.) The media is made of corrugated polythene pipes (diameter $d = 63$ mm) of 2.5 m height. The top part of 30 cm of the media is made of loose 5-10 cm long parts of the same pipe. Wastewater gets into the conical part of the filter and is slowly rising up. In the upper part of the media the wastewater is directed by catching chutes into the chamber of siphons, from which it is automatically distributed into the filtration fields.

Particularly efficient functioning of the anaerobic filter was observed in 1992, when the amount of organic pollutants (according to BOD_5) contained in wastewater was reduced by 81.4%, and the amounts of total nitrogen and total phosphorus were reduced by 23.0% and 60.1% respectively. In 1993, treatment efficiency of the filter decreased to 19% because the pollution of inflowing wastewater was fluctuating up to 40.5 times. Moreover, the filter improved sanitary-hygienic indices of wastewater – total amount of microbes was reduced about 10 000 times.

During the dry periods of the year, when the filter receives non-diluted domestic wastewater with the surface water, treatment efficiency in the anaerobic filter is 50%. Due to its complex construction and expensive operation, primary treatment of wastewater should be carried out in much simpler and cheaper three-chamber septic tanks.

After the treatment process in anaerobic filter, wastewater still cannot be released into open water bodies, because its average pollution with organic matter (according to BOD_5) is 38.0 mg $O_2 l^{-1}$, and maximum pollution value is 104.3 mg $O_2 l^{-1}$. Further wastewater was treated in the subsoil irrigation system where it was filtered through the soil and finally purified. As the investigations have shown, chemical indices of ground water are fluctuating from clean to slightly polluted and correspond to the environment protection rates, i.e., they are changing similarly as in intensively used agricultural land plots. In the control variant the average ground water pollution according to BOD_5 reached 3.1 mg $O_2 l^{-1}$. When the load of filtration fields was 150, 300, and 600 m^3 ha^{-1}, the average ground water pollution was 4.2, 4.3 and 5.9 mg $O_2 l^{-1}$, respectively (Fig. 1).

The pollution of ground water is indicated by the increase in the amount of nitrate or ammonium ions. Having compared the values of chemical compounds concentrations contained in ground water of the studied period with the rates allowable for drinking water (Geriamasis ..., 1998) it was determined that ground water is of good quality according to the average
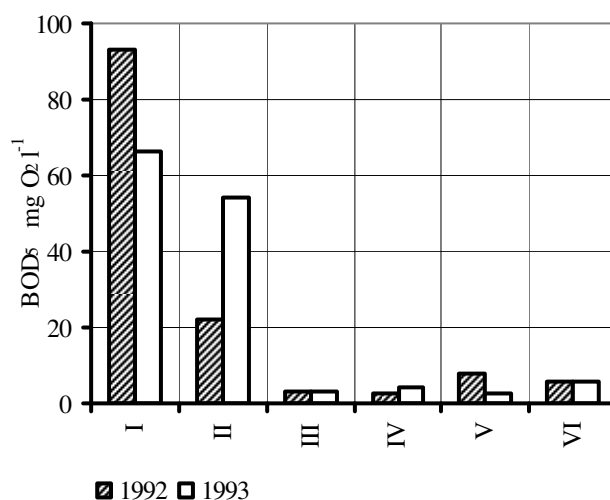
246

Figure 1. Average amount of organic pollutants contained in ground water in different study years: I – from settlement; II – from filter; III – control; IV – 150 m^3 ha^{-1}m^{-1}; V – 300 m^3 ha^{-1}m^{-1}; VI – 600 m^3 ha^{-1}m^{-1}.

as well as maximum concentrations. Even in the fields with maximum load of 600 m^3 ha^{-1} of wastewater per month, maximum N-NH$_4$ concentration was 0.64 mg l^{-1}, maximum N-NO$_3$ and P-PO$_4$ concentrations were 9.74 and 0.71 mg l^{-1}, and the concentrations permissible for water of good quality were 0.78, 10, and 1.1 mg l^{-1} respectively. Nitrites contained in ground water are particularly harmful: they are more toxic than nitrates even 40 times (Rutkovienė et al., 1991). The average N-NO$_2$ concentration was comparatively low in all the filtration fields (0.02-0.1 mg l^{-1}).

During the study period, the fluctuations of ground water level were observed. No relation between the load of filtration fields and ground water level was determined.

Technical condition of the pipeline of subsoil filtration system was analyzed after two years of operation. The thickness of sludge particle layer on the inner walls reached 0.1-0.2 mm. Thus it can be stated that after the anaerobic destruction only very fine hydro-mobile colloidal suspended solids remain, therefore there is no danger for immediate silting of irrigation systems.

The usage of subsoil filtration fields is limited because their arrangement requires light soils; and the arrangement of the distribution pipeline below the freezing ground does not meet the requirement specifying that pipes must be arranged 1 m above the maximum ground water level.

Flowing ponds are often arranged for the treatment of domestic wastewater from small settlements. After the clarification in a septic tank, wastewater flows into the system of biological ponds where further it is treated in the vicinity of complex biochemical processes.

The pollution of wastewater flowing from Tiskūnai settlement with organic matter is not high: the average BOD$_5$ value was 68.8 mg O$_2$l^{-1}, and in some study years it was fluctuating from 54.3 to 104.3 mg O$_2$l^{-1} (Fig. 2). In the first treatment stage of domestic wastewater (in a septic tank) it decreases by 30.4% on the average. The average pollution of wastewater flowing into the first pond is 51.3 mg O$_2$l^{-1} according to BOD$_5$. When wastewater flows through the system of ponds, the amount of organic matter contained in it decreased by 49.5% during the last three years when the bio-community has finally formed in the ponds. BOD$_5$ amounts contained in wastewater flowing out of the first, the second, and the third ponds were 39.0, 37.2 and 25.9 mg O$_2$l^{-1} respectively. The maximum allowable BOD$_5$ rate contained in wastewater outflow from the treatment facilities is 25.0 mg O$_2$l^{-1} (Aplinkosaugos..., 2001).

The amount of total nitrogen contained in wastewater outflow from the treatment facilities with biological ponds was 22.2 mg l^{-1} on the average. Maximum pollution of wastewater outflow was 50.0 mg l^{-1}. During three and a half years, 40 investigations of N$_{total}$ concentrations were performed, from which 17 times N$_{total}$ exceeded the allowable rate (7 times exceeded significantly) and reached 23.0-50.0 mg l^{-1}.

P removal from wastewater is least efficient. Having compared P$_{total}$ concentration contained
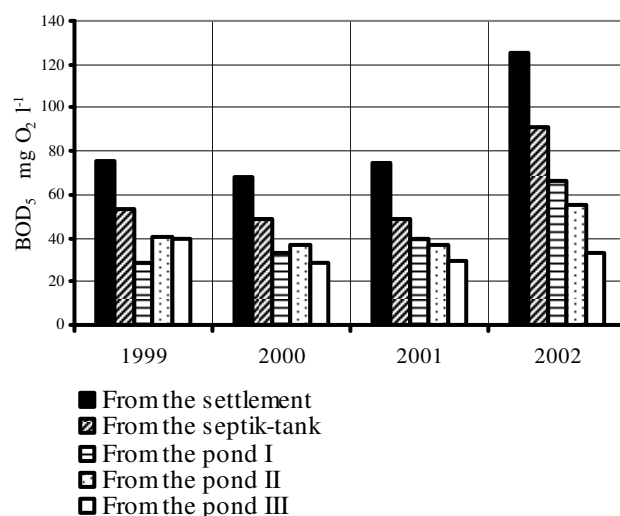
Figure 2. Average amount of organic pollutants contained in wastewater in different study years.

in wastewater outflow from the septic tank and the third pond it is obvious that in most cases wastewater treatment was more efficient when the treatment facilities received more polluted wastewater. However, wastewater outflow from the third pond still did not correspond to the required concentration of 1.5 mg l^{-1}: during the first study year the concentration was 2.5 mg l^{-1}, during the second, the third and the fourth study years it was 2.8, 3.4, and 5.6 mg l^{-1} respectively. Even the average amount of P_{total} contained in wastewater outflow from the treatment facilities exceeded the allowable rate 2 times, and its treatment efficiency was only 29.5%. Maximum P_{total} concentration contained in wastewater outflow from the treatment facilities reached even 11.3 mg l^{-1}.

During the warm period of the year, phosphorus tends to impair wastewater purification in biological ponds because it enhances the development of microorganisms that use dissolved oxygen. This may result in the lack of dissolved oxygen for the oxidation and nitrification processes of pollutants.

As it is seen, three biological ponds are not always enough for the treatment of wastewater until the allowable rates. As Balevičius has determined, in the microphytes biofilter the removal of biogenic pollutants from wastewater is particularly efficient: N and P removal is up to 90% (Balevičius, 2002). Therefore water horizon in the third pond is to be reduced to 0.5 m, and a microphytes filter must be arranged (i.e., the filter must be planted with reed).

Recently, constructed wetlands have become more popular. They have become one of the most acceptable models of wastewater treatment facilities from engineering as well as hygienic points of view. Their construction requires no expensive local materials. In such treatment systems wastewater is not exposed to the environment and is treated without energetic input or continuous supervision. These are the reasons why such wastewater treatment facilities are particularly popular in rural territories, because here their employment is higher, and larger area of technical treatment facilities from 10 to 100 times is not such problematic as in larger towns. In Lithuania, the first constructed wetlands of horizontal flow were arranged in Pagiriai settlement in 1996. Due to the non-economy and complicated maintenance, former aeration equipment contained in the filter were neglected and not operated.

From the very beginning of the arrangement, the constructed wetlands were functioning reliably. The average BOD_5 concentration contained in wastewater outflow reached 10.4-13.0 mg $O_2 l^{-1}$ (Fig. 3). In different periods, particularly in summer, the concentration of wastewater inflow into the filter according to BOD_5 reached 87.0-130.4 mg $O_2 l^{-1}$, while the concentration of the outflow water was 17.4-21.7 mg $O_2 l^{-1}$.

As it was determined, the functioning of constructed wetlands is more efficient when they receive more polluted wastewater from the septic tank. For example, when the pollution of wastewater inflow into the filter according to BOD_5 is 50 mg $O_2 l^{-1}$, its treatment efficiency is
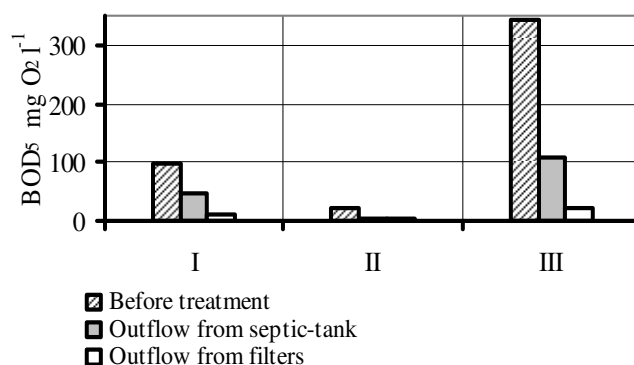
Figure 3. Average amount of organic pollutants contained in wastewater in different study years: I – mean value; II – min; III – max.

80%; when the pollution of wastewater inflow is 100 mg O_2l^{-1}, the treatment efficiency is 90%.

The authors have made the analysis of the treatment level in respect of the filter load according to BOD_5. The amount of pollutants for 1 m^2 of filter area according to BOD_5 was calculated and compared with BOD_5 value of the outflow water. As it was determined, in order to reach the treatment efficiency of wastewater from settlements up to 25.0 mg O_2l^{-1} (according to BOD_5), the load of filters should not exceed 6.0 g of BOD_5 per 1 m^2 of the filter per day; in order to reach the treatment efficiency of 15 mg O_2l^{-1}, the load of filters should not exceed 3.5 g of BOD_5 per 1 m^2 of the filter per day.

Constructed wetlands are suitable for the removal of biogenic pollutants from domestic wastewater. The average N_{total} concentration in wastewater inflow into the septic tank was 25.8 mg l^{-1}, in wastewater outflow from the filter it was 12.9 mg l^{-1} (the allowable average annual concentration is 20 mg l^{-1}).

During the treatment process of wastewater the organic nitrogen becomes mineral nitrogen. For the comparison, it was calculated which part of N_{total} is observed in the ammonia form when N concentration is 20 mg l^{-1}. Before the treatment process, wastewater contains 47.3% of ammonia nitrogen, after the treatment in the septic tank and in constructed wetlands ammonia nitrogen amounts contained in wastewater are 60.0% and 67.5% respectively.

The average P_{total} concentration contained in wastewater inflow into the septic tank was 2.9 mg l^{-1}, while the wastewater outflow from the filter contained 1.1 mg l^{-1} of P_{total} (the allowable average annual rate is 1.5 mg l^{-1}).

During the treatment process, qualitative composition of phosphorus is also changing.

For the comparison, it was calculated which part of P_{total} is in mineral form, when P_{total} concentration is 1.5 mg l^{-1}. The amount of mineral phosphorus contained in wastewater before the treatment process makes up 85.3%, after the treatment in the septic tank and in constructed wetlands it makes up 82.0% and 56.7% respectively.

Marshy plants improve the functioning of the filter. The best solution is to plant up the filter with reed. Reed roots and rhizomes are necessary for ground and oxygen to maintain the growth of aerobic microorganisms that enhance the decomposition of wastewater as well as increase and maintain the hydraulic conductivity of the soil. Two years are needed for reed to take root in the filters and in the sand. Only after such period of time their full effect in biological treatment processes is observed. Bacteria also need a certain period of time for the adaptation to the wastewater.

Constructed wetlands are reliable facilities for the treatment of domestic wastewater. Here different complicated physical-biochemical processes occur, during which 85-95% of organic pollutants and 67-95% of biogenic compounds are removed.

Due to the entering of extraneous waters into the sewerage networks during wet periods of the year and the resulting wastewater dilution as well as the increase in their amount, in settlements with badly arranged sewerage network the designed area of constructed wetlands is calculated according to the normative wastewater amount; while the treatment of the rest amount of wastewater needs additional equipment. For this purpose the flowing biological ponds may be used.

From the economical point of view, domestic wastewater treatment facilities with flowing

biological ponds is cheapest. Their arrangement requires 1-1.5 thousand LTL for 1 m^3 of wastewater treated per day. The arrangement of domestic wastewater treatment system with subsoil filtration requires 2-3 thousand LTL for the treatment of 1 m^3 of wastewater per day; the arrangement of constructed wetlands requires 2.5-3.0 thousand LTL of investments for the treatment of 1 m^3 of wastewater per day. Exploitation expenses are minimal in all wastewater treatment facilities functioning by natural methods.

Conclusions

1. From all the investigated three natural wastewater treatment facilities, constructed wetlands are most efficient, where the removal efficiency of organic pollutants and biogenic matter are 85-95% and 67-95% respectively. The area of filters is to be calculated in respect of the normative amount of wastewater. The excess amount of wastewater is to be treated in additional cheaper equipment (e.g., flowing biological ponds).

2. Flowing biological ponds are most suitable for the treatment of domestic wastewater, the discharge and pollution of which is fluctuating within a wide range. However, the mentioned ponds do not always ensure the treatment of wastewater until allowable rates. According to BOD$_5$, the treatment efficiency of the ponds is 49.6%. The most important problem of the ponds is rather low removal of phosphorus (only 29.5%). Therefore wastewater outflow from the biological ponds needs additional treatment in the shallow macrophyte biofilter.

3. In order to avoid the pollution of ground water, the load of filtration fields should not exceed 300 m^3 ha^{-1} per month. In such case the amount of nitrogen and phosphorus getting into one hectare will not exceed 100 kg and 16 kg respectively. Such filtration fields should be arranged where there is no recipient for the release of treated wastewater nearby.

4. The cheapest solution is domestic wastewater treatment facilities with biological ponds. The arrangement of such treatment facilities requires only 1.5 thousand LTL of investments for the treatment of 1 m^3 of wastewater per day. Domestic wastewater treatment system with subsoil filtration is 2 times more expensive, while constructed wetlands require 2.2 times higher expenses.

References

1. Aplinkosaugos reikalavimai nuotekoms tvarkyt (2001) (Environmental requirements for wastewater). Vilnius, pp. 3-10. (in Lithuanian).
2. Balevičius A. (2002) Makrofitų biofiltro įdiegimas ir funkcionavimo bei efektyvumo tyrimai (The implementation of macrophyte biofilter. And investigations of macrophyte biofilter functioning and efectiveness). Vandens ūkio inžinerija. Mokslo darbai. 19 (41), pp. 14-21. (in Lithuanian).
3. Geriamasis vanduo (1998) Kokybės reikalavimai ir programinė priežiūra (Drinking water. Requirements for quality and rules of operation) Vilnius, pp. 6-19. (in Lithuanian).
4. Gumbricht T. (1991) Nutrient reductionusing macrophyte systems in temperate climate. Licentiate thesis. Royal Ins. Of Tech., TRITHKUT/91; p. 10. Sweden.
5. Haberl R., Perfler R, Mayer H. (1995) Constructed Wetlands in Europe. Water Sci. Technol., vol. 32 (3}, pp. 305-316.
6. Rutkuvienė V., Kusta A., Pocius A., Žibas A. (1997) Drinking water quality in rural areas. International Symposium on Environmental Epidemiology in Central and Eastern Europe: Critical Issues for Improving Health September 24 – 27, Smolenice, p. 32.
7. Sodybų ir kaimo gyvenviečių nuotekų valymo efektyvumo, panaudojant smėlio-augalų filtrus, tyrimas (2000) (The investigation of wastewater treatment efficiency in rural settlements by using of constructed wetlands). Vilainiai, baigto mokslo tiriamojo darbo ataskaita, pp. 21-80. (in Lithuanian).
8. Николаев М.В. (1972) Подпочвенное орошение сточными водами по трубчатым увлажнителям из полиэтиленовых труб (Subsoil irrigation using wastewater through drainsystem with polythene and fenestrate pipes). Сельскохозяйственное использование сточных вод. Москва, стр. 120-128. (in Russian).
9. Принципы проектирование систем почвеной очистки сточных вод в США (1988) (Design rules for subsoil wastewater treatment systems in USA). Мелиорация и водное хозяйство. Москва, стр. 12-34. (in Russian).

10. Проектирование систем внутрипочвенного орошения с использованием природной воды подготовленных сточных вод животноводческих комплексов, городов, сельских населенных пунктов и промышленных предприятий (1987) (Design of system of subsoil irrigation using natural water, processed wastewater of stocks, cities, rural areas and industrial enterprises). Москва, стр. 14-35. (in Russian).

THE EFFECT OF SLURRY APPLICATION ON THE QUALITY OF GROUND WATER

Stefanija Misevičienė

Water Management Institute of Lithuanian University of Agriculture

E-mail: s.miseviciene@takas.lt

Abstract

The paper deals with the analysis of ground water quality when slurry is applied on crop rotation fields. The investigations were carried out in Juodkiškis study object of the Lithuanian Institute of Water Management in 1995-1998.

According to the average concentrations, the quality of ground water samples taken from the borehole arranged in Juodkiškis test field was good compared with hygienic rates for drinking water. All samples taken for the estimation of ammonia and nitrate nitrogen amount were of good quality. However, nitrate-N concentration increased to 5.5-5.6 mg l^{-1} in some periods. Having compared actual phosphate phosphorus concentrations with the allowable ones it may be confirmed that ground water is not polluted with phosphates as phosphate phosphorus concentrations did not reach P-load permissible for drinking water.

Considering the correlation connection between ground water level and chemical compounds concentrations, it was determined that ammonia nitrogen and phosphorus compounds concentrations were influenced by ground water level fluctuations (correlation coefficient $r = 0.54$ and $r = 0.62$). (Given r values correspond to the reliability criterion $t_{actual} > t_{theor95\%}$). Lower ground water levels in a borehole determine higher $N - NH_4^+$, $P - PO_4^-$ and P_{total} concentrations. No relation between nitrate nitrogen ($N - NO_3^-$), N_{total} and K^+ and ground water level fluctuations was determined.

Keywords: ground water, nutrients, slurry.

Introduction

As it is specified in the European Union Nitrate Directive, only economically and ecologically balanced agricultural development may form preconditions to support clean and healthy natural environment. The primary direction of the environment protection strategy of Lithuania is the improvement of water quality. Recently, the human factor (i.e., non-point source and local pollution) makes more and more significant influence on the ground water quality (Tumas, 1999). As the results of the investigations carried out in Vokė branch of the LUA have shown, the systematic application of manure and manure with mineral fertilizers tends to change the migration intensity of nitrogen, potassium, calcium, magnesium chlorides and sulphates in brown soil of light grain-size composition non-saturated with water (Tripolskaja and Romanovskaja, 2001).

Currently, cattle-breeding is particularly of great importance in Lithuania. Its significance will increase in the future, as dairying is one of the principle branches of agriculture. All the future diary farms will contain no less than 50 cows. Those farms will employ slurry handling technologies therefore the amounts of accumulated slurry will even be larger. Now about 14 million tones of slurry are formed on farms; due to improper handling and accumulation of manure about 40% of nutrients get into the environment.

Being close to the ground surface, the ground water is particularly susceptible from the point of view of pollution. It is being polluted by non-point source as well as local pollution sources. In the lower land of the Middle Lithuania with little permeable moraine loams prevailing, the horizontal spread of pollutants is insignificant; here the pollutants are spreading mostly vertically. In such situation the pollution is particularly dangerous for lower situated aquatic horizons (Žemaitis, 1993), because during the nutrient circulation nutrients are leached into deeper soil layers as well as into drainage water and ground water.

In Lithuania there are about 300 thousand shaft wells; about 1 million (one third) of Lithuanian inhabitants make use of them (Kadūnas and Mašanauskas, 1992). Shaft wells accumulate drinking water from ground aquatic horizon which is least protected from the surface pollution.

According to some ecologists, about 80% of all diseases in the world as well as high death-rate of rural inhabitants are related to unsatisfactory

quality of drinking water (Drinking..., 1990).
Agriculture has the strongest effect on water
quality. Considering the data of the European
Environmental Agency, pollution with nitrogen
from cattle-breeding complexes makes up 20-
40% of all N-emission, the ambient air receives
96.5% of ammonia, 48.4% of nitrogen dioxide, and
45.2% of methane gas (Air..., 1997). During
the decomposition of nitrogen fertilizers and
cattle manure, nitrate ions are formed that are
soluble in water, mobile in the soil and quickly
permeable into ground water. In respect of the
hydrogeological conditions, nitrates may pollute
water in wells until the rate that is dangerous for
human health (Rutkovienė et al., 1997; Kutra et
al., 2002).

The objective of the studies was to determine
optimal slurry spreading time under the
conditions of intensive farming, seeking to reduce
nutrient leaching into the environment and the
effect of slurry application on ground water
quality.

Materials and Methods

The study object was arranged in Juodkiškis
village, Kėdainiai district. Soil of the study object
is Endocalcari-Endohypogleyic Cambisols (CMg-
n-w-can) (Buivydaitė et al., 2001). According to
the texture, the soil is attributed to sandy loam
soils. Soil density is 1.5 g cm^{-3}, density of the
hard phase is 2.6 g cm^{-3}. Soils are carbonate-
rich, as the layer of 40-50 cm contains 24.6% of
alkali reaction, pH>7; humus content is low or
middle because the arable soil layer, the depth of
which is 0.3 m, contains on the average 1.2-2.2% of
humus. The limit moisture susceptibility is 18.6%
of absolutely dry weight.

The study area is drained with the drainage (9
draining systems were arranged). One treatment
consists of three drainage systems with the area
of 0.54 ha each: in two of them drain spacing
was 20 m, in one drainage system the drainage
spacing was 15m. Total study area covers the
area of 4.86 ha. In order one drainage system had
no effect on the other one, polythene film screens
were arranged between them down to the draining
depth (1.2 m). The scheme of the study area is
presented in Figure 1.

Four-field crop rotation was selected for the
studies. The following agricultural crops were
grown (amount of inserted slurry – in the
brackets):

1. sugar beet (40 t ha^{-1}) ($N_{232}P_{75}K_{230}$);
2. barley with undercrop (20 t ha^{-1})
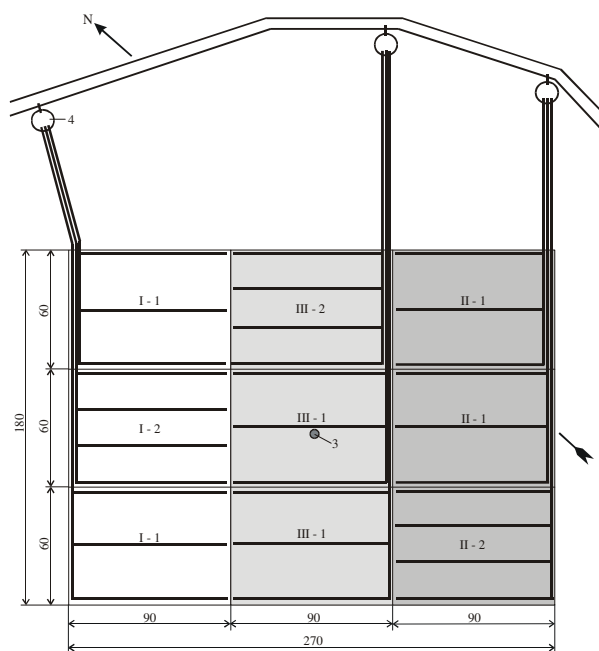   ($N_{44}P_{39}K_{63}$);

Figure 1. Study scheme:
Treatment I – slurry applied in autumn (the whole rate); treatment II – slurry applied in spring (the whole
rate); treatment III – slurry applied in autumn and spring (0.5 rate in autumn, 0.5 rate in spring); 1 - fields
with drain spacing of 20 m; 2 - fields with drain spacing of 15m; 3 - ground water borehole.

3. clover (70%) with timothy (30%) (No fertilization);

4. spring rape (30 t ha^{-1}) (N$_{66}$P$_{33}$K$_{108}$).

Samples for the determination of the chemical composition of drainage and ground water were taken once or twice per month. Precipitation water was sampled after the fall of precipitation. Meteorological conditions were evaluated on the basis of the data of Vilainiai meteorological post with the improvements made by a rain-gauge arranged in the study area. Water analysis was done by Chemical Analysis Laboratory of Lithuanian Water Management Institute according to the methodology specified in the literature (Unifikuoti..., 1994).

In the sampling places, total nitrogen (N$_{total}$) was determined by Kjeldahl method, total phosphorus (P$_{total}$) was determined by spectrometric method after the mineralization with potash persulphate, ammonium nitrogen (N-NH$_4{}^+$) was determined by spectrometric method with Nessler reagent, nitrate nitrogen (N-NO$_3{}^-$) was determined by spectrometric method with phenoldisulph acid, and the residue of phosphorus acid (P-PO$_4{}^-$) was determined by spectrometric method with ascorbic acid and potassium (K$^+$) was determined by flame photometric method. Colorimetric analyses were made with the help of the analyzer 'FIA star 5012 system'.

Drainage runoff was measured in a volumetric way every 5 days, but during spring and autumn floods - every day. Daily runoff was calculated in a linear interpolation way.

Soil samples for the agrochemical tests were taken in autumn and spring before the slurry was spread, from 0-20, 20-40, and 40-60 cm deep soil layers.

Samples for the determination of the fertilization value of slurry were taken in three replications from each reservoir transported in the test field. Fertilization value of slurry and NPK amounts transported with the slurry were determined in a Chemical Analysis Laboratory.

The yield was determined in a direct way. The area of the accounting field of sugar beet was 40 m^2, that of barley, clover and rape was 10 m^2. NPK amount was determined in the main as well as in the side production.

During the study period annual precipitation amount was changing between 422 mm in 1996 (28% lower than average perennial rate) and 725 mm in 1998 (23% higher than average perennial rate); maximum average air temperature reached 7.1 °C in 1995, and exceeded the average perennial air temperature by 13% (Table 1).

According to yearly precipitation amount, the year 1998 was wetest (725 mm, which is 10% higher than average perennial rate). In vegetation period the precipitation amount was biggest (532 mm, which is 33% higher than average perennial rate).

Mathematical and statistical analysis of test study results was performed with the help of standard computer programs. To determine the interrelations, 'Excel' program was used.

Results and Discussion

During the studies the attention was focused on nutrient leaching processes. Having determined drainage runoff heights and chemical composition of the drainage water, nutrient amounts leached by drainage water in separate treatments were determined (Table 2).

The biggest nutrient amounts inserted with slurry in 1995, therefore most nitrogen has been leached. In 1998 the biggest drainage runoff influenced a large leaching of nutritious.

Pollution of ground water is best indicated by the increase of the amount of nitrate and ammonium ions. Having compared chemical compounds concentrations of ground water of the study period with the background values

Table 1

Meteorological conditions of the study period

Indexes	1995		1996		1997		1998	
	I-XII	IV-X	I-XII	IV-X	I-XII	IV-X	I-XII	IV-X
Precipitation, mm	599	406	422	288	574	422	725	532
% from average perennial rate	102	102	72	72	97	106	110	133
Average air temperature, °C	7.1	13.3	5.4	12.5	6.9	12.5	6.8	12.6
% from average perennial rate	87	109	87	102	111	102	110	103

Table 2

Inputs and leached amounts of NPK within a 4-year study period in the experiment field

Year	Treatment	Runoff	Input			Leaching		
			N	P	K	N	P	K
		mm	kg ha^{-1}					
1995	I	230	36	26	82	37	0.08	1.8
	II	190	149	29	148	30	0.1	1.9
	III	175	150	29	119	20	0.08	??.5
1996	I	44	34	13	46	5	0.05	1.3
	II	28	52	20	11	4	0.03	0.8
	III	38	45	18	25	7	0.03	0.5
1997	I	101	0	0	0	9	0.02	0.8
	II	73	0	0	0	8	0.04	1.0
	III	74	0	0	0	10	0.12	0.8
1998	I	241	68	16	89	29	0.16	2.5
	II	215	65	13	82	27	0.12	3.0
	III	202	65	14	89	24	0.05	2.3

(Кондратас, 1969) determined in moraine sediment until the intensive land use, it can be said that ground water is being polluted. Although NH_4^+ concentrations did not exceed the background ones (NH_4^+ 0.1-1.5 mg l^{-1}) and were fluctuating from 0 to 1.4 mg l^{-1}, no existence of NO_3^- ions in ground water until the intensive land use was observed, and during the study period the average amount of this element observed in all samples was 7.9 mg l^{-1}.

Comparison of the values of chemical compounds concentrations of ground water of the study period with the rates allowable for drinking water (Lietuvos..., 2003) (Table 3) suggests that according to the average concentrations (N-NH$_4^+$ - 0.2, N-NO$_3^-$ - 1.8, P-PO$_4^-$ - 0.03 mg^{-1}) the ground water is of good quality.

When determining the nitrate nitrogen, all samples were of good quality because the concentration of this element did not reach the limit of 10 mg l^{-1}. However, during certain periods the concentration of nitrate nitrogen increased to 5.5-5.6 mg l^{-1}. Comparison of the actual values of phosphates with their allowable values suggests that the ground water

is not polluted with phosphates as phosphate concentration did not exceed the allowable limit for drinking water. Although the amount of nutrients contained in ground water rarely exceeds the determined limit, it is obvious that nutrient concentrations have a tendency to increase.

It is found in the literature (Tumas, 1999) that ammonium concentration in ground water seldom is higher than 0.2 mg l^{-1}. However, in Juodkiškis study object concentrations of this element reached even 0.8-0.9 mg l^{-1} (NH_4^+) due to intensive land use.

The highest ammonia nitrogen (N-NH$_4^+$) concentrations in ground water were determined in 1995 (0.6-0.7 mg l^{-1}), in 1996 (1.1 mg l^{-1}), and in 1998 (0.3-0.4 mg l^{-1}), when intensive farming was being developed. Whereas While in 1997, when perennial grass was grown, the maximum ammonia nitrogen concentration reached only 0.2 mg l^{-1}. In 1996, a distinct concentration was determined by the mineralization or ammoniphication processes, during which organic nitrogen is being transformed into inorganic one. In autumn of 1995, the mineralization process of ploughed up residuals of sugar beet started, and

Table 3

Actual and allowable values of ground water indices

Indices	Actual values	Permitted limit (PL)
(N-NH$_4^+$) mg l^{-1}	0 − 1.1	2.0
(N-NO$_3^-$) mg l^{-1}	0.2 − 5.6	10.0
(P-PO$_4^-$) mg l^{-1}	0 − 0.18	0.23

intensive autumn precipitation as well as spring flood water in 1996 leached ammonia nitrogen into deeper soil layers, which resulted in the highest concentration of this element during the whole study period.

The highest nitrate nitrogen ($N\text{-}NO_3^-$) concentrations were observed in spring of 1996, when the soil was not sown up, and in 1998, when spring rape was grown. When organic matter containing nitrogen gets into the ground water, nitrification process starts, because usually water of mineral soils always contains dissoluble oxygen (from 5 to 10 mg l^{-1}) (Juodkazis and Kučingis, 1999). This process is not interrupted until the concentration of dissolved oxygen decreases to 0.3 mg l^{-1} (Tumas, 1999). However, if there is no oxygen, nitrification decreases to minimum (Wetzel, 1983), and then the denitrification process starts.

Although phosphate amounts were very low in ground water, their fluctuations are similar to those of ammonia and nitrate nitrogen. This means that fluctuation reasons of those nutrients are the same. The highest phosphate ($P\text{-}PO_4^-$) concentrations were observed after sugar beet was harvested (0.18 mg l^{-1}) and in spring of 1996 (0.16 mg l^{-1}), when the soil was not sown up.

The fluctuation of potassium (K^+) concentrations in ground water is more dynamic than that of other elements. Higher potassium concentrations were observed at the beginning of the year (3.1-4.1 mg l^{-1}), and later they decreased (1.5-2.1 mg l^{-1}). The highest concentrations were observed at the beginning of summer (3.4-4.6 mg l^{-1}), while in autumn they used to decrease again (3-3.1 mg l^{-1}). The data in the literature shows that, potassium contained in the soil is a structural element of clay minerals. Therefore the soils of a heavy grain-size composition contain larger amounts of potassium than those of light grain-size composition (Motuzas et al., 1996). In soils of the test field, the sum of physical clay particles is fluctuating from 10 to 28%, but the sum of physical sand particles – from 59.7 to 84.1%. This determined the low concentrations of potassium in ground water.

In the borehole arranged in the study object of Juodkiškis, the ground water was fluctuating depending on the precipitation amount. It was slightly late until the precipitation penetrated to the level of ground water. The lowest water level in the borehole was observed in the August of each year, when precipitation is not abundant and the air temperature is highest. In 1995, the ground water level decreased to 206 cm, in 1996 – to 207 cm, in 1997 – to 237 cm, and in 1998 – to 167 cm. The highest level of the ground water from ground surface is observed during the spring flood or after heavy precipitation. For example, in January 1995 it was only 65 cm deep, in years 1996, 1997, and 1998 - 97, 77 and 59 cm deep respectively.

Considering the correlation connection between ground water levels and chemical compounds concentrations it was determined that the concentrations of ammonia nitrogen and phosphorus compounds depend on the fluctuations of ground water level (Table 4).

Concentrations of ammonia nitrogen ($N\text{-}NH_4^+$), $P\text{-}PO_4^-$ and P_{total} contained in water of the ground water borehole much depend on the depth of water abatement: the deeper the water, the higher the concentrations of those elements. No similar relation was determined between nitrate nitrogen ($N\text{-}NO_3^-$), N_{total}, and K^+.

Conclusions

1. Ground water quality in the borehole arranged in Juodkiškis study object was good, because concentrations of the studied elements did not exceed the hygienic norms set for the drinking water.
2. The highest ammonia-N, nitrate-N, and phosphate concentrations depended on plant residuals in the test field as well as on precipitation amount: in spring of 1996 and in summer of 1998 concentrations of those elements were highest, because in autumn of 1995 sugar beet residuals

Table 4

Correlation coefficients between ground water level and chemical compounds concentration

Number of observations	Water level fluctuation range, cm	Values of the correlation coefficient					
		$N\text{-}NH_4^+$	$N\text{-}NO_3^-$	N_{bendr}	$P\text{-}PO_4^-$	P_{bendr}	K^+
31 - 28	59 - 237	0.54*	0.05	0.27	0.62*	0.5*	0.28

Note: Correliation connection values reliable according to the criterion t ($t_{actual} >_{theor}$) are signed with stars.

of a fast mineralization were ploughed up. Meanwhile, during the vegetation period of 1998 the precipitation exceeded the annual rate by 33%.

3. Although after slurry application the highest nitrate nitrogen concentrations were 5.5-5.6 mg l^{-1} and did not reach the rate allowable for drinking water (10.0 mg l^{-1}), comparison with background values suggests that the quality of ground water is decreasing.

References

1. Air and health, (1997) WHO European Environment Agency, 19 p.
2. Buivydaitė V.V., Vaičys M., Juodis J., Motuzas A. (2001) Lietuvos dirvožemių klasifikacija, (Classification of Lithuanian soils). Spauda, Vilnius, 137 p. (in Lithuanian).
3. Drinking water treatment for small Communities (1990) USA, EPA – 625 – 5 – 90025, 15 - 18 p.
4. Juodkazis V., Kučingis Š. (1999) Geriamojo vandens kokybė ir jos norminimas (Drinking water quality and its standardization). Vilniaus universiteto leidykla, Vilnius, 153 p. (in Lithuanian).
5. Kadūnas K., Mašanauskas V. (1992) Ūkininkavimas ir požeminio vandens kokybė (Farming activity and subsurface water quality). In: Ūkininkavimas ir vandens kokybė (Farming activity and water quality). Pranešimų tezės. Kaunas, pp. 81 – 82. (in Lithuanian).
6. Kutra S., Kusta A., Rutkovienė V. (2002) Šachtinių šulinių vandens kokybės rodiklių variacijos tyrimai (Investigations on the change of qualitive indices of water in dug wells). Vandens ūkio inžinerija. Mokslo darbai. 20(42), pp. 56-65. (in Lithuanian).
7. Lietuvos geologijos tarnybos prie Lietuvos Respublikos Aplinkos ministerijos direktoriaus 2003 m. vasario 3 d. įsakymas Nr. 1-06. (Order of the Director of Lithuanian Geology Service under the Environment Ministry of the Republic of Lithuania approved on the 3 February 2003 No. 1-06) (2003), 17 p. Vilnius (in Lithuanian).
8. Motuzas A.J., Buivydaitė V., Danilevičius V., Šleinys R. (1996) Dirvotyra (Soil experiments). Mokslo ir enciklopedijų leidykla, Vilnius, Lithuania, 375 p. (in Lithuanian).
9. Rutkovienė V., Kusta A., Pocius A., Žibas A. (1997) Drinking water quality in rural areas. International Symposium on Environmental Epidemiology in Central and Eastern Europe: Critical Issues for Improving Health, September 24 – 27. Smolenice, pp. 32.
10. Tripolskaja L., Romanovskaja D. (2001) Trąšų poveikis cheminių elementų migracijai (Migration of chemical elements in manured soil). Vandens ūkio inžinerija. Mokslo darbai. 17(39), pp. 34-42. (in Lithuanian).
11. Tumas R. (1999) Vandenų ekologija (Water ecology). LŽŪU Leidybinis centras, Kaunas. 132 p. (in Lithuanian).
12. Unifikuoti nuotekų ir paviršinių vandenų kokybės tyrimų metodai D.1 (Unified study methods of wastewater and surface water quality D.1). (1994) Vilnius, pp. 223. (in Lithuanian).
13. Wetzel R.G. (1983) Limnology. Saunders College Publishing, 767 p.
14. Žemaitis V. (1993) Drėgmės ir teršiančiųjų medžiagų migracija aeracijos zonoje (Migration of moisture and polluting matter within the aeration zone). Moksliniai pranešimai, 3, pp. 32. (in Lithuanian).
15. Кондратас А. (1969) Литовская СССР. In: Сидоренко А. В. (eds) Гидрогеология СССР (Hydrometeorology USSR), издательство 'НЕДРА', Москва, 63 – 83 стр. (in Russian).

GROUND WATER REGIME AND POLLUTION IN THE VICINITY OF KARST SINKHOLES

Alvyda Šaulienė, Povilas Šukys
Water Management Institute of the Lithuanian University of Agriculture
E-mail: lygis@water.omnitel.net

Abstract

The most urgent environmental problem in cultivated land areas of Lithuanian karst region is the protection of subsurface water from technogenic pollution. In terms of subsurface water pollution, the ambience of sinkholes is considered to be particularly dangerous. The work was carried out in 2004–2006 in the district of Biržai.

Having analyzed the regime of sinkhole water formed in the vicinity of sinkholes as well as the regime of ground water of their vicinity it was determined that this regime is different in respect of the local hydrogeological conditions. A common regularity was observed: during the snow thaw period and rainy period sinkholes are fed with water from ambient soil and with shallow ground water, during the dry period water accumulated in peat of the failures of sinkholes flows into the ambience, and during the particularly dry periods subsurface water abates in sinkholes and they start draining the ground water very intensively.

Analyzing the interrelations of water quality indices it was determined that in most cases the quality of ground water in sinkholes and in their vicinity is closely related. Sinkholes with water level higher than the ground water level and with higher chemical compounds concentrations make no adverse effect on ground water quality due to comparatively low runoff into the environment. However, such sinkholes are considered to be potential pollution sources of lower aquatic layers.

Nitrate nitrogen is one of the most harmful pollutants getting into the sinkholes from agricultural fields and farming land plots where mineral fertilizers are applied. Ground water of higher level polluted with the nitrogen is obviously polluting the subsurface water of the sinkhole as well.

Keywords: ground water, sinkhole water, water regime, pollution.

Introduction

In the karst region of northern Lithuania (in the territory of Biržai, Pasvalys, and part of Panevėžys districts) the soils are rather fertile; here under the conditions of intensive farming there is a danger for nutrients (mineral salts) not assimilated by plants to get into the subsurface water. Water polluted with salts is more aggressive and dissolves gypseous dolomite layers more intensively. As a result, subsurface moraine sediment falls into the hollows, and sinkholes are formed. Currently, more intensive karsting processes have been observed.

Most of the sinkholes were formed many years ago; some of them are overgrown with bushes and trees, others are overgrown with marshy vegetation. Such hollows overgrown with peat cover from 0.01 to 0.2-0.4 ha and even larger relief territories. Moreover, they collect quite large amounts of surface and soil water forming from snow thaw and precipitation water. There is an opinion that such sinkholes are considered to be the direst pollution sources of the subsurface water (Vodzinskas, 1967; Narbutas, 1995; Taminskas, 1999).

In respect of gypsum, the water circulating in karst forming layers near the soil surface is more aggressive as it is more intensely diluted with infiltration water (Марцинкявичюс and Буцявичюте, 1990). Compared with the pollution of water layers in non-karst terrains, karst ground water (water in karst layer) is polluted much easier and in shorter time (Kaarolu, 1999). A threatening phenomenon is the infiltration of polluted surface water into subsurface layers, especially the pollution of gypsum dissolving subsurface water with different chemical and organic materials increasing its aggressiveness (Narbutas et al., 2001). Small sinkholes are considered to be the most susceptive to pollution by nitrates and the level of this kind of pollution in them is the highest (Hallberg and Hoyer, 1982). A considerable amount of biogenic materials and other pollutants come to sinkholes together with precipitation, organic materials (dust, pollen, tree leaves) get in together with surface outwash, and bush and tree leaves are considered to be the greatest source of sinkhole water pollution (Taminskas, 2002).

A complicated circulation of subsurface water evidently related with surface water and filtration water of soil surface layers takes place in a peat-

covered sinkhole and its vicinity. The research data of the Lithuanian Water Management Institute (LVŪI mokslo..., 1998) shows that concentration of potassium (K) is normally 2–5 times, of phosphorus (P-PO$_4$) – up to 9 times, and of ammonium nitrogen (N-NH$_4$) – up to 50 times higher in the water of peat-covered karst failure compared with the ground water of mineral soil in the vicinity. It was observed that during the rainy season of the year sinkholes are fed with ground water, and during the dry season, – on the contrary, the water accumulated in their peat flows into the environment (Šukys and Šaulienė, 2005). During especially dry periods, the subsurface water of some sinkholes abates heavily and they drain the ground water intensively. This proves the fact that the regime of sinkhole and ground water of their vicinity can differ greatly depending on climatic factors changing in respect of time and local hydrogeological conditions.

The researchers of different fields have been carrying out different kinds of research for several decades to assess and solve the problem of subsurface water protection against agricultural pollution in the karst region; the results have been published in the national and foreing press. However, the relationship of the regime of sinkhole and soil-ground water of the vicinity and pollution have not been analysed much in terms of scientific

approach.

Work objective is to establish the interrelation of ground water regime and pollution in the vicinity of karst sinkholes.

Materials and Methods

The work was carried out in 2004–2006. The research was performed in the vicinity of four peat-covered sinkholes in land areas of Paežeriai and Lyglaukiai villages, Biržai D. The sinkholes are formed in 5–10 m thick moraine sediment with sandy loams and light sandy clay loams prevailing. Under these permeable to water moraines the layers of karst gypsous dolomite and gypsus occur. One of the investigated sinkholes is surrounded by a cultivated pasture, the second - by a natural bushy meadow, the third is located between farm gardens and a pasture, and the fourth is surrounded by arable land. Mineral slopes of these sinkholes are overgrown with grey alders and aspens. In the bottom peat, mainly goat-willows and willows grow with their dying remains scattering around. On the ground surface the diameter of these sinkholes reach about 15–30 m.

In each study place of the four sinkholes, 2 plastic wells (piezometers) of 50 mm in diameter are installed for monitoring the water level and taking the water samples. They are placed in an
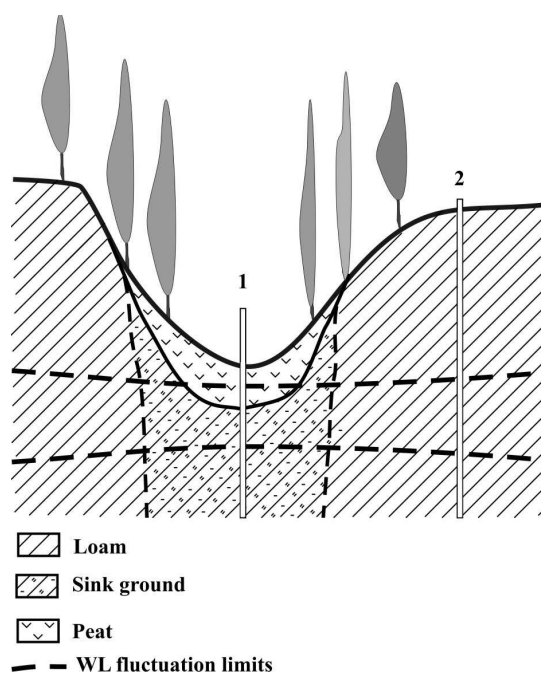

Figure 1. Location of the geological cross–section of the study area and observation wells.

analogous order (Fig. 1): one well is installed in the sinkhole and the other – higher on the slope with respect to the sinkhole at 2–3 m from the edge of the sinkhole. The wells in the sinkholes are fixed in the mineral soil that moved over them long ago in such a way that their filtrating part is below the lowest level of subsurface water.

The level of ground and sinkhole water was measured once in one or two months. At the same time, water samples from the observation wells were taken for chemical analyses, and concentrations of six chemical components of the water – $N-NO_3$, $N-NH_4$, P_{total}, SO_4,- K, and Cl - were analysed in the Laboratory of Chemical Analyses of the Water Management Institute of the Lithuanian University of Agriculture. The statistical analysis included estimation average and standard deviations of data of research, and also correlation Pearson by means of the standard computer program 'Excel'. Student test criterion was used for interrelation significance level estimation.

Results and Discussion

During the research period the regime of ground and sinkhole water level in each study place was of different but clearly correlated nature (Table 1). The underwater level in sinkhole 1 was 0.5–0.8 m almost all the time, in sinkhole 3 – 0.6–2.2 m above the ground water level, and in study places 2 and 4 the level of ground water in the vicinity was higher, mostly up to 0.5 m and sometimes even up to 1.2 m.

The regime of ground and sinkhole water level in each study place was of different but clearly correlated nature (Fig. 2). Common regime regularity is that the highest levels are observed during spring snow thaw which can last to midsummer quite often and later they abate with deceleration up to late autumn or even the beginning of winter. In addition, the change in these levels was relatively synchronous in sinkholes, in which the level of subsurface water was regularly higher than the level of ground water in the vicinity. In other sinkholes the water level changed with frequent lateness and asynchronicity in respect of a similar and especially higher level of ground water in the vicinity.

The quality of ground and sinkhole water was different depending on the place of study (Table 2). Concentration of $N-NO_3$ in ground and sinkhole water fluctuated relatively slightly in study place 1 (cultivated pasture) – from 0.01 to 4.1 mg l^{-1}, and even less in place 2 (natural bushy grassland) – from 0.01 to 0.71 mg l^{-1}. The established concentrations of this nitrogen in the water of sinkhole 3 (between farm gardens and pasture) were rather high (14.8–50 mg l^{-1}) and concentrations in the ground water of this sinkhole bank 2 m deeper were low (0.06–3.7 mg l^{-1}). Concentration of $N-NO_3$ in the water of sinkhole 4 (arable land) fluctuated comparatively little – 0.1–1.16 mg l^{-1}, but in the ground water of the sinkhole bank - from 7.4 to 23.4 mg l^{-1}, at which is not allowed to drink such water.

Concentration of $N-NH_4$ in the water of all sinkholes was 2 times higher or more than that in ground water and the highest concentration (fluctuated from 1.3 to 14.0 mg l^{-1}) was established in the water of sinkhole 4. Concentrations of other three analysed elements were higher in sinkhole water compared

Table 1

The indices of fluctuations of ground water levels in sinkholes and their vicinity

No. of the study place	Studied water	Water level height, m			Fluctuation	Indices of the relation levels	
		highest	lowest	average		R^2	t_{actual}
1	Ground water	63.01	60.37	61.46	2.64	0.82	7.67
	Water in sinkhole	63.04	60.60	62.02	2.44		
2	Ground water	64.63	62.46	63.27	2.17	0.76	6.70
	Water in sinkhole	64.11	62.03	63.21	2.09		
3	Ground water	55.33	52.16	53.40	3.16	0.76	6.69
	Water in sinkhole	57.66	53.97	55.79	3.39		
4	Ground water	65.58	63.15	64.12	2.41	0.81	7.61
	Water in sinkhole	65.72	62.06	63.73	3.66		

Note. R^2- coefficient of determination; t – actual criteria for reliability or determination; P- probability corresponding by the calculated t_{actual} criterion; $t_{actual} > t_{95\%} = 2.1$, the relation significant.
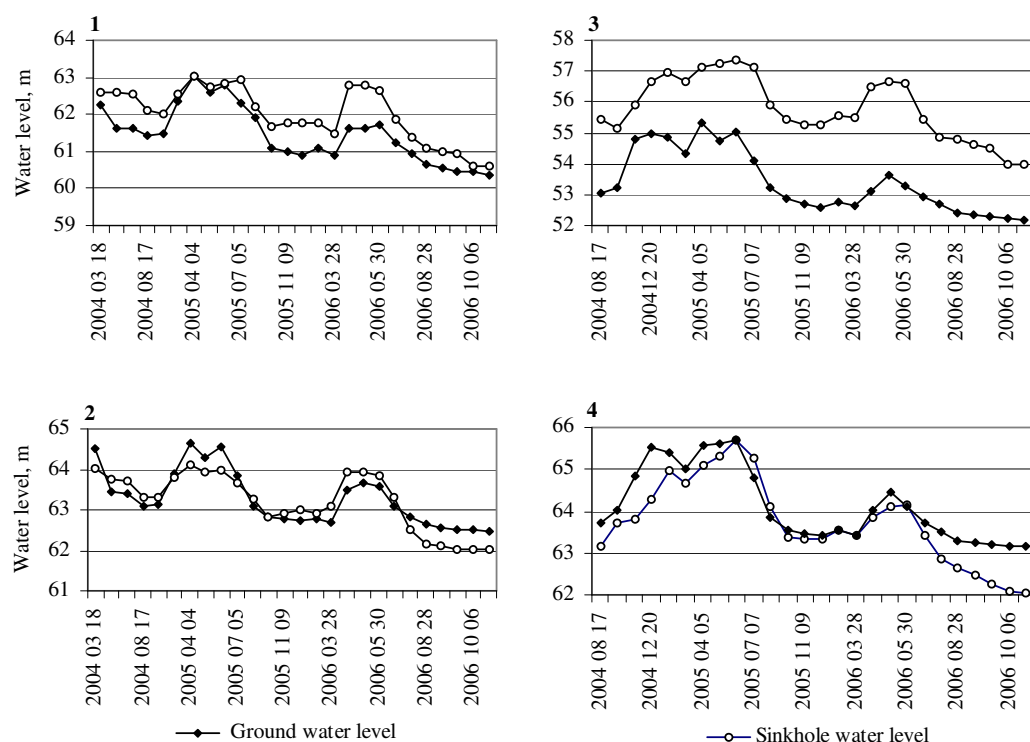
Figure 2. Fluctuations of ground water level in sinkholes and their vicinity. Sinkhole place: 1 - cultural field; 2 - in natural bushy grassland; 3 - between gardens and pasture; 4 - in arable land.

Table 2

Concentrations of chemical compounds in water of sinkhole and in ground water

Water of a sample	Concentrations, mg l^{-1}					
	N-NO$_3$	N-NH$_4$	P$_{total}$	K	SO$_4$	Cl
Study place 1						
Ground water	0.01–3.8 0.97	0.01–4.2 0.90	0.012–0.22 0.060	0.4–2.7 1.4	2.3–36 13.0	0.76–15.1 7.7
Water of a sinkhole	0.01–4.1 0.94	0.04–8.2 1.95	0.069–0.66 0.31	1.0–2.3 1.5	37–117 73	3.8–17.9 12.2
Study place 2						
Ground water	0.01–0.25 0.09	0.02–0.29 0.11	0.007–0.11 0.040	0.4–3.5 1.3	17.0–50.0 26.5	1.96–23.0 9.1
Water of a sinkhole	0.01–0.71 0.22	0.08–1.8 0.42	0.089–0.60 0.280	0.8–7.5 2.6	14.0–380 220	2.0–18.4 13.0
Study place 3						
Ground water	0.06–3.7 1.33	0.01–0.96 0.53	0.02–0.11 0.056	0.2–2.3 1.0	1.7–23.0 8.2	6.0–22.0 11.2
Water of a sinkhole	14.8–50 32.2	0.16–2.5 1.52	0.011–0.16 0.055	2.9–4.9 3.4	100–206 167	14–31 25.3
Study place 4						
Ground water	7.7–23.4 16.3	0.13–6.8 1.56	0.028–0.39 0.099	1.5–5.4 3.2	15.0–37,0 24.8	15.0–28.0 20.1
Water of a sinkhole	0.10–1.16 0.67	1.3–14.0 4.62	0.164–0.42 0.262	2.9–6.4 4.1	630–2116 1570	38–194 147

Note. Numerator – fluctuation ranges of concentrations, denominator – average concentration

Table 3

Interrelation of chemical compounds concentrations in water of sinkhole and in ground water

Study places	Sampling volume	Values of relation R^2 between concentrations					
		N-NO_3	N-NH_4	P_{total}	K	Cl	SO_4
1	26	**0.45**	**0.70**	0.07	0.25	0.70	0.00
2	26	**0.63**	**0.71**	0.18	-0.04	0.13	-0.05
3	26	**0.66**	0.00	0.06	0.42	0.70	0.00
4	26	**0.45**	**0.64**	0.33	0.00	0.06	**0.43**

Note. Statistically significant R^2 values are given in bold. R^2 - coefficient of determination; t – actual criteria for reliability or determination; P- probability correspondly to the calculated t_{actual} criterion; $t_{actual} > t_{95\%} = 2.1$, the relation is significant

with ground water as well. Especially high concentration of SO_4 (630 – 2116 mg l^{-1}) was established in the water of sinkhole 4. As the values of sulphates indicate the amount of dissolved gypsum (Narbutas, 2001), they suggest a statement that gypsum dissolving is still taking place in the moraine rock which came down on the original failure and this dissolving is obviously activated by fluctuations of the level of ground water in the vicinity polluted with N-NO_3 nitrogen (16.3 mg l^{-1} on average).

Correlation analysis shows that the quality of water in all sinkholes and ground water in their vicinity mainly depends on nitrogen compounds, as well on chlorine in study place 1, also on potassium and chlorine in place 2, and also on sulphates in place 4 (Table 3).

Local hydrogeological conditions determine the nature of relationship of chemical compound concentrations in sinkhole water and in the ground water in the vicinity. The sinkhole water which is higher and more polluted than the ground water leaks into the vicinity ground, which probably pollutes the ground water. Such case is typical for study place 3 in which the sinkhole is fed with surface and soil water after a more intensive snow thaw or profuse rainfall. However, due to the small volume, the runoff of the polluted sinkhole water into the ambience is relatively minor and in fact has no impact on ground water quality. This is proved by a comparison of N-NO_3 concentrations. It was established that the average concentration of this nitrogen in sinkhole water was 32.2 mg l^{-1} and in ground water it was only 1.3 mg l^{-1}. Obviously, the polluted sinkhole water leaks deeper into karsting layers through a more conductive failure soil.

In study place 4, on the contrary, N-NO_3 concentration is higher in the ground water of higher level in the vicinity (16.3 mg l^{-1} on average) and comparatively low (0.67 mg l^{-1}

on average) in the sinkhole water. However, a relatively high concentration of N-NH_4 was established in the sinkhole water (4.62 mg l^{-1} on average). This can be explained by the fact that the nitrates which get into sinkhole peat from higher layers of ground water in the vicinity turn into ammonium as reduction takes place under anaerobic conditions and continue polluting the subsurface water. In this case it can be stated that the polluted ground water which gets into the sinkhole has an undoubtedly adverse effect on the quality of sinkhole water.

Conclusions

1. The regime of the ground and sinkhole water level in each study place was of different but correlated nature. The local hydrogeological conditions determine the nature of correlation between sinkhole water in their vicinity and ground water quality.

2. Nitrate nitrogen is the most harmful pollutant which can get into subsurface water from agricultural fields and farming land plots where mineral fertilizers are applied. Such pollutant gets into peat-covered sinkholes when they receive soil and shallow ground water of snow thaw and after rains.

3. It was established that the ground water feeding sinkholes from their vicinity has high concentration of nitrate nitrogen (up to 23 mg l^{-1}) and relatively low concentration of ammonium nitrogen (about 0.3 mg l^{-1}). Such ground water goes through the peat layer into moraine loamy failure and acquires concentration of ammonium nitrogen (up to 14 mg l^{-1}) which is considered to be a dangerous pollutant from the point of view of environmental protection and health care.

4. When water level in sinkholes is higher and water unallowably polluted, it leaks into the ground water of their vicinity. Though due to rather low runoff, it makes no adverse effect on the quality of ground water. There is a greater probability that the polluted sinkhole water will leak into a more conductive moraine failure, therefore, such sinkholes are considered to be potential pollution sources of lower aquifer layers.

References

1. Hallberg G.R., Hoyer B.E. (1982) Sinkholes, hydrogeology, and ground water quality in Northeast Iova. Iowa Departament of Natural Resources, Geological Survey Bureau, Open File Report 82-3, 120 pp.

2. Kaarolu F. (1999) Review of Groundwater Pollution and Protection in Karst Areas. Water, Air and Soil Pollution, vol. 113, No 1–4, July, pp. 337–356 (20).

3. Klimas A., Paukštys B., Taminskas J. (1992) Technogeniniai veiksniai ir jų poveikis karstiniams procesams. (Technogenical factors and theirs impact to the karst processes). Geologija, t. 13, pp. 86–99. (in Lithuanian).

4. LVŪI mokslo tiriamojo darbo ataskaita (1998) (Scentific report of WMI) (darbo vadovai dr. R. Čižauskas ir dr. P. Šukys). Vilainiai, 103 pp. (in Lithuanian).

5. Narbutas V., Linčius V., Marcinkevičius V. (2001) Devono uolienų karstas ir aplinkosaugos problemos Šiaurės Lietuvoje: monografija. (Karst of the devonian rocks and the problems of environment protection in North Lithuania: monograph). Vilnius: Agora, 191 pp. (in Lithuanian).

6. Narbutas V. (1995) Šiaurės Lietuvos karstinio regiono žemių ir požeminio vandens ekologinis pažeidžiamumas. Geologijos mokslo pasiekimai – gamtosaugai. (The ecological vulnerability of land and ground water in karst region in the North Lithuania. Geological science to nature protection). Seminaro medžiaga, (Material of the seminar), 1995 m. lapkričio 29d, Vilnius, pp. 23–25. (in Lithuanian).

7. Paukštys B. (1991) Ūkinės veiklos reglamentavimas karstiniame rajone. Lietuvos požeminės hidrosferos ištekliai, režimas ir apsauga. Infomacinis biuletenis, (The regulation to farming in karst zone. The resources of ground water regime and protection. Newsletter) Vilnius, Valstybinė Vilniaus hidrologijos įmonė AKVA, pp. 39–42. (in Lithuanian).

8. Šukys P., Šauliene A. (2005) Gruntinio vandens už umo tyrimai karstinių smegduobių aplinkumoje. (Investigation of ground water pollution in vicinity of karst sinkholes). 2005 m. mokslo tiriamieji darbai. Vilainiai, ISSN 1392–3250. pp. 65–68. (in Lithuanian).

9. Taminskas J. (1999) Smegduobių susidarymas ir raida. (Generation and development of karst pits) Geografijos metraštis, t. 32, pp. 194–203. (in Lithuanian).

10. Taminskas J. (2002) Smegduobių apsaugos optimizavimas. (Optimization of sinkholes protection) Geografijos metraštis, t.35, pp. 87–94. (in Lithuanian).

11. Vodzinskas E. (1967) Kai kurios pastabos apie Šiaurės Lietuvos karstines įgriuvas ir jų susidarymą. (Some comments on about the failures and theirs formation in the North Lithuania). Geografinis metraštis, t. 8, pp. 161–166. (in Lithuanian).

12. Марцинкявичюс В.И., Буцявичюте С.В. (1990) Геологические и гидрогеологические условия сулъфатного карста в Северной Литве. (Geological and hydrogeological conditions of the vitriolic karst in the North Lithuania). Геология, т. 11, Вильнюс, с. 112-115. (in Russian).

ECOLOGICAL AND ECONOMICAL ASPECTS OF THE MANAGEMENT OF DRAINAGE SYSTEMS IN LITHUANIA

Valentinas Šaulys, Nijolė Bastienė
Water Management Institute of Lithuanian University of Agriculture
E-mail: valentinas@water.omnitel.net

Abstract

After the private ownership of land was restored and a part of land reclamation structures was given to land owners, the intensity of land use has changed. In the areas of Lithuania, which are less favoured for agriculture, the land is not intensely used. Further financing of land reclamation of such areas from the state budget grants is economically inefficient as the return of relatively high investments is very low. With the changing of land reclamation infrastructure it is necessary to prepare measures which would facilitate rational, regional agricultural specialization corresponding to natural conditions. The routine procedure of financing the land reclamation has to be changed as well.

The paper analyses the changes in usage of drained land areas and financing of the land reclamation sector in Lithuania during the last decade (1997-2007). The purpose of this research is to establish the criteria of the economical efficiency of drainage systems and to propose methods how to change the financing of state-owned land reclamation infrastructure.

On the grounds of the carried out situation analysis, a methodology of distributing state grants for land reclamation to municipality budgets are presented. To have an efficient use of the state budget funds, the operation and maintenance of shared land reclamation systems have to be carried out according to the maintenance plans approved by municipalities, which would provide for arrangements and compensations due to conflict of interests arising when land plots are used in different ways. Possible ecological measures that could be applied when carrying out repair and reconstruction of drainage systems are discussed.

Keywords: land reclamation facilities, financing, economic criteria, ecological measures.

Introduction

Agricultural hydrosystems are a constituent part of water economy. They play an important role in agro-industrial development of many Eastern European countries. Therefore, it is necessary to pursue policy and monitoring of reclaimed land management coordinated in all European countries (Maziliauskas, 2001; Schultz, 2001). For Lithuania, the state of drainage systems is one of the main issues to solve. Maintenance of these systems can be performed at the right time and with required quality only with sufficient financing (from different subsidies, taxes, through applying different variants of labour force contributions and using other alternative resources) or by reducing the plot of reclaimed areas. All this has to be closely connected with the Lithuanian Agricultural Development Strategy (Stanikūnas et al., 2002; Šaulys and Lukianas, 2003).

The research shows that land reclamation facilities must be owned by direct users of the reclaimed areas (Peter et al., 1996; Marshall and Tenev, 1996). Privatization of drainage systems had to be started several years ago, together with the land reform. Unfortunately, the decision was taken to wait until the finalization of the reform. In fact, that was not the most appropriate decision. Due to insufficient maintenance, some part of land reclamation property has been lost: the areas with inefficiently operating drainage areas have increased significantly (Bastienė, 2002). The new Land Reclamation Law regulating the ownership of land reclamation facilities was passed on 21 February 2004 (Lietuvos melioracijos įstatymas, 2004). According to this Law, subsurface drainage network has become the ownership or the land user, i.e., they are considered as appurtenances of land plot. Now the owners of the drained land will have to maintain the drainage structures at their own expenses. In the rules of the state financial support allocated to the owners of the drained land for carrying out the implementation, repair, reconstruction and maintenance it is laid down that a share of own funds must be at least 15% of all costs. The full financing from the state budget will be applied only for the repair of collectors, if their diameter is 12.5 cm or larger.

At the moment, active discussions are in progress regarding the methodology of distribution of the state grants for land reclamation. After the private ownership to the citizens was restored, the intensity of land

use has changed. In some areas of Lithuania, which are less favoured for agriculture, the drained land is not used intensively for agriculture development. There are places where drainage systems are deteriorated. Further financing of rehabilitation of such systems from the state budget is economically inefficient as the return of such relatively high investments is very low. Investments should not be made in such areas. The state is planning to provide for the procedure, which would promote the denaturalisation of this kind of land.

The purpose of this research is to establish the criteria of the economical efficiency of drainage systems and to propose methods how to change the financing of state-owned land reclamation infrastructure.

Materials and Methods

Lithuania has enough natural resources to develop agricultural production efficiently. Agricultural land occupies more than a half (51.6%) of total land area of the country, and more than 88% of agricultural land is drained. Fairly high land productivity allows active integration into the EU market of agricultural products (Buivydaitė et al., 1999). However, soil cover in Lithuania is not uniform. Due to the non-homogeneous texture and fertility of topsoil layer, the regional income of agricultural subjects also draining efficiency is different. The activities of the Lithuanian water economy sector – land reclamation – is important to farmers and constitutes an essential part of agricultural production infrastructure. On 1 January 2006, the total residual value of land reclamation structures accounted for 3.32 milliard Lt (1 Lt equals 0.29 euros). The percentage of state owned drainage structures and private ownership there

is nearly the same: 50.1 and 49.9% respectively (Melioruota..., 2007).

The research was done with reference to the analysis and evaluation of the laws and regulatory legal acts in the field of water management. The data from the Department of Statistics of Lithuania, the State Land Survey Institute, the Lithuanian Institute of Agrarian Economics, the Ministry of Environment, and the Ministry of Agriculture were used. The algorithm for calculating special subsidies from the state budget was prepared by using 'MS Excel 2000' programme.

Results and Discusion

After the provision, that drainage structures belong to the owner of land plot was legitimated; the value of land reclamation property was changed. The routine procedure of financing of land reclamation activities has to be changed as well. Moreover, for the implementation of agricultural and rural development strategy and for changing the land reclamation infrastructure, it is necessary to form measures which would background a rational regional agricultural specialization adequate to natural conditions.

The need of funds for the maintenance of drainage systems is not reasoned. The Ministry of Agriculture is increasing allocations for these activities gradually. During the years of 2000–2006, drainage systems were implemented only in the area of 101 ha, but reconstructed - in the area of 9220 ha. In fact all funds are allocated for the maintenance of the existing land reclamation structures (Fig. 1).

It was determined that yearly maintenance costs of drained areas reach 76–87 Lt ha^{-1}. The average annual price of ditch maintenance is 50–55 Lt ha^{-1}, and the average annual price
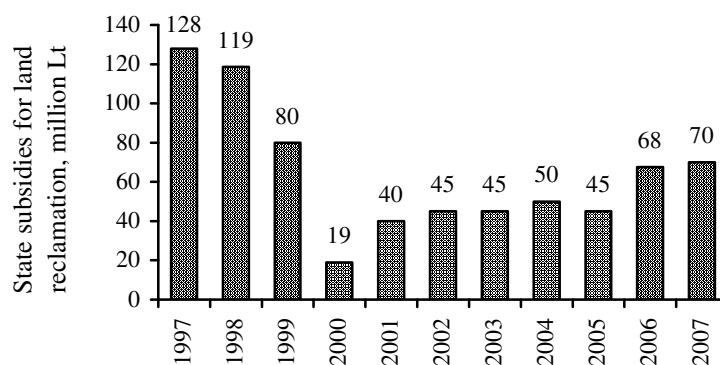

Figure 1. State grants for land reclamation in 1997–2007.

of reparation of damaged subsurface drainage network is 26–32 Lt ha^{-1}. These costs are changing: they decrease when using new technologies and machinery, and increase by absolute value as the probability of drainage system failures increase with time. However, the yearly allocation for maintenance of drainage systems is less than 76–87 Lt ha^{-1} (in 2007 only 23.4 Lt ha^{-1}. Therefore the necessary maintenance work is not carried out timely resulting in the increase of damages.

Special state subsidies for land reclamation purposes are distributed depending on the area of drained land in municipalities. Without the funds allocated to polder systems, the finances received by municipalities (D) very closely correlate with the area of drained land (A) (correlation coefficient $r = 0.98$). The principles of distribution for land reclamation did not change in 2007 (Fig. 2).

In order to achieve a more efficient use of the land reclamation infrastructure, it is necessary to take into account the regional agricultural specialization corresponding to natural conditions. Regional differences of agricultural entities determine unequal possibilities of profitableness to create competitive farms. According to the data of the Lithuanian Institute of Agrarian Economics, it is expedient to take on commercial plant production only in those regions where the productivity of agricultural land is higher than the average of the country (Lietuvos..., 2001). The level of income from plant production in farms (calculating per 1 ha of agricultural land) on soils of different fertility differed 3.5 times and the total income of the farmers with the best and the worst soils differed 1.5 times. Statistical estimation shows a strong dependence of the income of farms from crop cultivation on the land productivity ($r = 0.98$).

The review of rural development tendencies and regional agricultural specialization of the recent years showed that due to low profitableness of farms on fertile land and loss-making agricultural activities in the regions of land less favoured for farming, the areas of abandoned agricultural land are increasing (Fig. 3).

Recording of abandoned drained areas is rather problematic. Firstly – there is no adequate definition which land should be defined as abandoned. Secondly – little interest of districts administration is shown in recording results due to high expenditure on its realization. Today, undeclared land areas in municipalities, which reflect the land areas not used for intensive agricultural production quite accurately, can change abandoned areas unexploited for agricultural production in districts. In addition, the methods elaborated by the EU for such land accounting present highly reliable data.

The analysis of abandoned areas show that in municipalities where agricultural land productivity is higher than the average, relatively better land is abandoned more often than in municipalities with lower land productivity (Fig. 4). It should be mentioned that, in fact, the amount of abandoned land depends on land productivity and a whole complex of factors of economic nature. In 1995-2002 it was possible to observe an increase in arable land areas used for cereal growing in the regions of fertile soil, whereas in hilly regions with less fertile soil, a decrease in such land areas was observed.

However, quite a different tendency is observed in the development of rural tourism business. In less fertile areas, where agricultural activities
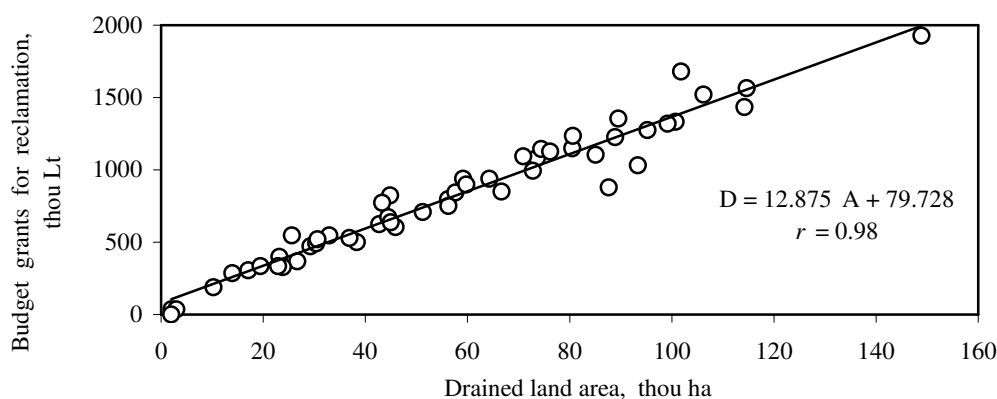
Figure 2. Relationship between drained area and land reclamation grants from the state budget for municipalities in 2006 ($p < 0.01$).

Figure 3. The percentage of abandoned and undeclared agricultural land areas in municipalities:
1 - less than 16 percent, 2 - 16-32 percent, 3 - more than 32 percent.

are less profitable and the areas of abandoned agricultural land are increasing, the rural tourism business is developing faster (Fig. 5). In the southeast region (Utena, Vilnius, and Alytus counties) the number of rural tourism homesteads reaches 69.2%.

On the basis of the analysis results, a new methodology of the allocation of special state budget grants for land reclamation activities has been developed. Having applied the methodology

suggested, the funds designated for this purpose would be allocated considering the residual value of the state-owned land reclamation structures located in the territories of municipalities, and adjusting them according to the increased land productivity point due to water regime control and the area of abandoned land plots (Šaulys and Bastienė, 2006). The start of distribution of the state budget grants for land reclamation, taking into account the tendencies of rural development,

$$y = 135.58\ x^{-0.3455}$$
$$r = 0.84$$
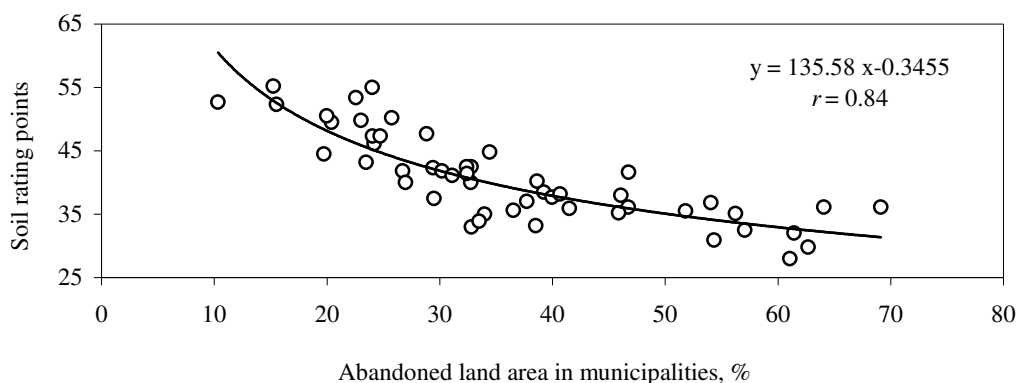
Figure 4. Relationship between land productivity and abandoned (undeclared) land areas in municipalities
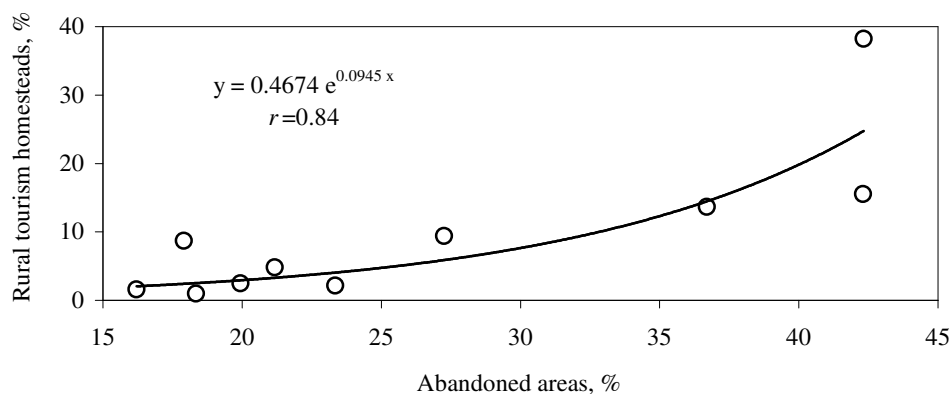in 2005 ($p < 0.01$).

Figure 5. Relationship between the abandoned land areas in counties and the number of rural tourism homesteads in 2005 ($p < 0.01$).

would promote a better maintenance, repair and reconstruction of land reclamation structures in the districts with land areas more favourable for farming.

An efficient employment of the state budget funds requires that the use and maintenance of the state land reclamation structures are carried out according to the plans approved by municipalities; the plans have to be reviewed every year, if at least one owner or user of a land plot requests that. When drawing the plans of the use and maintenance of shared drainage systems, the following aspects have to be evaluated:

- agricultural priorities in a municipality;
- agricultural development and intensity level in a municipality;
- environmental issues (formation of riparian protective strips and wetlands);
- interests of land owners and other users;
- agreements with contracting companies and organizations responsible for the maintenance and repairs;
- responsibility and compensations for carrying out the shared commitments.

Today environmental issues become priorities. In the territories of intensive agriculture, surface and ground waters are polluted; no conditions are created to increase biological diversity and landscape attractiveness. Due to the regulation of streams, the landscape of valleys is transformed. Therefore the priorities of land reclamation activities and environmental protection must be defined. The principles of the naturalization of low-productivity drained areas as well as the necessity and expedience of the rehabilitation of imperfect drainage systems should be determined too. Ecological criteria

should help in evaluating the ecological situation in a region (whether ecological land is lacking or sufficient). Attention should be paid to the re-naturalization of regulated streams and their valleys. The spillways, weirs and ponds constructed on the streams break the natural ecological connection between the upstream and downstream. Renovation of valleys of the regulated streams will promote renewal of biodiversity.

The majority of researchers consider ecological measures related with the drainage network, by allowing tree and bush growing on ditch slopes. According to the authors (Šaulys et al., 1999), by applying an alternative – biological - way of maintenance of the drainage network it is necessary to assess the processes taking place in ditches as accurately as possible. These processes are the washing of watercourse bottom, deformations of slopes and their lower parts, movement of silt, and sediment, of the covering channel bottom with vegetation, and growing of shrubs on the slopes. It is necessary to take into account the financial possibilities of the users of land drainage and to plan the maintenance work and benefits achieved both for the farmer and for the nature. Tree and bush growing on channel slopes has to be based on hydraulic calculations. The water of spring and summer floods has to contain in the watercourse and the water level of vegetation period should not interfere with drainage operation. Field experiments showed that ligneous vegetation in Southeast Lithuania is mainly prevalent in the section of regulated stream slopes between 1.58±0.16 and 4.13±0.22 m measuring from the ditch bottom (Survilaitė et al., 2006). The width of the overgrown strip on the slope is 2.55±0.24 m. When hydraulic

roughness of the lower part of a channel cross-section and other morphometric parameters are equal, hydraulic conductivity of regulated streams overgrown with ligneous vegetation in southeast Lithuania is more than 2 times higher than that of overgrown ditches in the central lowland. In this respect there are more possibilities to apply ecological measures in the drainage network in southeast Lithuania. This could be implemented by expanding riparian strips near the ditches, shaping an environmental ditch profile and also by allowing tree and bush growing on the slopes. During the increase of drainage system areas, small marshes, valleys, close depressions and other wet plots were drained, which was very important for nature protection. Farming activities in such areas are usually loss-making. In such locations the probability of drainage damage is higher (due to the activity of risk factors of the main drainage system condition). It is recommended to implement the optimization and naturalization of drainage systems when the repair and reconstruction work of imperfect drainage is at hand.

The research established that when draining heavy texture soils and incorporating liming materials into the backfill of a drainage trench, the trench conductivity to water increases (Šaulys and Bastiene, 2006). In addition, potassium concentrations in the drainage systems, which were implemented by mixing trench backfill with lime, were lower by 1.71 times than that in the outflow from the control drains. Run-off of potassium cations was 1.9 times lower than that from the systems of control drains. An essential difference between the average concentrations of potassium cations in drainage variants was established. The average phosphate concentrations in the outflow from the control drains were 2.53 and 2.64 times higher compared to the systems with lime admixture (Šaulys and Bastiene, 2007). Having made the statistical analysis, it was estimated that these differences are significant. Carrying out of drainage system reconstruction and installing additionally interceptor drains with lime admixture into drainage trench backfill for surface water coming from agricultural fields would substantially reduce the run-off of potassium and phosphorus into a stream.

Conclusions

Economic efficiency of operating land reclamation systems depends on the profitability of agricultural activities in drained land areas. Regional differences in profitableness of agricultural subjects are determined by natural and economic factors. Analysis show that the basic financing of state-owned land reclamation structures should be adjusted taking into account the criteria which would assess the increase of land productivity points due to water regime control and abandoned land areas in municipalities.

An efficient employment of the state budget funds requires that the use and maintenance of the shared land reclamation systems are carried out according to the plans approved by municipalities. The plans should take into account agricultural priorities, agricultural development and intensity level, environmental issues, interests of land owners and other users, and responsibility and compensations for carrying out the shared commitments. Environmental issues become priorities. Today, while carrying out repair and reconstruction of the drainage systems, additional ecological measures must be applied.

References

1. Bastienė N. (2002) The main problems of drainage systems exploitation in Lithuania. International scientific conference 'Research for rural development 2002', Jelgava, Latvia, 22-24 May, 2002. pp. 133-139.
2. Buivydaitė V., Vaičys M., Juodis J. (1999) Lietuvos dirvožemių klasifikacija (Classification of Lithuanian soils). DKL_99LT. Kaunas, 137 pp. (in Lithuanian).
3. Lietuvos Agrarinės ekonomikos institutas (2001) Lietuvos žemės ūkis 2000: raida ir perspektyvos (Lithuanian Agriculture 2000: Development and Prospects). Vilnius, 152 pp. (in Lithuanian).
4. Lietuvos melioracijos įstatymas (2004) (Law of Land Reclamation of the Republic of Lithuania). IX-2009. Valstybės žinios, Nr. 28-877, 46-48 pp. (in Lithuanian).
5. Marshall D.S., Tenev B. (1996) Problems of Irrigation Management Transfer in Bulgaria. Proceedings of International Conference 'Hydraulic Engineering and Land management'. Kaunas, pp. 86-89.
6. Maziliauskas A. (2001) Analysis of Integrated Water Resources Management in Lithuania. Water Management Engineering, 14 (36), pp. 111-116.

7. Melioruota žemė ir melioracijos statiniai (2006-01-01) Land Reclamation (2006 01 01) (2007) Informative publication. Vilnius, 53 pp. (in Lithuanian).

8. Farley P.J., Simon B. M. (1996) Privatizing, Government Irrigation Projects in New Zealand. Water Resourses Bulletin, 32(3), pp. 585-593.

9. Schultz B. (2001) Irrigation, drainage and flood protection in a rapidly changing world. Irrigation and Drainage, 50(4), pp. 261–277.

10. Stanikūnas D., Baležentis A., Krikščiukaitienė I., Naujokienė R., Skulskis V., Tarvainytė Dž., Zemeckis R. (2002) Lietuvos žemės ūkio ir kaimo plėtros įgyvendinimo programos (Implementation programs of Lithuanian agricultural and rural development). Vilnius, 700 pp. (in Lithuanian).

11. Survilaitė O., Šaulys V. (2006) Reguliuotų upelių (griovių) apaugimo sumedėjusia augalija tyrimai pietryčių Lietuvoje (Investigations of Regulated Streams Covered with Woody Vegetation in South–East Lithuania). Vandens ūkio inžinerija, 29(49), pp. 50-56 (in Lithuanian).

12. Šaulys V., Bastienė N. (2006) The effect of lime admixture to trench backfill on the functioning of tile drainage in heavy soils. Irrigation and Drainage, 55(4), pp. 373-382.

13. Šaulys V., Bastienė N. (2007) The impact of lime admixture into trench backfill on the variation of phosphorus in drainage outflow. Irrigation and Drainage, 56(1), pp. 99–105.

14. Šaulys V., Lukianas A. (2003) Melioracijos įrenginių eksploatavimo perspektyvos kaimo ekonominių problemų kontekste (Prospects of land reclamation equipment exploitation in the context of rural economic problems). Journal of Environmental Engineering and Landscape Management XI (2 supplement) pp. 11-18. (in Lithuanian).

15. Šaulys V., Vaikasas S., Lamsodis R., Bastienė N., Poškus V. (1999) Griovių priežiūros būdų techninis ir ekonominis pagrindimas (Technical and Economical Substantiation of Ditch Maintenance Methods). In: L. Katkevičius (ed.) Melioracijos įrenginių privatizavimo ir efektyvaus naudojimo sistema. Kaunas, pp. 260-316. (in Lithuanian).

ECONOMICS

RELATION BETWEEN SPREAD OF CULTURAL HERITAGE AND INDICATORS OF REGIONAL DEVELOPMENT: CASE OF LATGALE REGION (LATVIA)

Juris Paiders, Inese Stūre
University of Latvia
E-mail: jpaiders@nra.lv, Inese.Sture@lu.lv

Abstract

The paper deals with statistic analysis of the relation between variables of cultural heritage and that of regional development in Latgale region. Latgale was selected as the study area – it is one of the five cultural or historical ethnographic regions of Latvia with stable original features, which are formed in the result of the specific historical processes but stands out among other regions of Latvia with the lowest indicators of development. According to the results of analysis of correlation, the number of architectural and archaeological monuments per 1000 people or their density in area have no close correlation with the major part of the parameters under examination. The analysis of regression was carried out between 'the number of architectural monuments against the area' and 'the natural logarithm from the density of population in 2005'. The ratio is expressed by the function $y = 0.0339x^2 - 0.1422x + 0.1671$, where y is the number of architectural monuments per square kilometre, but x – natural logarithm from the density of population (the number of people per square kilometre). The coefficient of determination for this relation is almost the same as for a functional one - 0.9499. Both for the coefficients of the equation and free member of equation have very high validity (t – empirical respectively 21.7; -11.1; 7.9).

Keywords: regional development, cultural heritage, EU structural funds, Latgale, density of population.

Introduction

Nowadays the cultural heritage and its protection are activated not only as the preservation of values of the past and handing them over to the next generations, but also in relation to the research of long-term development possibilities of places and regions. The cognition of the interrelation between both of these phenomena (cultural heritage and regional development) is grounded because of many reasons, among which the following should be mentioned as the most significant ones:

1. Regional development, including the challenge of equal territorial development, has come in the forefront within the context of modern spatial processes determined by the global economy. Some places concentrate the capital and human resources, while other places are depleted. When solving this problem, new resources and possibilities of development are sought, which outline also the need for new ways of thinking. The European Common Agricultural Policy (CAP) can be mentioned as a typical example for such changes, which for the development of the countryside set out the preservation of rural environment and lifestyle as the main target, instead of food production.

2. Protection of cultural heritage is constantly expanding, the number of items included on the list of protected units is increasing (for example, in Latvia from - 1454 in the year 1940 (LR KM, 2001) to 8423 in the year 2007, in France - from 16546 in the year 1970 to 28202 in the year 1993 (Benhamou, 1997)), though, of course, it becomes more and more difficult to ensure their preservation. Protective paradigms are also changing, replacing simplified administrative instructions by coordination between protective tasks and other purposes of development and involving various interest groups in their implementation (Ashworth, 1994; Stūre, 2004; Burgess, 2000). Hence, the protection of cultural heritage becomes more integrated with other processes occurring on the territory.

In the context of the regional development, the cultural heritage is considered as one of the potential resources, which not only increases the aesthetic value of landscape, but also can promote both investment and employment in the region (e.g., Power of Place, 2000). In Latvia these trends are also resounding with the rhetoric of

state political documents: 'The cultural heritage and diversity of culture is one of the conditions for sustainable and balanced development of regions' (LR KM, 2006).

The aim of this research project is to assess possibilities of use of resources of cultural heritage in the planning process of regional development. The main objectives are (1) to define main quantitative parameters of region's cultural heritage; (2) to define main quantitative indicators of regional development; (3) to identify interrelations between them by statistical data processing. Latgale was selected as the study area – it is one of the five cultural or historical ethnographic regions of Latvia with stable original features, formed in the result of the specific historical processes (Cimermanis, 1999). The most striking accents in the cultural identity of Latgale region are made by the dominance of the Roman Catholic religious confession, the Latgalian language, and the multicultural and multiethnic population with outspoken presence of the Slavic culture. The peculiarity has developed because of different sources of impact – lots of elements are common with the Slavic nations, but the catholic churches are built according to the Italian, Austrian, and Polish design patterns, which were transferred to Latgale by the active monks of catholic orders (Taivāns, 1993). The regional peculiarities of the culture of Latgale are more pronounced than anywhere else and they are precisely represented by the character of cultural heritage in the region.

At the same time, Latgale stands out among other regions of Latvia with the lowest indicators of development (amount of population income tax, unemployment rate, changes in the number of population, number of economically active enterprises, non-financial investments, gross domestic product), in addition, these negative differences are increasing (VRAA, 2006b). In many researches Latgale is singled out as a peculiar region which should be studied separately (Rivža et al. 2006; Trapeniece, 2002; Zelča, 2006). Therefore it is even more important to take an innovative look at the processes of the regional development, including not only the traditional indicators in the analysis, but also resources of cultural environment.

Materials

The region under research – Latgale - takes 22% of the present-day territory of Latvia. For the purpose of this study, by the region under research, the territory conforming to the cultural historic region of Latgale, which existed until the year 1940, is understood, and in the public awareness it is still related with the concept of Latgale, encompassing the Balvi, Ludza, Rēzekne, Krāslava, and Preiļi districts, the territory of the right-hand bank of Daugavpils district, and several civil parishes in Madona and Jēkabpils districts. The cities of the republican status - Rēzekne and Daugavpils - are not included in this research.

The research is based on the following publicly accessible information of the governmental institutions, published and unpublished, as well as on evaluation data of the situation of the protection of cultural monuments obtained in the field work: (1) 489 objects included in the list and in the project of the list of architectural and historical culture monuments, as well as 1046 archaeological monuments (Valsts..., 1998; VKPAI, 2002); (2) data basis of the Central Statistics Board regarding the number of population in municipalities of Latvia, the area (LRCSP 2006); (3) information regarding tax revenues of the municipalities (cash flow) (LRVK, 2007), (4) information regarding implementation of the EU support for the business (VRAA, 2006a; LIAA, 2006).

The scope of support in the Latvian currency (lats) and the number of projects were summarized according to the administrative units of Latvia, following the addresses of the registered offices of the beneficiaries as indicated in the Register of Enterprises of Latvia (Lursoft, 2007).

Methods

In the data processing, the methods of primary (descriptive statistics) and secondary statistical data processing (analysis of correlation and analysis of regression) were used (Arhipova and Bāliņa, 2003). In the estimation of the situation in the protection of cultural heritage, both qualitative and quantitative data processing methods were used, because the former researches in this area prove the need to use them in a tandem (Stūre, 2004). Taking into account that tax revenues of municipalities per capita and the distributing of parameters of density of population correspond with logarithmical normal distribution, the linearized data of these indicators were also included in the group of data, using the natural logarithms of the basic indicators. In the statistical data processing, the analysis of correlation and regression was applied, using the Microsoft Excel programme.

As an indicator for the statistical evaluation

of receipt of EU funds, the relative frequency of the beneficiaries was used against the number of municipalities in the group concerned. For evaluation of the funds granted, the method of sign frequency difference was applied, using the Fisher's transformation (Fisher and Yates 1963) to normal distribution by the arcsin function (Krastiņš and Ciemiņa, 2003). Vasermanis and Šķiltere (2003) suggest to use another method in cases when the relative sign frequency tends to 0.5, while Krastiņš (1985) holds the view that transformation of relative frequency applying the arcsin function, is more universal and precise.

When checking the null hypotheses, thefunction was evaluated (Krastiņš and Ciemiņa, 2003):

$$\varphi = \frac{2\pi}{180} \arcsin(\sqrt{p}), \qquad (1)$$

where p is the relative sign frequency.

Empiric ratio, comparing the relative sign frequency b in the representative samples and, is obtained by the formula

$$t_b = \frac{|\varphi_1 - \varphi_2|}{\sqrt{\frac{n_1 + n_2}{n_1 \times n_2}}}, \qquad (2)$$

where φ_1 is the value of φ function of $b$relative frequency for representative sample n_1;

φ_2 – value of φ function of relative sign $b$frequency for representative sample n_2.

If the empiric t_b was less than the critical t for the probability concerned, then the null hypothesis was denied.

Results

Location and protection of culture monuments in Latgale region

The catholic churches, 90 in total, constitute the most significant part in the overview (see Table 1) of the architectural heritage of Latgale. They are called as the prime architectural dominant in Latgale landscape by the historian L.Taivāns (1993). Most of the orthodox churches are situated within the border zone with Russia, but the old-believers'preaching-houses are concentrated in the central and southern part of Latgale. In many communities there are churches of several religions, indicating the multicultural character of the region (Riebiņi, Brodaiži, Līvāni), which is one of substantial cultural-geographical characteristics of Latgale. The second largest group of architectural monuments is the complexes of manor buildings (45), including the landlord houses (42), household buildings (67), and parks (40). The characteristics

of the technical condition of architectural monuments of Latgale indicate that almost 70% of them are in good and satisfactory conditions (Stūre, 2004). However, the technical condition is not similar throughout different groups of monuments. The catholic churches constitute the best maintained group of the architectural monuments. On the whole, the public buildings are also quite well maintained, being used nowadays mainly as schools or premises for authorities. The pubs, mills and household buildings of manors find themselves in the poorest technical condition. These buildings are very often not used at all, for example, the mills in Daudzene, Rijnieki, Krāslava, or the way they are used does not contribute to their preservation. The pubs and manor household buildings are in critical conditions, and more than half of the manor household buildings and traditional construction units seem to be threatened by inevitable decay which has already started.

Until nowadays the major part of the architectural monuments of the other typological groups, except churches, have lost their primary meaning and function, for example, the manor buildings and commercial facilities. The pre-conditions for the preservation of these units are their functional conformity to the actual needs of society. None of the architectural monuments of Latgale is managed in commercially efficient mode. All units (except churches), which are in good technical condition, receive the public sector grants.

Relation between the spread of cultural monuments and indicators of regional development

According to the results of analysis of correlation (table 2), the number of architectural and archaeological monuments per 1000 people or their density in area have no close correlation with the major part of the parameters under examination. The indicators 'the number of archaeological monuments against the area (the density) with the density of the population' and 'the natural logarithm from the density of population' have an average and positive correlation. The number of architectural monuments to the area (density), in its turn, is forming close (0.69) correlation with natural logarithm from the density of population.

When analysing the regression between the density of architectural monuments and natural logarithm from the density of population, four municipalities – Varakļāni and Viļaka, where there is a disproportionately large amount of protected architectural units, and Kuprava and

Table 1

Number of architectural and historic monuments of Latgale by typological groups

Typological group	Catholic churches	Complexes of manor buildings	Manor household buildings	Landlord houses, palaces	Manor parks	Building units of manor parks	Lutheran churches	Synagogue	Public buildings	Mills	Castle ruins	Old-believers' preaching-houses	Complex build. of old-believers	Orthodox churches	Churchyard chapels	Folk building monuments	Pubs	Historic monuments
Number of units	**90**	**45**	**67**	**42**	**40**	**5**	**12**	**1**	**37**	**13**	**4**	**33**	**1**	**29**	**21**	**18**	**3**	**2**
incl. of national importance	57	11	11	18	10	3	4	0	4	1	4	0	0	9	6	2	0	2
incl. of local importance	33	34	56	24	30	2	8	1	33	12	0	33	1	20	15	16	3	0

Viļāni, where there aren't at all though should be according so big density of population, – should be removed from the group under research.

When looking at the data aggregation of 128 municipalities of Latgale (excluding the data of Varakļāni, Viļaka, Kuprava and Viļāni), the analysis of regression was carried out between 'the number of architectural monuments against the area' and 'the natural logarithm from the density of population in 2005' (Figure 1).

The ratio is expressed by the function $y = 0.0339x^2 - 0.1422x + 0.1671$, where y is the number of architectural monuments per square kilometre, but x – natural logarithm from the density of population (the number of people per square kilometre). The coefficient of determination for this relation is almost the same as for a functional one - 0.9499. Both for the coefficients of the equation and free member of equation have very high validity (t – empirical respectively 21.7; -11.1; 7.9) (Figure 1).

Evaluating the territorial distribution of the structural funds managed by the Investment and Development Agency of Latvia (IDAL), no substantial influence on researched parameters of regional development or spread of the cultural heritage is observed in Latgale, because in the period concerned from the 132 municipalities of Latgale (except Rēzekne and Daugavpils) only one company registered in the municipality (Nagļi civil parish) received the support managed by IDAL. This forms the frequency of receipt of EU structural funds - 0.0076 (0.76% of the municipalities of Latgale). The frequency of support of programs managed by IDAL in Latvia is on average 0.0925 (on average 9.25% of companies registered in the municipalities of Latvia received the support). Using R.Fisher's transformation for verification of null hypothesis, the obtained results indicate that the municipalities of Latgale receive statistically less significant support of IDAL (t empirical 4.56) than the municipalities throughout Latvia on average and it is not influenced by differences between the municipalities of Latgale.

The distribution of EU support administered by the National Agency of Regional Development (NARD) was compared among the four groups. The first group included all 530 municipalities of Latvia, the second group – all 132 municipalities of Latgale (exclusive of Rēzekne and Daugavpils), the third one – the municipalities of Latgale, where there are more than five protected units of archaeology (42 municipalities), and the fourth group included those municipalities of Latgale, where there are more than four protected architectural monuments (37 municipalities). Throughout the municipalities of Latvia, the frequency of EU support administered by NARD is 0.1226 which was received by 12.3% of 530 municipalities of Latvia. In the municipalities of Latgale in total this index is 0.1212, in the

Table 2

Matrix of mutual correlation of cultural heritage and economic social parameters in the analyses of 132 municipalities of Latgale

Parameters	AHI	AHP	ATI	ATP	IS1	IS2	NI	lnNI	BL	lnBL
AHI	1									
AHP	0.21	1								
ATI	0.22	0.03	1							
ATP	-0.18	0.33	0.14	1						
IS1	-0.32	-0.01	-0.15	0.02	1					
IS2	-0.21	-0.07	-0.15	0.03	0.49	1				
NI	-0.31	0.14	-0.08	0.32	0.12	0.14	1			
lnNI	-0.31	0.12	-0.08	0.29	0.12	0.15	0.98	1		
BL	-0.21	0.42	-0.11	0.62	0.02	0.11	0.46	0.39	1	
lnBL	-0.36	0.38	-0.14	0.69	0.16	0.19	0.47	0.42	0.83	1

Nomenclature for Table 2:

AHI – the number of archaeological monuments against population

ATI – the number of architectural monuments against population

IS1 – changes in population in the year 2006 against the year 2000 (‰)

NI – municipal tax revenues in the year 2004 in lats

BL – the density of population in year 2005

AHP – the number of archaeological monuments against the area

ATP – the number of architectural monuments against the area

IS2 – changes in population in the year 2006 against the year 2005 (‰)

lnNI – natural logarithm from municipal tax revenues in the year 2004

lnBL – natural logarithm from the density of population in the year 2005

municipalities of Latgale with more than five protected archaeological units – 0.1190, but in the municipalities of Latgale with more than four protected architectural monuments – 0.2162.

Using R.Fisher's transformation for testing the null hypothesis, the obtained results indicate, that in all municipalities and in the municipalities of Latgale, where there are more than five protected archaeological units, the frequency of beneficiaries of EU support administered by NARD substantially does not differ from the index of all Latvia (t empirical respectively 0.04 and 0.06). Whereas in the municipalities of Latgale, where there are more than four protected architectural monuments, in their turn, 21.6% of municipalities received the EU support administered by NARD, and it is possible to declare with 80% credibility that this difference from the average is statistically significant (t empirical - 1.48).

Results and Discussion

It should be noted that even the spatial indicators of separate underlying dimensions are analysed rarely, for example, the territorial distributing of EU resources. The regional percentage distribution of subsidies of the Rural Support Service was analysed by Mazūre (2005),

while the distribution of the financial support according to the purposes of the programme of structural funds was analysed by Rukmanis and Pilvere (2006), Vītola (2006), Musial (2004), and Parts et al. (2004).

So far the interrelations between the spread of resources of cultural environment and economical development and density of population and density of cultural monument have not been studied in Latvia. At the same time, in particular the resources of cultural environment and their protection are mentioned quite often as one of the pre-conditions for long-term development of regions, as it is, for example, in 'Territorial planning of Latgale planning region' (Latgales..., 2006). Also within the contents of this planning, in the analysis of the spatial structures of region the attention towards the cultural heritage as the resource of development is paid only mediately - just in connection with the development of tourism.

The statistical analysis indicates close relation between the density of population and the density of architectural monuments, which could be explained by the system of the distribution of population in Latgale being conservative. It has changed very little over the centuries. Consequently the trend is there: the bigger
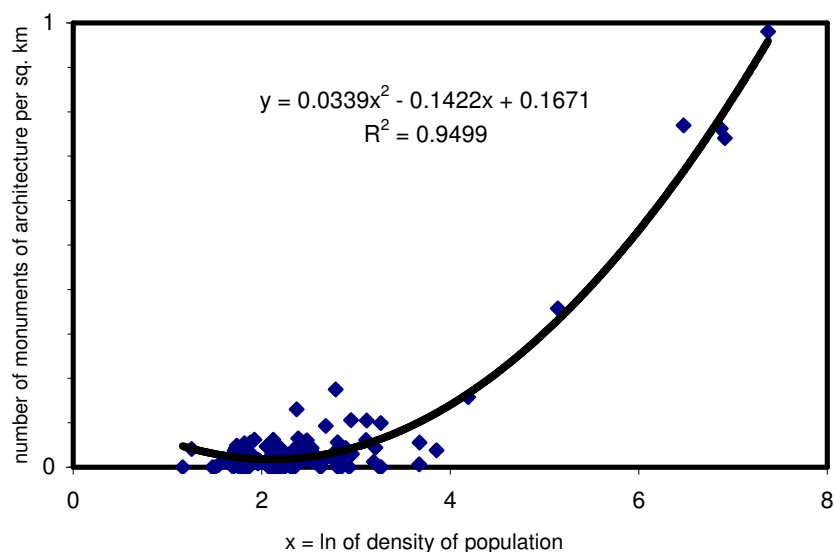
Figure 1. Results of analysis of regression between the density of number of architectural monuments and natural logarithms of the density of population.

the density of population on the territory, the greater the probability that over centuries architectural values will be created on that territory, which will acquire the status of cultural monuments. The quantitative indicators of cultural monuments differ from economic and demographic indicators. In course of time the indicators characterizing cultural monuments change very little, their dynamics is incomparably slower than the economic or social indicators.

Conclusions

1. The analysis of interrelation of indicators of the concentration of cultural monuments and the regional development open up opportunities for broadening the concept of economic development of territories, including therein also the resources of cultural and historic development of the area.
2. The density of the protected architectural units can be expressed as a function from the natural logarithm of the density of population of the civil parish concerned. The correlation is functional and of extraordinarily high credibility. The concentration of the protected architectural units in the municipalities of Latgale increases the possibility to receive the EU resources for regional development with the credibility of 80%.
3. The municipalities of Latgale receive the statistically less significant IDAL support than municipalities on average throughout Latvia, and this increases the risks for the preservation of cultural heritage in Latgale in comparison with the rest of the territory of Latvia.

Acknowledgements

References

1. Arhipova I., Bāliņa S. (2003) Statistika ekonomikā. Risinājumi ar SPSS un Microsoft Excel. (Statistics for Economics.Solutions for SPSS and Microsoft Excel). Datorzinību centrs, Rīga, 352 p. (in Latvian).
2. Ashworth G.J. (1994) From History to Heritage – from Heritage to Identity. In Search of Concepts and Models. In: Ashworth G.J., Larkham P.J. (eds.) Building a New Heritage. Tourism, Culture and Identity in the New Europe. Routledge, London, pp. 13-30.
3. Benhamou Fr. (1997) Conserving Historic Monuments in France: a Critique of Official Policies. In: Hutter, M., Rizzo, I. (eds.) Economic Perspectives on Cultural heritage. Macmillan Press, London, pp. 196-210.

4. Burgess J. (2000) Situating Knowlegdes, Sharing Values and Reaching Collective Decisions. The Cultural Turn in Environmental Decision Making. In: Cook, J., Crouch, D., Naylor, S. and Ryan, J.R. (eds.) Cultural Turns/Geographical Turns: Perspectives on Cultural Geography. Prentice Hall, Essex, pp. 273 – 287.

5. Cimermanis S. (1999) Par Latvijas vēsturiski etnogrāfiskajiem apgabaliem (On Historic Ethnographic Regions of Latvia). In: Caune A. (ed.) Latvijas zemju robežas 1000 gados. Latvijas vēstures institūta apgāds, Rīga, 34.-53. lpp. (in Latvian).

6. Fisher R.A., Yates F (1963) Statistical Tables for Biological, Agricultural and Medical Reserch. Oliver and Boyd, London, 146 p.

7. Krastiņš O. (1985) Varbūtību teorija un matemātiskā statistika. (Probability theory and mathematical statistics). Zvaigzne, Rīga, 360 p. (in Latvian).

8. Krastiņš O., Ciemiņa I. (2003) Statistika. (Statistics). LR Centrālā statistikas pārvalde, Rīga, 267 p. (in Latvian).

9. LIAA (2006) Informācija par LIAA izmaksātajām summām ES struktūrfondu finansējuma atbalsta saņēmējiem, stāvoklis uz 10.08.2006. (nepublicēta). (List of finished Projects from EU business development support grant schemes, on 10.08.2006. not published). Latvijas Investīciju un attīstības aģentūra, Rīga (in Latvian).

10. LR KM (2001) Nacionālā programma 'Kultūra' 2000-2010. (The National Program 'Culture' 2000-2010) Latvijas Republikas Kultūras ministrija (Ministry of Culture of the Republic of Latvia), Rīga. Available at: http://www.km.gov.lv/UI/ImageBinary.asp?imageid=306, 01.03.2007 (in Latvian).

11. LR KM (2006) Valsts kultūrpolitikas vadlīnijas 2006.-2015.gadam. Apstiprinātas ar LR MK 2006.gada 18.aprīļa rīkojumu nr. 264. (Main Cultural Policy Postulates of Latvia 2006-2015) Available at: http://www.km.gov.lv/ui/imagebinary.asp?imageid=3526, 12.02.2007 (in Latvian).

12. LRAA (2006) Latgales plānošanas reģiona teritorijas plānojums. (Territorial planning of Latgale planning region). Latgales reģiona attīstības aģentūra. Available at: http://www.latgale.lv/lv/lraa/planosana, 10.03.2007 (in Latvian).

13. LRCSP (2006) Demogrāfija 2005: statistisko datu krājums. (Demography: collection of statistical data). Latvijas Republikas Centrālā statistikas pārvalde, Rīga, 140 p. (in Latvian).

14. LRVK (2007) Pašvaldību pamatbudžeta pamatrādītāji (kases izpilde). (Basic indicators of municipally budgets (cash flow)) Latvijas Republikas valsts kase. Available at: http://www.kase.gov.lv/?sadala=224, 24.02.2007 (in Latvian).

15. Lursoft (2007) Latvijā reģistrēto uzņēmumu datu bāze (Database of all companies registered in Latvia). Available at http://www.lursoft.lv/?a=26&v=lv, 24.02.2007 (in Latvian).

16. Mazūre G. (2005) Implementation of State Support Policy for the Development of Agriculture. In: Regional Development of European Countries and Increase of Their Competitiveness. Proceedings of the 9th International Scientific Conference 'Economic Science for Rural development-2005', Academy of Agricultural and Forestry Sciences of Latvia, Jelgava, pp. 61-69.

17. Musial W. (2004) SAPARD Pre-accession Programme as an Instrument for Preparing Polish Rural Areas and Agriculture for Using European Union Structural Funds.- In: Possibilities for Rural Development in the Enlarged Europe - Proceedings of the 5th International Scientific Conference 'Economic Science for Rural development': Academy of Agricultural and Forestry Sciences of Latvia, Jelgava, pp. 58-62.

18. Parts V., Visberg A.E., Kalberg I. (2004) Establishment and Development of Rural Enterprises after the Integration into the European Union. In: Possibilities for Rural Development in the Enlarged Europe. Proceedings of the 5th International Scientific Conference 'Economic Science for Rural development'. Academy of Agricultural and Forestry Sciences of Latvia, Jelgava, pp. 69-76.

19. Power of Place: the Future of the Historic Environment (2000) Report of the Historic Enviroment Review Steering Group, Chairman Sir Neil Cossons. The Power of Place Office, London. 48 pp.

20. Rivža B., Svanberga L., Kruzmetra M., Jermolajeva E. (2006) Reduction of Regional Diversities still on Agenda in Latvia. In: Agriculture Regional development. Proceedings of the 10th International Scientific Conference Economic Science for Rural development, Academy of Agricultural and Forestry Sciences of Latvia, Jelgava, Latvia, pp. 176.-182.

21. Stūre I. (2004) Kultūras un dabas mantojuma aizsardzība un attīstības plānošana (Protection and Development Planning of Cultural and Natural Heritage). LU Akadēmiskais apgāds, Rīga. 194 lpp. (in Latvian).

22. Taivāns L. (1993) Kristietības ceļi Latgales sakrālajā mākslā. (Routes of Christianity in Sacred Art of Latgale) In: Acta Latgalica 8. Zynōtnisku rokstu krōjums. Latgolas Kulturas centra izdevnīceiba, Rēzekne, 250.-258. lpp. (in Latvian).

23. Trapeniece I. (2002) Par dažiem nabadzības un sociālās izstumtības aspektiem Latvijā. Sociālekonomiskā procesa trajektorijas Latvijā laikā no 1985. līdz 2002. gadam. Kur tā ved Latviju? (Trends of socioeconomic process in Latvia 1985-2002. Where Latvia is going?) Ventspils Augstskola, Ventspils, pp. 70- 88. (in Latvian).

24. Valsts aizsargājamo kultūras pieminekļu saraksts (1998) (List of Protected Monuments of Culture) Latvijas vēstnesis, nr. 369/372 (1430/1433).

25. Vasermanis E., Šķiltere D. (2003) Varbūtību teorija un matemātiskā statistika. (Probability theory and mathematical statistics). SIA Izglītības soļi, Rīga, 186 p. (in Latvian).

26. Vītola I. (2006) Eiropas Savienības struktūrfondu finansējums Latvijā/European Union Structural Funding in Latvia - Latvijas Universitātes Raksti. 696. sēj. Ekonomika un vadības zinātne, Latvijas Universitāte, Rīga, pp. 264-271. (in Latvian).

27. VKPAI (2002) Arhitektūras pieminekļu saraksta projekts, nepublicēts. (Draft List of Monuments of Architecture, not Published). Valsts kultūras pieminekļu aizsardzības inspekcija, Rīga.

28. VRAA (2006a) Noslēgto atbalsta projektu līgumu saraksts Valsts atbalsta programmā 'Īpaši atbalstāmo teritoriju uzņēmējdarbības (komercdarbības) attīstība', kas ir apstiprināta Eiropas Komisijā ar Nr. LV/08/2003 un tiek īstenota Eiropas reģionālās attīstības fonda grantu shēmu veidā: 'Atbalsts ieguldījumiem uzņēmumu attīstībā īpaši atbalstāmajās teritorijās', stāvoklis uz 20.09.2006, nepublicēts. (List of accepted Project applications in State Regional Development Agency, that administrates a grant scheme of European Regional Development Fund 'Support to investment in business development in specially supported territories', on 20.09.2006, not published). Valsts reģionālās attīstības aģentūra, Rīga.

29. VRAA (2006b) Reģionu attīstība Latvijā 2005. (Development of Regions in Latvia, 2005) Valsts reģionālās attīstības aģentūra, Rīga. (in Latvian).

30. Zelča S. (2006) Latgales pašvaldību pamatbudžetu analīze: Daugavpils pilsētas piemērs. (Analysis of Basic Budgets of Latgale's Municipalities, Example of Daugavpils City) Sociālo zinātņu vēstnesis. 2(4), pp. 131-142. (in Latvian).

SUBJECTS OF ENTREPRENEURSHIP AS COMPONENTS OF LOGISTICS SYSTEMS IN STRATEGIC INTRAREGIONS OF LATVIA

Agnese Radžele, Ināra Jurgena
Latvia University of Agriculture
E-mail: Agnese.radzele@llu.lv, Inara.jurgena@llu.lv

Abstract

After the regaining of independence in Republic of Latvia, a new period in the structural-politics of national economy, in choice of enterprise forms and business companies, in their foundation and development began. Beginning from the regain of independence, there has been no published research on these issues for about 16 year period. All studies on this topic were dedicated to separate periods, processes or regions. In the Paper format results of original research have been expounded on the development of entrepreneurship content forms in four separate urban, strategic territories: Daugavpils or Southern-Latgale, Rēzekne or Eastern-Latgale, Liepāja - Ventspils or Western-Kurzeme and Riga intra-regions. In the research the whole period since regaining of Latvia independence has been analyzed, as well as the adaption of the law package on entrepreneurship and the beginning of the real entrepreneurship activity in years 1991-1992. Substantial differences between the territories (agglomerations) and also conformities of common development have been defined. There are essential differences in the activity efficiency of entrepreneurship subjects and in the results of the work contributed. The urban influence of big cities increases. The subjects and components of logistics systems develop faster.

Keywords: forms of entrepreneurship, logistics, intra-regions.

Introduction

We can point out several periods in researches on subjects and foundation forms of entrepreneurship, its composition, structure, transformation, liquidation and studies of other questions in Latvia.

Larger-scale studies in Latvia Republic in 1920-1940 were done by Ed. Balodis (1934) and A. Aizsilnieks (1968) - the time, when Latvia was a typical agrarian state with an absolute dominant of farmers house-holds, but in the trade sector developed customers co-operation system with accordant infrastructure of logistics. From the studies of this time it is already possible to see certain regional differences.

After renewal of independence in Republic of Latvia a new period in the structural-politics of national economy, in choice of forms of enterprises and business companies, in their foundation and development began (Špoģis, 1992; Špoģis et al., 1996; Torgāns, 1991; Zīle, 1997; Grūtups et al., 1995). In national economy and in forming of Gross Domestic Product (GDP) now service branches (74%) dominate absolutely, but part of agriculture is insignificant. On its turn in the group of service sectors the group of logistics branches is the second largest.

Active research work on this topic has been carried out during the last years (Jurgena et al., 2006; Jurgena, 2003; Špoģis et al., 2003; Špoģis et al., 2004).

But these published researches are for separate periods, processes or regions. There is no published research for period of 16 years, starting form adaption of the law 'On Entrepreneurship' and the law 'On Latvia Republic Register of Enterprises' – in 1991, and the law package following these - for particular forms of entrepreneurship.

The necessity for studies on dislocation tendencies of entrepreneurship subjects is also dictated by the today's large-scale processes in dislocation of logistics infrastructure objects.

By evaluating and analyzing the regional aspect of development of industrial objects of logistics infrastructure we should draw the conclusion that they both become more powerful (tonnage, capacity, speed) pretending service of wider systems of logistics, more dedicated, more target-oriented.

Choice of service spectrum of these logistics enterprises, their dislocation and development directions are determined or substantially influenced by the placement of other entrepreneurships subjects, their composition, types of cargo transport, directions. Therefore, they can be different, for example, in Rēzekne intra-region, in Ventspils and Liepāja ports region or in Riga, but also can form powerful, universal as the new Logistic centre 'Wellmak Latvia'

operating in form of Limited Liability Company.

Therefore, our research was carried out in specially selected strategic territories with the aim to find out general and different indications and phenomena in the historical development of dislocation of entrepreneurship subjects in these territories and to evaluate forming processes of logistics systems infrastructure.

In compliance with the objective, the following tasks were fulfilled in the research:

- amount and dynamics proportion of economically active entrepreneurship subjects identified in four different intraregions as well as similar and different features or regularities in these territories;
- the quantitative development of entrepreneurship forms defined by Commercial Law analyzed in the whole period to be analyzed – 16 years – and the economical connections of their time-rows have been evaluated;
- the regional tendencies of dislocation of entrepreneurship subjects in the context of logistics infrastructure have been analytically evaluated.

Materials and Methods

To do these tasks the following economical research methods were used:

- dynamic time-row of entrepreneurship subjects amount was created for each territorial unit (intraregion) and for each quantitative time-row the increase of its basis and chain, and speed of increase was calculated;
- for each form time-row was calculated correlative connections and development trends.

The explored strategical territorial units have been chosen by such hypothesis and conception:

- in the centre of each territory there is a city of a state importance (Daugavpils, Rēzekne, Liepāja - Ventspils, Riga) and urban influence;
- for each city and territory there are different strategic missions and economic and political environment of entrepreneurship:

  – Daugavpils is the city of industry, transport and Southern-Eastern border-line of Latvia,

  – Rēzekne is the dry-land transport junction of Latgale and of European Union Eastern border-line district,
  – Liepāja and Ventspils are the free-port cities of special economic area with spacious possibilities in the European Western-Eastern transport corridor,
  – Riga – a metropolis with many suburbs, free-port and attractive city for foreign investors;

- activities of entrepreneurship in each intraregion from logistics aspects can change in different ways, both in absolute and in relative estimate.

In intraregions the following territories were included:

- In Southern-Latgale – the region of the Byelorussian and Russian border-line district – city and district of Daugavpils and districts of Krāslava, Preiļi, Jēkabpils;
- In Rēzekne (Eastern-Latgale) intraregion – Rēzekne city and district, and Ludza district that borders with Russia;
- In Western-Kurzeme intraregion – Liepāja and Ventspils with their districts;
- In Riga region – metropolis and Riga district, city and district of Jelgava, Bauska, Tukums, Dobele and Ogre districts.

In general these regions cover both the Eastern border-line of European Union and strategically important components for Eastern-Western transit corridor logistics infrastructure.

To do the tasks the necessary information and data were obtained in the LURSOFT database, Eurostat, Statistical Yearbook of Latvia and in scientific publications.

Results and Discussion

Dynamics of entrepreneurship subjects amount in the researched urban regions (intraregions)

Calculation results of entrepreneurship subjects amount dynamics in the whole period of their registration in Latvia in the urban regions influenced by greatest, state importance cities can be seen in Table 1.

From the Table 1 a few definite conclusions can be drawn. In the analyzed period, it is – in the two beginning years of enterprises and business companies' registration (1991-1992) the greatest activity was in Southern-Latgale or Daugavpils intraregion. It can be understood logically and can be explained, if we know the

Table 1

Entrepreneurial activity subjects (enterprises and business companies) amount dynamics in Western-Kurzeme, Southern-Latgale, Eastern-Latgale and Riga regions in years 1991-2006

Years	Change ratio of subjects amount basis, %			
	Southern-Latgale	Western-Kurzeme	Eastern-Latgale	Riga region
2006	63	55	44	93
2005	51	46	37	74
2004	63	43	41	66
2003	50	36	23	49
2002	37	31	24	40
2001	47	37	29	48
2000	51	38	38	51
1999	58	37	35	51
1998	54	45	42	55
1997	68	52	43	55
1996	76	49	46	55
1995	93	69	57	61
1994	173	146	106	118
1993	250	115	148	110
1992	313	255	214	154
1991	0	0	0	0

fact that Daugavpils traditionally was the centre of industry. Historically in this centre the enterprises of logistics infrastructure maintenance and forming – factories of Baltic Railway infrastructure, Access-chain factory, Fabric of Cord textiles etc. operated.

But during the next 10 years (1993-2002) there was a sharp negative base increase. Analyzing the absolute numbers, we can see that in years 1993-2002 there was tenfold decrease of newly-established enterprises amount. Obviously there was a lack of political and economical support to save and continue Daugavpils industrial traditions; therefore, initiatives of the new businessmen sharply dissapeared.

During the last years of analyzed period (2003-2006) considerable progress is already visible.

If we compare data of Daugavpils intraregion with the indicators of Daugavpils city, we can draw the conclusion that the whole entrepreneurship environment concentrated mainly in Daugavpils city.

Analyzing entrepreneurship activities from the aspects of logistics infrastructure and its service, subjects amount dynamics of entrepreneurship in this region, we can conclude that logistics (transport, warehousing and connections) branches proportion here is the smallest from all four strategical regions, and it constitutes only 6.6%.

Similar dynamic processes took place in the other side of Republic of Latvia – on the coast of the Baltic Sea – strategic Western-Kurzeme. Looking into the time-rows analysis data of entrepreneurship subjects amount dynamics, the conclusion was drawn that in this region the fluctuations were yet deeper than in the South-Eastern part of the state. Substantial progress of enterprises foundation in Liepāja - Ventspils intraregion began only in year 2003 and sharp increase continued during the last years.

Very substantial particularity of this strategical intraregion opened analysis of the logistics branches enterprises dynamics: their amount in 2000-2006 years period had sharply grown and proportion exceeded by 10% which is the greatest indicator from all other researched regions.

In the region influenced by Rēzekne, decrease of establishment of entrepreneurship subjects foundation continued 12 years till the year 2003, and only the last years noticeable signs of the stabilization and development were noticed. In this intraregion, according to its strategical role in the economy of Latvia, logistics branches developed sharply, and already came to 9% from amount of entrepreneurship subjects.

In Riga and Riga region vicinity the fluctuations of entrepreneurship activities were smaller, and already from the year 2003 the

number of new enterprises increased sharply. This can be considered to be the process of entrepreneurship activities concentration and redislocation. More than 88% of all logistics branches entrepreneurship subjects in Latvia operate in this region.

Proportion of established entrepreneurship subjects in explored intraregions

The calculations were carried out in every explored region – registered number of entrepreneurship subjects of each year was related to this number indicator of the whole Latvia. Calculations revealed the continual increase of metropolis urban influence. The process of entrepreneurship subjects concentration and redislocation to the centre began with the year 1992, and has consistently been continuing for already 15 years. In addition, during the last two years – 2005 and 2006 – the speed of concentration increase grows. But analysis of logistics enterprises and business companies quantitative development revealed a substantial and interesting fact: - the new entrepreneurship subjects of logistics branches locate mainly in territories close to Riga.

When summarizing proportions of these four urbanized regions, it was discovered that in other 12 districts taken together the registered enterprises and business companies make only 8 %.

The number of the newly-established enterprises on 1000 inhabitants in the explored urban regions in the beginning of nineties was more equal. In the year 1992, in Ventspils - Liepāja intraregion it even exceeded Riga proper indicator.

In addition, the tendency of development equilibrium between Riga and Liepāja - Ventspils urbanized regions is visible during the last years. In the Western-Kurzeme (Liepāja – Ventspils) urbanized region entrepreneurship subjects number on 1000 inhabitants doubled in the period from 2002 to 2006, in Riga region it increased 2.3 times, but this indicator was identically low in both Eastern border-line district intraregions – Southern-Latgale and Eastern-Latgale.

Indicators of effectiveness

In research macroeconomical indicators from statistical data – Gross Domestic Product (GDP), number of the employed inhabitants and the number of resident inhabitants were used. Calculated, comparable macroeconomical indicators are given in the Table 2.

Comparing the proportion of produced GDP in each region with the proportion of all registered

Table 2

Proportion of Entrepreneurship subjects, logistics branches entrepreneurship subjects, resident inhabitants, employed inhabitants and produced GDP in the explored regions (intraregions) in Latvia, in year 2005

Regions studied (intra-regions)	Proportion of the entrepre-neurship subjects, %	Proportion of the logistics branches entrepre-neurship subjects, %	Proportion of produced GDP, %	Proportion of inhabitants doing permanent job, %	Proportion of resident inhabitants, %	Number of entrepre-neurship subjects on 1000 resident inhabitants
Riga (Riga region vicinity)	78.9	71.7	71.4	64.1	54.0	23.0
Western Kurzeme	5.0	8.2	7.7	7.7	8.1	12.0
Southern Latgale	5.0	5.6	6.1	9.3	12.0	4.0
Eastern Latgale	3.1	2.7	2.3	3.7	4.8	4.0
Other regions	8.0	11.8	12.5	15.2	21.1	-
In total	100.0	100.0	100.0	100.0	100.0	-

entrepreneurship subjects and logistics branches entrepreneurship subjects in Latvia the conclusion was drawn that the most powerful subjects operate in Western Kurzeme – in Liepāja - Ventspils region, where 7.7% of GDP was given by 5% of entrepreneurship subjects. Thus, the proportion of logistics branches entrepreneurship subjects is larger than the total part of GDP.

Relatively powerful enterprises and business companies operate also in Sauthern Latgale, where the proportion of produced GDP is considerably greater than the proportion of the registered subjects.

Comparing the proportion of individuals doing permanent job, it is possible to evaluate that Latgale businessmen have relatively low work productivity where the proportion of GDP is firmly below the proportion of employees.

In Riga region 64 % from all Latvia inhabitants doing permanent job formed 71% from the GDP of Latvia.

Interesting results were obtained comparing proportion of inhabitants and employees: - in Riga and in its urbanized region where people work, but they live in some other place (district or town), but in Latgale both intraregions (Sauthern Latgale and Eastern Latgale) 17% of inhabitants live there, though there is only 13% of employees which form only 8% of GDP.

In all surveyed regions the logistics and its infrastructure enterprises more often appear on the lists of outstripping growth enterprises and business companies. The development of transport services branch exceptionally stands out: cargos shippment with road transport in years 1995-2005 has grown up by 2.6 times.

Forms of Entrepreneurship

In the study program the objective to clarify the consequences of changes in content and legal forms of registered entrepreneurship subjects was included. Due to limited volume of the Paper only results of regression analysis are shown in Table 3.

As seen in Table 3 Joint Stock Companies and Proprietorships have the closest connection ($r = 0.94$) for subjects count dynamical changes within the years of the analyzed period.

Limited Liability Companies have different – weaker connection ($r = 0.51$) Reason for it can be the changes of law norms or issue of new laws that can facilitate or vice versa – hinder the choice of Limited Liability Company form. But this indicator cannot be related to the subjects logistics systems, because in this type of fast growing enterprises and business companies the form of Limited Liability Company dominates completely.

Conclusions

1. In the urban intraregions studied, we can observe common features in the amount dynamics of newly-established entrepreneurship subjects: in the beginning of the analyzed period – year 1992 – a sharp increase, in the next 10 years (1993.-2002.) multiple decrease of these subjects, but they increase again in the last four years (2003.-2006.)

2. Influence of metropolis (Riga) still increases, but urban influence from other cities of Republic is also significant, as in the four studied intraregions 92% of registered entrepreneurship subjects were concentrated and only 8% remained for other 12 districts. Even bigger proportion in those are for entrepreneurship subjects of logistics branches.

3. From the point of view of Value Added the most powerful subjects are in Western-Kurzeme – in Liepāja - Ventspils intraregion, where 7.7% GDP were provided by 5% of entrepreneurship subjects.

Table 3

In Latvia registered entrepreneurship subjects form dynamic time-rows regression equations in years 1991-2006

Entrepreneurship forms	Correlation coefficient, r	Determination coefficient, R^2	Regression equation
Joint Stock Companies	0.94	0.88	$y = 366.172^{-0.1921x}$
Individual Merchants	0.94	0.88	$y = -314.2^{+4122.7x}$
Farms	0.87	0.76	$y = 6960.80^{-0.2353x}$
Proprietorships	0.74	0.55	$y = 108.9x - 370.93$
Limited Liability Companies	0.51	0.26	$y = -387.11x + 10401$

4. In Latgale intraregions, where study was done (Southern-Latgale and Eastern-Latgale) proportion of inhabitants is 17%, but share of employees – 13% which has provided only 7% of GDP.

References

1. Aizsilnieks A. (1968) Latvijas saimniecības vēsture, 1914-1945 (History of Latvia Economy, 1914-1945). Daugava, Stockholm, 983 p. (in Latvian).
2. Balodis E. (1934) Latviešu kreditkooperācija no viņas sākumiem līdz pasaules karam (Latvian Credit Co-operation from its Beginnings till the World War). Edition of the Latvian Cooperative Congress Board, Riga, 79 p. (in Latvian).
3. Grūtups A., Krastiņš E. (1995) Īpašuma reforma Latvijā (Property Reform in Latvia). Mans īpašums, Riga, 367 p. (in Latvian).
4. Jurgena I. (2003) Integration of Entrepreneurs and Their Investments Among Enterprises, Regions and Cities. In: Špoģis K. (eds) Proceedings of the International Scientific Conference Economic Science for Rural Development Nr. 4, Latvia University of Agriculture Faculty of Economics, Jelgava, Latvia, pp. 412-416.
5. Jurgena I., Špoģis K. (2003) Zemgales reģiona uzņēmēju (komersantu) virzība komercdarbības formu izvēlē (Strategy of Zemgale District Entrepreneurs (Merchants) in Selection of Commerce Forms). In: Špoģis K. (eds) Proceedings of the International Scientific Conference Economic Science for Rural Development Nr. 4, Latvia University of Agriculture Faculty of Economics, Jelgava, Latvia, pp. 440-445. (in Latvian).
6. Jurgena I., Radžele A., Jalce L., Špoģis K. (2006) Composition and Structure of Forms of Entrepreneurial Activities (Commercial Activities) and Land Managed by Groups of Commercial Farms of Different Size in the Regions of Latvia. In: Špoģis K. (eds) Proceedings of the International Scientific Conference Economic Science for Rural Development Nr. 11, Latvia University of Agriculture Faculty of Economics, Jelgava, Latvia, pp. 193-199.
7. Lībermanis G. (1998) Īpašuma attiecības un uzņēmējdarbības formas (Ownership Relations and Forms of Entrepreneurship). Kamene, Riga, 132 p. (in Latvian).
8. Latvijas Statistikas gadagrāmata (2006) (Statistic Yearbook of Latvia 2006) Central Statistical Bureau Republic of Latvia, Riga, 300 p. (in Latvian).
9. Špoģis K. (1992) Uzņēmējdarbības formas (Forms of Entrepreneurship). Latvian University of Agriculture, Jelgava, 10 p. (in Latvian).
10. Špoģis K., Jurgena I., Zaharova Ž. (2004) Uzņēmumu un uzņēmējsabiedrību dibināšanas un likvidēšanas procesi un tos ietekmējošie apstākļi (Processes of Enterprises and Business Companies Foundation and Liquidation and their Influencing Circumstances). In: Strīķis V. (eds) Proceedings of the International Scientific Conference Economic Science for Rural Development Nr. 7, Jelgava, Latvia, pp. 18-22 (in Latvian).
11. Špoģis K., Vedļa A., Mihejeva L., Viekals U., Ruskule S., Asejeva A., Dobele A. (1996) Uzņēmējdarbība laukos (Entrepreneurship in the Country). Latvian Republic Ministry of Agriculture Training Methodical Centre Riga, 296 p. (in Latvian).
12. Torgāns K. (1991) Uzņēmumu un uzņēmējsabiedrību dibināšana (Foundation of Enterprises and Business Companies). Latvian Legal Centre, Riga, 132 p. (in Latvian).
13. Zīle R. (1997) Īpašuma reforma Latvijas lauksaimniecībā un integrācija Eiropas Savienībā: publicēto zinātnisko darbu apkopojums Dr. oec. zinātniskā grāda iegūšanai (Property reform in Latvian Agriculture and Integration in European Union: Summary of Published Scientific Papers for Obtaining Scientific Degree Dr.oec). Latvijan State Agrarian Economic Institute, Riga, 726 p. (in Latvian).

SOCIAL CAPITAL IN PIERIGA REGION

Edīte Igaune
Latvia University of Agriculture
E-mail: edite.igaune@inbox.lv

Abstract

At rural enterprises, besides the traditional resources - natural, financial, and human capital - there is some other kind of capital - it is social capital. Foreign scientists have done a lot of researches on it. The nature of social capital and its role in economics is not much studied in Latvia. The present scientific article reflects consumptions on social capital by different foreign scientists. The World Bank as an institution has also approached to the research of social capital. It studies social capital at institutions. The World Bank describes the social capital of two kinds. The scientific article characterizes Pieriga region. Rural enterprises and businessmen of agricultural, industrial and service branches in Pieriga region have been enquired. By the results of the enquiry, the presence of social capital in rural enterprises and its impact on their development have been analysed.

Keywords: social capital, enterprise, region.

Introduction

In 1990s, besides the already existing concepts of finance, real and human capital, a new concept appeared - social capital. It is considered that social capital is as important in analysis of small business and entrepreneurship as the rest kinds of the capital. Therefore the author studied some of the multiple links between social capital and entrepreneurship.

Social capital as a feature of community is involved in usefulness of an individual and gives satisfaction or dissatisfaction with oneself. It forms important aspects of the behavior of an individual - the behavior that presents tendency of a person towards concrete contexts of social capital. An individual gets positive usefulness from the very existence of social capital and acts correspondingly. We have to assume that straight involvement of social capital can be negative or positive: a person can be delighted knowing that there is social capital at the community or the person can be dissatisfied with the fact. The variant depends on the kind of social capital - links, loyalty, nets, support, and trust - in the community or enterprise.

There are some countries in the world, also Latvia, where, in the result of fast urbanization, citizens of towns are situated equally throughout the state territory in many towns but there is one city with inadequately huge number of residents. The percentage of Riga citizens makes 32% of all the state inhabitants but the number of the employed is even greater (Ozoliņa, 2006), which is characteristic of many developing countries.

Since first years of work of the European Union, the role of the states tends to decrease but the role of the regions in the EU tends to increase. 'Region' and 'regional development' have become commonly used notions. Nowadays there is a lot of regional research performed, and controversial discussions on objective validity of a region take place.

The aim of the present paper is to determine the influence of social capital in enterprises of Pieriga region.

The tasks of the research are:

1. to explain the role of social capital;
2. to characterize Pieriga region;
3. to study the influence of social capital on development of the enterprises in Pieriga region.

Hypothesis was advanced: social capital promotes the development of rural enterprises in Pieriga region.

Materials and Methods

For the aim and the tasks of the scientific article, scientific literature was studied in monographic way. Resources were explored also regarding Pieriga region and enterprises. The most important scientists and their devotion were determined. It was important to clear indicators of social capital that could be used to determine its influence on enterprises of Pieriga region. Research methods were developed as the result. To approbate the suggested methods, the author inquired 320 enterprises in the rural territory

of Pieriga region in the year 2006. Differently employed respondents took part in the inquiry: agricultural producers, industrially employed, and workers of service sphere. All their enterprises were situated in rural area. For the analysis of the results, 313 inquiry forms were used because the others were assumed as invalid. The analysis of the results showed which features and indicators characterize the presence of social capital the best and how social capital influences the development of an enterprise. To express social capital numerally, the situation balance method and confidence indicator were used. In all, 28 questions were included in the inquiry form. The owner of the enterprise could choose one to five answers to a question that characterizes his/her social capital and development of his/ her enterprise. The results of the research were processed using MS Excel and SPSS - Exact Test programmes.

Results of the Research and Discussion

Role of social capital

In economics, conception of capital describes all production means created by people and gathered by generations that serve for goods production and service. Capital is one of production factors, i.e., land, work, finance, and entrepreneur skills. Capital is created by human work. Money flow reflects the flow of real material values. Real capital wears out physically and morally. Physical wearing out takes place due to production process and natural forces. Moral wearing out is connected with scientifically technical progress that results in constantly improved capital benefits - they become more productive, consume less energy, and become more compact. To use the productive capital, land and its resources, human work is necessary. But to do a job, knowledge, experience and skills are needed. It means that human work abilities have to be developed and corresponding to modern demands. Such developed human working skills are called human capital. Therefore human capital can be considered to be a special kind of capital. Human capital is particularly connected with people. But it is not the only capital of this kind. Recently, one more such kind of capital is researched and acknowledged in the world. It is social capital. Human capital is an individual resource but social capital can be found in relationships among the individuals. Sociologist L.Hanifan (Hanifan, 1916) defined the notion of social capital in 1916, although it was

researched also earlier. Nowadays, this issue is studied widely and there is not unequivocal explanation of this concept yet. Therefore almost each scientist who researches this question gives also a definition. Sociologist P.Bourdieu defines social capital as all the active and passive resources connected with long, more or less institutionalized relations of mutually recognized cooperation nets (Bourdieu, 1986). P.Bourdieu considers that amount of social capital to each individual depends on expanse of the net he/she can mobilize effectively for his/her needs, and on amount of capital that he/she can get from each element of the involved net. P.Bourdieu perceives social capital as a tool for gains of individuals by their skills to involve in groups and be sociable to get to needed resources. Sociologist A.Portes defines it similarly: 'Social capital is ability of individuals to manage selected resources due to their participation in nets of relationships or some social structure; this ability is not within an individual but in his/ her relationships with the others' (Portes, 1998). Social capital is a result of liabilities.

Sociologist J.Coleman considers that 'social capital is group of multiple different elements with two common features: they all have some peculiarities characteristic to the social structure; and they release some activities to the individuals within the structures' (Coleman, 1988). He speaks about three forms of social capital: duties and expectations, channels of information, and social norms. J. Coleman stresses difference between social capital and private resources even more when he speaks about social capital as public benefit, i.e., it forms social structures with involved people and 'social capital is not a private property to everybody who benefits from it'.

From the theory of social capital, it is known that 'social capital could be defined as social relationships in the society' (Pizza - Georgi, 2002). Not only particular sociologists have turned to research of social capital but also institutions, for instance, the World Bank. In its researches, social capital refers to institutions, relationships and norms forming quality and amount of social interactions of the society. This institution speaks about two kinds of social capital:

1. binding social capital with horizontal links among people, social collaboration and norms influencing productivity and prosperity of group work. Social capital releases coordinating and collaboration. These links give feeling of identity and common aim to groups;

2. connecting social capital with vertical links needed for 'bridge' relationships, stepping over lines of a social group (religion, nationality, socially economical status etc.).

Social capital could be considered as special form of human capital expressed in relationships among individuals. J.Coleman (Coleman, 2000) states that human capital is abilities possessed by a person but social capital is contribution by people interacting with activities and problems solving. The concept 'social capital' is associated with benefits for an individual, a family and social groups from society and close connections that help to solve different problems. Social links go through any sphere of human activities including rural development. R.Putnam considers 'social nets and the involved exchange norms' as the central idea of social capital. At first, it is important for the involved; and sometimes social nets are benefit for those who are not involved. Therefore such social nets are individually and socially important. As the most important thing, now he assumes to make 'theoretically united and empirically valid dimensions of social capital that could be really measurable'. The scientist observes statistical data on USA organizations and formal institutions in 20th century till 1997. He agrees with M.Woolcock (Woolcock, 2001) that social trust is not basic index of social capital but rather its consequences. R.Putnam considers that social trust diminishes with generations in the USA: younger Americans trust less than older ones. He assumes also that social links determine level of altruism in the society. Analyzing social capital, the scientist reveals that the states closer to Canada have higher level of social capital while it is lower in the states with previously widespread slavery. Migration is connected with also higher social capital. R.Putnam (Putnam, 2001) compares social capital with economical success and reveals strong connection between individuals of higher education and social capital. Income and social inequality are lower in the states with high social capital. R.Putnam considers that causality works in both directions. Economist G.Becker (Becker, 1996) observes the concept of social capital and connects it with function of household usefulness: 'Function of usefulness depends not only on different benefits at any time period but also on personnel and reserve of social capital at the same moment' (Becker, 1996). By this scientist, social capital is compound of advantages caused by experience 'succeeding prosperity, regularly takes part in production that promotes welfare'. This view

seems to be fundamentally different from the Coleman's (social capital is individual resource used to increase one's usefulness). Social capital can be a resource and an advantage at the same time. It increases individual usefulness of an individual and 'releases some activities of an individual'. Therefore social capital is connected also with entrepreneurship both as a resource for activities and advantage (for instance, life style of the entrepreneur).

Regional social capital is expressed through relationships at households, with workers at enterprises or people beyond the municipality. Business outside the territory of municipality is arranged formally and informally (Strīķis, Pelše et al., 2004).

An interesting effect of social capital is observed regarding the living place. An entrepreneur can follow his/her ideas or character of the new business and leave the community. But his/her financial expectations - property and debt - increase with longer time at community because it broadens his/her access to local social capital (Gleaser et al., 2000). And, of course, local leaders and investors have great interest to keep the entrepreneur there. If an entrepreneur involves in the community successfully then dynamic feedback occurs: people with businesslike thinking remain because of financial reasons and can take part at local social capital.

Different forms of capital are formed basing on combination of fixed capital, other forms of capital and work. Financial, physical and human capitals need each other and social capital is also necessary to realize and collect them. In the case of human capital, it often happens practically. Theoretically speaking, human capital can be collected without interventions of financial and physical capital but not without social capital. Many forms of social capital are less dependant on financial and physical capital than human capital. Although some kinds of real capital release forming of social capital (investments in projects which is socially important for the most part of the society), human capital helps to generate social capital. Time is the value that is most of all invested in social capital. J.Coleman (Igaune, 2006) considers that social capital differs from other kinds of capital by its character of offal. Other kinds of capital are formed purposely but social capital is an outcome of purposeless social interaction that is commonly orientated towards profitability.

Characteristics of Pieriga region

The statistical region is regional division of the state territory, used for statistical registration

and gathering of regional information. Statistical regions are set in all the territory of the EU. They are based on the Nomenclature of Units of Territorial Statistics (NUTS) by EUROSTAT. There are 6 statistical regions set in Latvia: Riga, Pieriga, Vidzeme, Kurzeme, Zemgale, and Latgale. It has to be marked that borders of the statistical regions agree with the borders of the administrative regions (Keišs, Kazinovskis, 2001). Planning region is a territory set by government or municipality for elaboration of development plan and realization of definite aims and tasks according to development planning. There are 5 planning regions in Latvia: Riga, Vidzeme, Kurzeme, Zemgale, and Latgale. Merging statistical regions of Riga and Pieriga (Jurmala, Limbazi district, Ogre district, Riga district, and Tukums district), the statistical region gets the same territory as Riga planning region (MK, 28.04.2004).

Planning of Riga planning region was elaborated basing on Decree No. 6 (02.05.2003) 'On Elaboration of Development Plan of Riga Planning Region' by Development council of Riga planning region. To secure successful elaborating of the plan, Agreement on Collaboration of Development Plan for Riga Planning region was set among Riga Council, Jurmala council and regional governments of Limbazi, Ogre, Riga and Tukums (20.05.2003). Spatial planning of Riga planning region for 20 years was worked out in connection with middle- term document (7 years) - development program of Riga planning region. Riga region consists of two cities of republic importance (Riga and Jurmala) and four districts (Riga, Limbazi, Ogre, and Tukums municipalities) as well as municipalities of rural areas. Totally Riga planning region is compound of 75 municipalities: two cities of republic importance, 13 towns' (including 8 towns with rural territories), 5 regions' and 55 local municipalities' (Ozoliņa, 2006). In this work, the author pays attention to rural territories, their inhabitants and entrepreneurship connected with agricultural production, industry and service. Number of farms per 1000 inhabitants is regionally different: from the year 1991 to 1995, the least was in Riga region - 0.8, but the greatest in Vidzeme region - 26, 6. Correspondingly from 2001 to 2005, in Riga region - 0.1 as the least, but the highest in Zemgale region - 1.4.farms (Data by Latvia Enterprises Register, 2006). A total of 1.2 million or 47% of all the inhabitants of Latvia live in Riga region. Near a million - 941 thousand or 86% - citizens of the region live in the core of it (Riga, Jurmala, and Riga district). Riga region is territory with the highest density in Latvia - it exceeds the average density of the state more than three times. Besides 60% of the inhabitants of Riga region are at giving age (15 to 60 years), 16% are before the giving age, and 24% - older than giving age (Data by Latvia Enterprises Register, 2006).

Almost one third (32%) of the territory of Riga region is agriculturally used land. Most part of it (101 830.9 ha) and the greatest percentage is in Tukums district - 41.4% of territory of the district. In Limbazi district, agriculturally used lands are 81 888.5 ha or 31.5% of the area of the district, then follows the Riga district (81 620.6 ha, 26.1% of the total territory). The least area of agriculturally used lands is in Ogre district (65773.5 ha) but it takes 35.7% of the territory. Taking into account the urban character of the region, percentage of the agricultural territories is lower in the region than in the state (38.3%) (Data by Latvia Enterprises Register, 2006).

Residential centres - concentration places of work, service, and homes - are forming residential functional structure within Riga region. Their connections are regional functional daily communications that are characterized by mobility and traffic of the inhabitants, as well as by internal and external economical and administrative communication. Comparing GDP per capita in prices, it was 5881 lats in Riga region, but the lowest in Latgale region - 1490 lats in 2004 (Regional statistics, 2007). This indicator is according to number of economically active enterprises in the regions. The more such enterprises, the greater the GDP per capita.

Influence of Social Capital on the Development of Enterprises

Economical development of different regions of Latvia is different. Farms near Riga are developing fast but development in Latgale region is very slow. New conditions have emerged in the development of economics with personal intellect and creativity as the main factors. It is as a symbol of economical boom. That is why social capital and trust have an increasing role in the society. Studying the researches of the scientists, indices of social capital were assumed that can be applied determining capacity of social capital in the economics of Latvia (Ancāns, 2002). They are as follows:

1. participation at some NGO or association;
2. participation at competitions 'The Best Yard' on the levels of municipalities and

the state;

3. cooperation characterizes economical collaboration;

4. number of members of trade unions shows interest in improving work conditions;

5. participation in election is an individually expressed attitude to social and political activities;

6. subscribers of newspapers participate actively in obtaining different information;

7. participation in different enterprises (cultural, sports) point to abilities of collaboration and communication;

8. trust, educating and patriotism show attitude to facts and personal traits (Igaune, 2006)

In economics, partly in rural entrepreneurship, presence of social capital is determined together with informal social nets and formal organizations where individuals and rural enterprises take part by production and services.

In 2006, in the rural territory of Pieriga region, sociological inquiry was performed in 320 enterprises. A total of 313 questionnaires were used in the analysis of data because the rest were assumed as invalid. Agricultural, industrial and service enterprises took part in the research. In the results analysis of the research, the indices of social capital were expressed by numbers, using the situation balance method and confidence indicator. The inquiry form included 28 questions. Owner of the enterprise could choose one to five answers of a question that characterizes his/her social capital and development of his/her enterprise. One part of the questions explained indices of social capital but another - economical indices during recent five years.

It can be concluded from the data of Table 1 that out of 313 respondents taking part in the inquiry, 252 or 80.5% are owners of the farms and enterprises, 205 of them or 65.5% are agricultural enterprises, 26 or 8.3% are industrial enterprises, and 82 or 26.2% are service enterprises. Financial turnover of the enterprises above 100 101 LVL is just 53 or 16.9%. By the results of the research, enterprises managing more than 200 ha of the land compound 19 or 6.1%. In all, 176 men and 137 women took part in the inquiry. Further the author is analyzing responses to the question 'Do you agree that your enterprise develops?' The author characterized the answers of Table 2 as frequency balance. Usage of the situation balance method (EU Programme of Business and Consumer Surveys, 1998) allows reducing responses of each question to a single number.

The situation balance of the answers to the question in Table 2 is +70.7%. It means that the respondents consider that their enterprises develop. It is a high level indicator. Further the responses to the question 'Who has the greatest merit in the development of enterprise or farm?' are observed.

Here the respondents could give more than one answer. By the data of Table 3 we can conclude

Table 1

Characterizing indices of participants of the inquiry in Pieriga region in 2006

Indices	Number	Structure, %
Owner	252	80.5
Manager	35	11.2
Specialists	26	8.3
Totally	313	100.0
Agricultural enterprises	205	65.5
Industrial enterprises	26	8.3
Service enterprises	82	26.2
Totally	313	100.0
Financial turnover in 2005:		
to 3 000 LVL	71	22.7
from 3 001 to 10 000 LVL	81	25.9
from 10 001 to 45 000 LVL	58	18.5
from 45 001 to 100 00 LVL	50	16.0
above 100 001 LVL	53	16.9
Totally	313	100.0

Source: data by the author's research (2006)

Table 2

**Responses to the question 'Do you agree that your enterprise develops?'
in Pieriga region in 2006**

No.	Variants of responses	Frequency of responses	Percentage, %
1.	I absolutely agree	197	62.9
2.	I agree partially	79	25.2
3.	I disagree partially	16	5.1
4.	I totally disagree	7	2.2
5.	Difficult to say	14	4.6
	Totally	313	100

Source: data by the author's research (2006)

that the greatest merit in the development of the enterprise is awarded to 'my ability to collaborate with other people' (25.9%). Such answer is given by more than one fourth of the respondents. It is known from the theory of social capital that 'social capital could be defined as social relationships in the society' (Pizza - Georgi, 2002). From the answers of the respondents it can also be concluded that owners or managers of the enterprises are with great capacity of social capital, they have it and social capital is of great importance in development of their farm or enterprise.

The author concluded five indices of social capital from the results of the inquiry. They are:

1. results of elections - participation in elections of Saeima or municipality is active position of an individual to social and political activities;
2. participation in competitions connected with living place in the country points to collaboration and communication ability;

3. subscribing of the press shows awareness and activities for information obtaining;
4. membership in associations and cooperatives characterizes voluntary economical collaboration. It gives remarkable support to its members;
5. trust and attitude to facts reveal personal traits.

These indices are evaluated separately in the branches of agriculture, industry and service. Then the author calculates the situation balance by branches of the enterprises.

At first, percentage of the responses by the branches is gained. Then the situation balance is calculated as difference between percentages of marginal responses. The answer 'difficult to say' is neutral, therefore it does not impact the balance. Situation balance in the branch of agriculture is +70.3 (Table 4). Analogically the situation balance is calculated for the branches of industry and service. In the industry, it is +61.5 and in services it is 75.0. Evaluating

Table 3

The responses to the question 'Who has the greatest merit in the development of enterprise or farm?' in Pieriga region in 2006

No.	Variants of responses	Frequency of responses	Percentage, %
1.	My personal traits	136	21.0
2.	My ability to assume new information	126	19.4
3.	My ability to collaborate with other people	168	25.9
4.	Support by the EU and the state	136	21.0
5.	Good market conditions	76	11.7
6.	Other variant	7	1.0
	Totally	649	100

Source: data by the author's research (2006)

**Responds on the question about development of branches
in rural enterprises in Pieriga region in 2006**

Contents	I absolutely agree	I agree partially	I disagree partially	I totally disagree	Situation balance
Percentage, %	61.95	25.85	6.34	1.43	
Coefficients	+1.0	+0.5	-0.5	-1.0	
% multiplied by the coefficient	+61.95	+12.93	-3.17	-1.43	
Situation balance					+70.3

Source: data by the author's research (2006)

responses of the respondents of the three branches on development of their enterprises, the author concludes that balance of answers is the greatest in the branch of service. Indicator of confidence of social capital indices is evaluated from the results of the research.

Organizations and institutions trusted the most by the respondents are: bank, municipality, and the State Revenue Service. Indicator of confidence: $\{+74.5 + (-73.8) + 89.5 + (-44.4) + 34.2\}/5 = +16.0\%$.

By the results of the inquiries and by the calculated indicator of confidence (+16%) we can conclude that leaders of the above- mentioned farms have social capital. The bigger the indicator of confidence, the greater the capacity of the social capital. Calculating the indicator of confidence to social capital by branches, it is as follows: in agricultural branch - $80.0 + (-65.9) + 88.2 + (-31.4) + 24.7 = +95.6/5 = +19.1$; in industrial branch - $+71.2 + (-92.3) + 61.5 + (-88.4) + 23.1 = -20.9/5 = -4.2$; and in service branch - $+61.6 + (-87.8) + 63.0 + (-63.4) + 29.3 = +2.7/5 = +0.5$.

The confidence indicator of the respondents of agricultural and service branches is positive. It means that owners and managers of these enterprises have big capacity of social capital. But owners and managers of industrial enterprises do not have enough capacity of social capital.

Conclusions

1. Using acknowledgement of social capital by scientists, adjusting it to economical processes and taking into account the presented research, the author concludes that social capital can be defined as net of relationships that is more or less institutionalized and gives access to necessary resources.
2. Inclusion of social capital in the analysis of economical data means that at least some social activities and relationships, processes and changes are becoming endogenous to economics in the society.
3. Evaluating researches by different scientists, indices of social capital are selected that are to be included in economical

Evaluation of social capital indices by the indicator of confidence in Pieriga region in 2006

No.	Questions	Situation balance, %
1.	Did you take part in recent two elections of the municipality?	+74.5
2.	Did you take part in competitions 'Sower' and 'Then icest yard of the district'?	-73.8
3.	Have you ordered the press during the last year?	+89.5
4.	Are you a member of some cooperative?	-44.4
5.	Name three organizations, institutions you trust mostof all.	+34.2
	Indicator of confidence	+16.0

Source: data by the author's research (2006)

researches - individual participation in the elections, activities and participation in associations and cooperation, and activities for information obtaining and trust.

4. By the results of inquiries of rural enterprises in Pieriga region and calculated indicator of confidence of social capital indicators that is +16%, the author concludes that leaders of the above-mentioned enterprises have social capital.

5. Social capital has positive impact on the development of enterprises. It promotes the development. It is seen by the results of the research that the most capacity for social capital is in the branch of agriculture. The hypothesis is proved: social capital promotes development of rural enterprises of Pieriga region.

References

1. Ancāns S. (2002) Sociālā kapitāla un tehnoloğiskās attīstības savstarpējās mijiedarbības aspekti (Aspects of Interaction between Social Capital and Technological Development). In: A. Povilaitis, J. Jarco, A. Matulionis, V. Majerova, M. Krūzmētra (eds.), Sociālais kapitāls, Starptautiskā zinātniskā konference, LLU SZF, Jelgava, 24.- 30. lpp. (in Latvian).
2. Becker G. (1996) Accounting for Tastes, Cambridge, MA: Harvard University Press, 336 p.
3. Bourdieu P. (1986) Les trois erats du capital cuturel (Three Eras of Social Capital). Actes de la Recberche en Sciences Sociales, 30, pp. 3-6. (in French).
4. Coleman J. (1988) Social Capital in the Creation of Human Capital. American Journal of Sociology. – Vol. 94, pp. 95-120.
5. Coleman J. (2000) Social Capital in the Creation of Human Capital. In: P. Dasgupta, I. Segareldin (eds.) Social Capital: A Multifaceted Perspective, Washington: The World Bank, pp. 14- 15.
6. Glaeser E., Laibson D., Sacerdote B. (2000) The Economic Approach to Social Capital Working Paper 7728, Cambrige, MA: National Bureau of Economic Research, pp. 485.
7. Hanifan L. (1916) The Rural School Community Center. Annals of the American Academy of Political and Social Science 67, pp. 130-138.
8. Igaune E. (2006) Society, Social Capital and Social Nets, Research for Rural Development, 12 International Scientific Conference, Jelgava, pp. 189-194.
9. Keišs S., Kazinovskis A. (2001) Reğionālā administratīvi teritoriālā iedalījuma reformas problēmas Latvijā (Problems of Regional Administratively Territorial Division in Latvia), 79 lpp. (in Latvian).
10. Latvijas Uzņēmumu reğistra dati (Data of Latvia Enterprises Register), available at: www.lursoft.lv, 18.12.2006.
11. Ozoliņa L. (2006) Rīgas plānošanas reğiona teritorijas plānojumi (Territorial Plannings of Riga Planning Region), Rīga, 78. lpp. (in Latvian).
12. Pelše M. (2006) Interrelationships between farm Development and Social Capital in a Regional Context. Proceedings of the international scientific conference 'Economic Science for Rural Development', No. 11, LLU EF, Jelgava., pp. 200.- 208.
13. Pizza-Georgi B. (2002) The role of human and social capital in growth: extending our understanding, Cambridge journal of Economics ,Vol.26, pp. 461-479.
14. Portes A. (1998) Social capital: its origins and applications in modern sociology. Annual Review of Sociology, pp. 24.
15. Putnam R.D. (2001) Social capital: measurement and consequences. ISUMA-Vol. 2 , Nr. 1, pp. 145.
16. Reğionālā statistika (Regional Statistics). Available at: http://www.csb.gov.lv/site/content/-?cat=2389, 14.02.2007 (in Latvian).
17. Strīķis V., Pelše M., Leikučs J. (2004) Researching social capital to promote successful entrepreneurship in rural areas- the Salzburg conference and rural development in Latvia Vol.3 (43), Humanites and social sciences in Latvia, LU, pp. 93.-103.
18. The Joint Harmonised EU Programme of Busines and Consumer Surveys (1998) European Economy, Reports and studies, No 6, 1997, Brussels: European Communities, pp. 231.
19. Woolcock M. (2001) Micro Enterprise and Social Capital: a Framework for Theory, Research and Policy. Journal of Socio-economics. Vol. 30, pp. 193.-198.

INFORMATION AND COMMUNICATION TECHNOLOGIES

FEATURES AND LIKENESSES OF INFORMATION MODELS OF ANIMALS REGISTRATION

Jekaterina Smirnova, Sergejs Arhipovs
Latvia University of Agriculture
E-mail: apodejktika@inbox.lv; sergejs.arhipovs@llu.lv

Abstract

The process of creation of the informative systems based on the account of such animals as horses, sheep and goats is analyzed in the work. Three structural models are created and their comparative analysis is conducted. As a result of analysis the general elements of structures, characteristic to each model were found. The Meta modelling approach to facilitate the system was udes. The system has a more abstract structure and allows dynamically to add not only the animal specimens but also new types of attributes in fly during runtime. Recompilation of the system is not required there is no necessity of the analytical restructuring of the model, the absence of type explosions is guaranteed in a database because not a new table-type, but a new record in one or two tables is added.

Keywords: Selection, object model, Meta modelling.

Introduction

Selection is the main task of animal breeding. To carry out this works animals should be compared. But in order to compare the animals their descriptions and measurements should be used. We made an effort to find out whether it is possible to define general criteria for comparison of different animals; thus it would allow to systematize work of secessionists.

The method of registration of sheep, horses and goats was studied. Based on these materials, the structure and procedure of estimation of each animal was made. Then these procedures and structures were compared, and using the qualimetric system of indexes of quality the invariant elements of the systems were found. As a result, there was a possibility of using a compatible Meta modelling approach to realization of tasks of the systems of different animal accounting.

Materials and Methods

To create the models of animal estimation, normative documents on selection were studied, specialists in this area were involved, the practical methods of domestic animal registration and selection were studied (Ministry of Agriculture, 2002).

When the materials of domestic animal estimation had been collected, there was a necessity to analyze them. The object - oriented approach to create and analyze the models was used. The objective models of account of sheep, horses and goats which obviously demonstrate the system of animal estimation accepted in Latvia were created (Microsoft, 2007). The qualimetric approach to the analysis of the created models predetermined the possible variants of universal parameters of comparison and domestic animal account (Rulko, 2003).

Qualimetric is a study of quantitative and quality estimations of quality. All the results were made into the whole model and the Meta modelling methodology for the general system realization of animal account was used.

Results and Discussion

On the first stage, three models of classes using the normative documents of Latvian Republic on registration of domestic animals were made (Ministry of Agriculture, 2002). Figures 1, 2 and 3 represent the formal objective models of account of horses, goats and sheep.

Similarly, the information on the estimation of goats was structured.

The objective estimation model of sheep qualities was made, too.

Basic entities in each model are a horse, goat and sheep. These are animals whose parents should be registered. It represented recurring associations, outgoing and ingoing into one entity, on the class model. An owner and animal passport are registered for each animal. In contradistinction to the animal passport the attribute 'the animal owner' can be changed during the life cycle of the object of a horse, goat
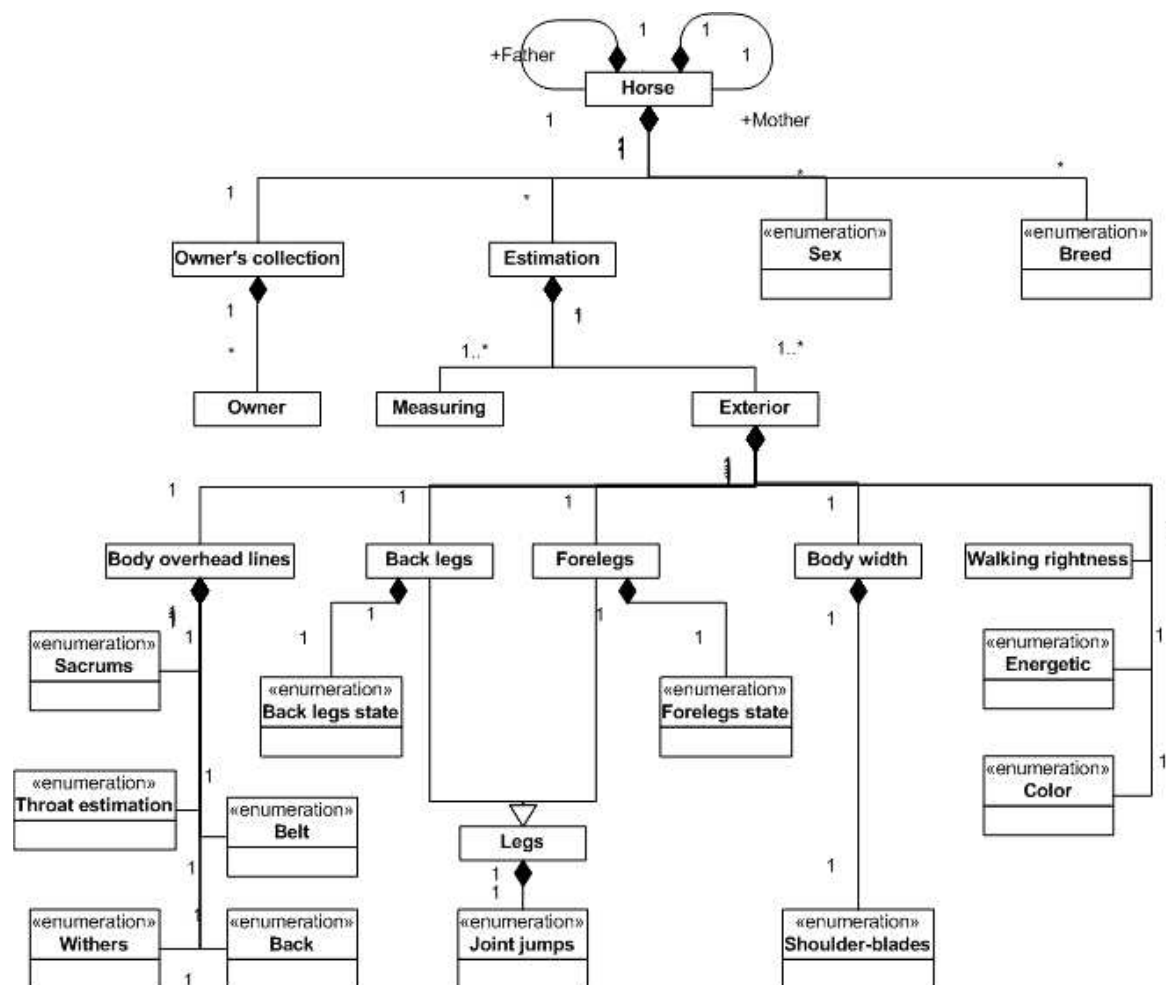
Figure 1. Object model of horse estimation.

and sheep type (Ministry of Agriculture, 2002). It is one of features of models of all animals which should be taken into account during realization of the systems of animal account. It is represented schematically not as a static owner, but as a dynamic structure of data type 'collection'. A great number of quality and quantitative indexes of animals influence an increase of the model. In the mentioned models quality indexes are modelled by the stereotype 'enumeration' and quantitative indexes are represented by numerical types. The main difficulty of comprehension of account models is a great number of quantitative and quality animal attributes. The other difficulty lies in the problem that these models are static, that at first the system is filled by the models of animal attributes, and then it is realized as the information system. Additions of a new attribute change the model structure and make recompile the whole system (Petraq and Panos, 2006).

In figure 4 there are general attributes of animals, characterizing horses, sheep and goats.

However, these model elements are insufficient for a complete account of each animal type. That is why the qualimetric approach which divides all quality indexes into two large categories was used (Rulko, 2003).

All animal characteristics were divided into two groups: quality (what) and quantitative (how many). Because of this division, it is not necessary to register a definite list of animal attributes, but instead of it, it is suggested that one provides a possibility of the generalized index registration in the system. It means that the registration record of each animal consists of two parts - quality and quantitative indexes (it refers to each animal). It is necessary to specify a definite list of qualities for registration of definite type. So this is a two-level modelling system. First, comes the so-called Meta level where there is information about
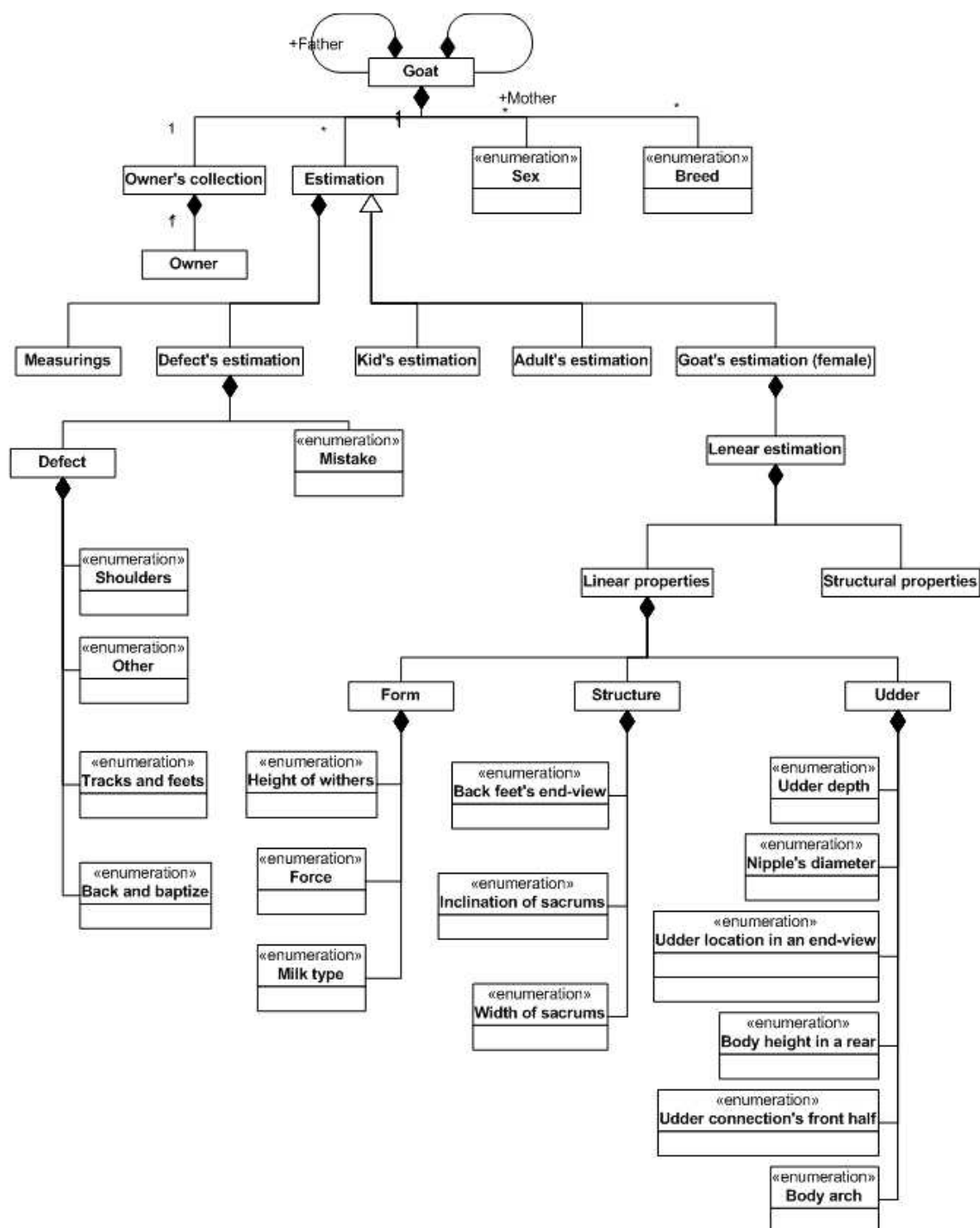
Figure 2. Object model of goat estimation.

the lists of quality and quantitative argument-types of parameters (information on the type of animal), the second level- implementation level where there is information on the definite meaning of attributes of definite animal specimens.

In figure 5 there is a generalized two-level chart of Meta modelling. It allows to disengage oneself from a definite animal during creation of the system, and definite information on an animal is given during its exploitation.
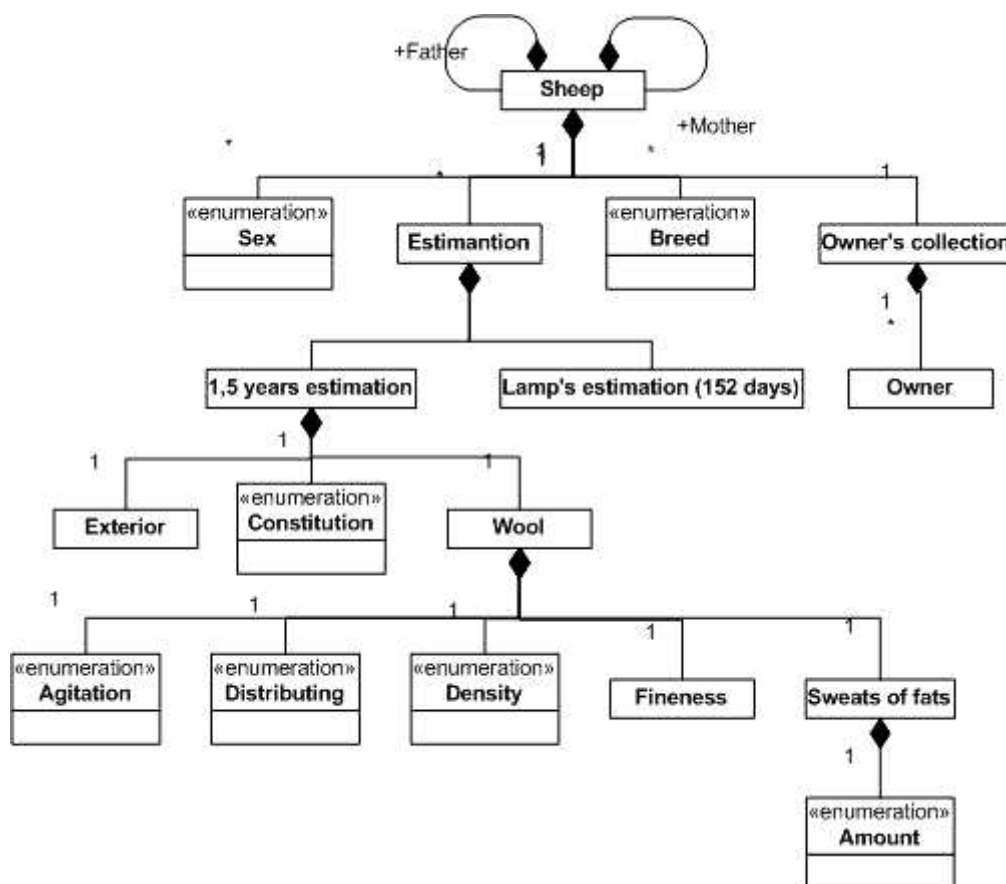
Figure 3. Object model of sheep estimation.

Conclusions

The two-level chart of Meta modelling was created as a result.

The prototype of information system of registration of any type animals was created founded dividing into quality and quantitative properties.

Usage of Meta types makes a model more abstract and facilitates it; thus, construction of
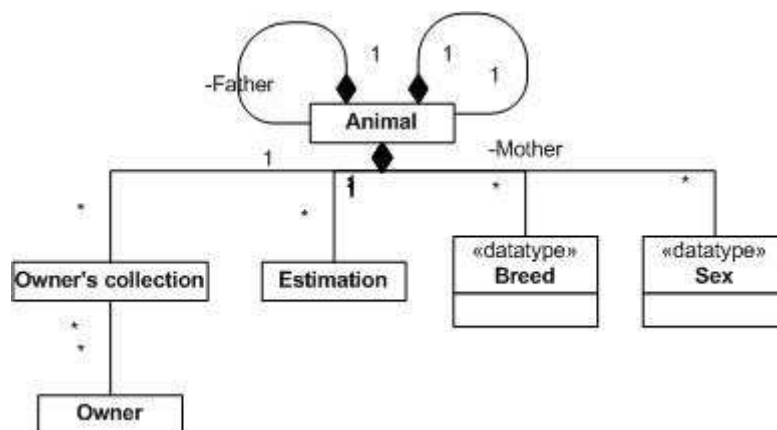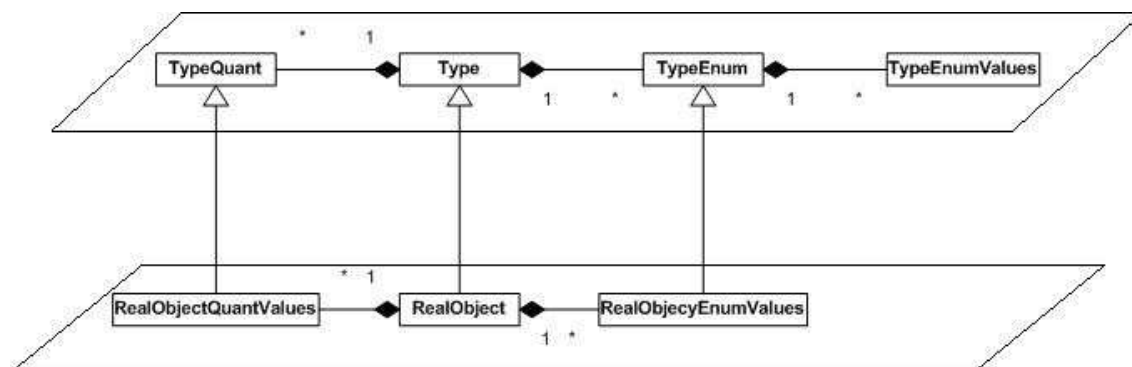

Figure 4. In the horse, sheep and goat models.

296

Figure 5. Dividing into quality and quantitative properties.

the program system consists of three stages: at the first stage such abstract essences as quality and quantitative types of information, abstract animal entities, its parents and the owner are determined. At the second stage an abstract model is specified by filling it with its definite list of quality and quantitative indexes.

Made as the class diagram of object model of animal account, it helps to analyze, structure and generalize system information.

Usage of qualimetric approach allows to create a compatible model of the animal account.

Usage of two-level model allows to decide the problem of different type animal account by determining not types and animals and their properties, but types of types.

References

1. Microsoft (2007) UML Resource Page. Available at: http://www.uml.org/, 01.03.2007.
2. Ministry of Agriculture (2002) Ciltsdarba normatīvie dokumenti, 3.sējums (Bloodstock Breeding Normative Documents, 3th volume). Ministry of Agriculture, Riga, Latvia, 128 p. (in Latvian).
3. Petraq J., Panos M. (2006) Software Engineering Techniques Applied to Agricultural System An Object Orientes and UML Approach, Springer, USA, 247 p.
4. Rulko A. (2003) Оценка качества. Структура квалитологии (Estimations of Quality. Structure of Qualitylogic). Available at: http://www.udc.com.ua/modules.php?op=modload&name=News-&file=article&sid=139&mode=thread&order=0&thold=0, 10.03.2007 (in Russian).

GROWTH REGRESSION MODELS PROBLEMS OF THE EXPERIMENTAL DATA ESTIMATION IN ENGINEERING APPLICATION

Sergejs Arhipovs
Latvia University of Agriculture
E-mail: sergejs.arhipovs@llu.lv

Abstract

If among engeniering phenomena exist nonlinear interconnections, they are expressed with help of corresponding nonlinear functions. Teaching the regression analysis for the engeniering science students one of the important topic is method of Least Square Method (LSM) and their application in the nonlinear regression analysis. Based on experience at Latvia University of Agriculture, the illustrated approach of teaching of nonlinear regression topics for undergraduate students in engenieing applications is presented. Teaching statistics on regression analysis, students usually have problems with interpretation of the transformed regression model parameters significance. The tasks of teaching using LSM in the nonlinear regression analysis are discussed.

Keywords: Nonlinear regression, Least Square Method.

Introduction

Models which are nonlinear in parameters, in sense, that by suitable (log) transformation the models can be made linear in parameters. In this case method of Least Square Method (LSM) has been used for transformed equations. However, it is possible that the stochastic term has different variability related to dependent variable: additive or more random and unpredictable. Depending on the stochastic term variability the nonlinear models can be intrinsically linear (in-parameter) regression models (in the sense that by suitable (log) transformation the models can be made linear in the parameters) and can be intrinsically nonlinear in parameters.

If for the linear models and models nonlinear in variables the least-squares criterion of minimization has been applied to initial (original) variables, then for the models nonlinear in parameters the least-squares criterion of minimization it has to be applied to transformed variables, for example LnY. However, the parameters estimation for the transformed models LSM is biased. It means that, although nonlinear models can be transformed into linear regression models and can be estimated by LSM, we have to be careful about the properties of the stochastic residual term that enters these models. As the preceding analysis shows, it is necessary to pay attention to the residual term in transforming a model for regression analysis. Otherwise, a formal application of LSM to the transformed model will not produce a model with correct statistical properties. The examples of the different nonlinear models and the application of LSM are considered, as well the transformed models estimated parameters has been compared.

The contents of regression analysis

Interconnectedness accordance between sets of numbers is defined by a function (Van Der Waerden, 1957). In particular, if X and Y are two subsets on a numerical axis, than the form of accordance between them in general is defined as equation $y = f(x)$. Here value of y examined as a dependent variable or function from other independent variable of x, which is named an argument. Term regression is used for denotation of dependence between two sets of values X and Y. All facilities which are used for description of dependence between values from a set of X and values from the set of Y are make maintenance of regression analysis. Distinguish two types of dependences between two sets of values: functional and statistical. In a difference of functional dependence, statistical dependence does not determine synonymous accordance between sets of values X and Y, but gives some estimation of the facts, that with probability 90% the height of 80-old year Latvian pine-tree makes 23 meters, and other 10% percents are distributed near this value.

At the same time it is possible with the 0.01% probability, that midget pine-trees, arriving at only heights 10 meters, sprout in Latvia. Thus, statistical connections aren't described the dependences of separate values of y and x, but

their mean values: in Latvia middling a statistical 80-old year pine-tree achieves 23 meter heights on the average. For the regression illustration the equations of dependences, graphs, tables of values, different coefficients are served. On a figure 1 regression dependence is shown between such sizes as age of pine-tree and his height. The main species in Latvia is pine-tree (47% from total Latvia forest area), growth of trees motion is stipulated by tips of growth circumstances (Statistical Yearbook of Latvia, 2005). Building the system of rectangular co-ordinates, the results of measuring are represented points on a plane in the system of rectangular co-ordinates, where a horizontal axis X is age of pine-tree in a range [0;140] and the vertical axis of Y is a height of tree in diapason [0;30]. It is possible to see that does not exist synonymous functional dependence between age of pine-tree and its height. However, it is empiric possible simply to estimate dependences between the average values of ages and proper mean values of heights. Points on figure 1 represent regression statistical dependence of height of pine-tree on its age, and the conducted continuous line expresses functional dependence between statistically middle ages and proper middle height.

Whether there must be an error of measuring of normal

At measuring of the same size identical values turn out not always. The looked after sizes have variation near some mean value. The difference of the mean value and observed value Gauss named as the error of one measuring. It is assumed in the theory of errors of Gauss, that the random variable x has a mean value Mx and squared deviation Sx, which Gauss named as the average error of all observation. On a figure 2 the results of the simultaneous weighing of three different samples are represented by three Force Sensor Resistors. The 10000 measuring were made. Weight of every sample is random variable with mean values 577.3, 600.5 and 626.3.

Gauss assumed that errors of measuring, which are random variables, are distributed normally (Van Der Waerden, 1957). Gauss pulled out a hypothesis, that a total error of observation is the sum of large number of independent small errors which possess small variances. It means that the central limit theorem is correct. The sum of very plenty of independent random variables with variance which makes small part of variance of all sums has normal distribution approximately. However, not always a measuring error is normal it must be taken into account at the analysis of their nature. For example, in case with regressive dependence of growth of trees on a figure 1, in an age range to ten years obviously there is a not normal error of measuring of height of tree. If to assume that an error of supervision of heights of young trees is normally distributed, at that rate there must be trees with a negative height. On a figure 3 the observation of measuring of a zero value of mass is shown. Calibration of mass is done in order to propose so-called zero mass of scales. On the analogs and digital scales it is often possible to see displacement of value of mass in a negative area. However at a 10 bit
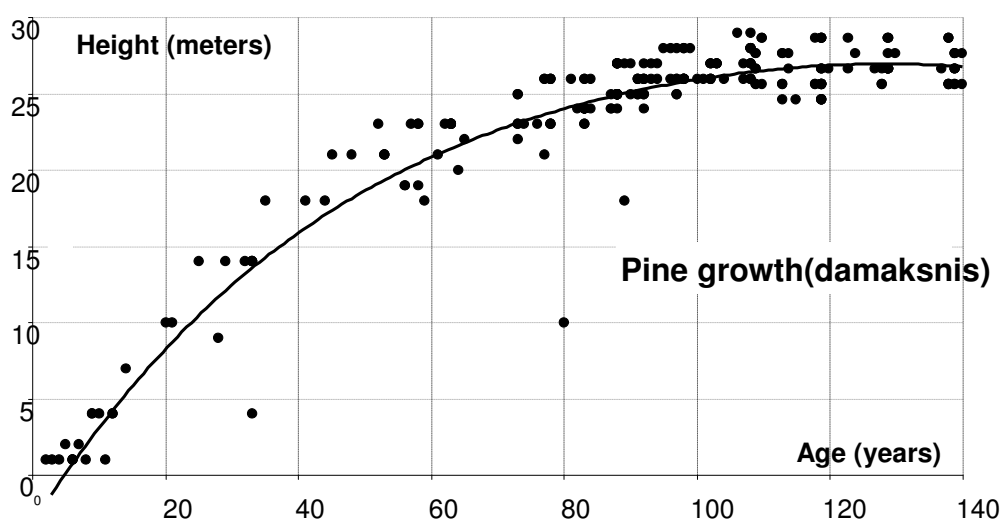

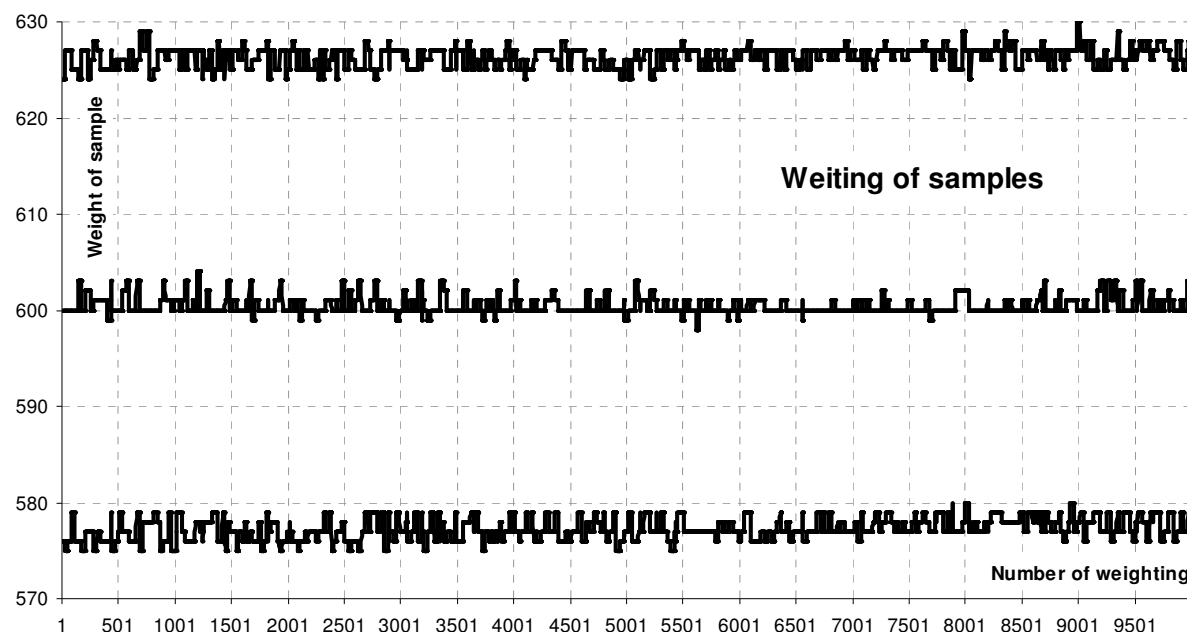Figure 1. The pine-tree age-height regression.

Figure 2. Weighting of tree different samples.

positive digital modulation, the negative values of normal distribution are lost and substituted by zeros. Moreover, the discrete measuring are given by discrete errors unlike assumption of their continuity.

In this case, Gauss grounded searching for of estimation of some parameter, which does not depend on supposition of distributing normality. Gauss over was brought by an example with the game of chance, in which it is possible only to lose. Truly, in case with measuring of a zero mass, it is necessary to take on some positive value of measuring for a zero mass, notoriously realizing the loss. If Z is accepted as an estimation of parameter of z, a loss will be the more than anymore |Z-z|. For the measure of loss Gauss adopted $(Z-z)^2$ and assumed, that an

estimation did not have a systematic error and its variance is minimal. He proved then, that the result of such minimization is given by the most probable value of estimation of parameter of z. At imposition of condition of normality Gauss specified obvious expression probability, that the results of observations will lie in strictly the small intervals set how many pleasingly. Thus, condition of normality of distributing of errors of observations generally speaking, is optional. In this case it is only necessary to consider, that the chosen estimation of parameter will be always in a loss.

Why a sum of squares of errors of measuring must be minimum

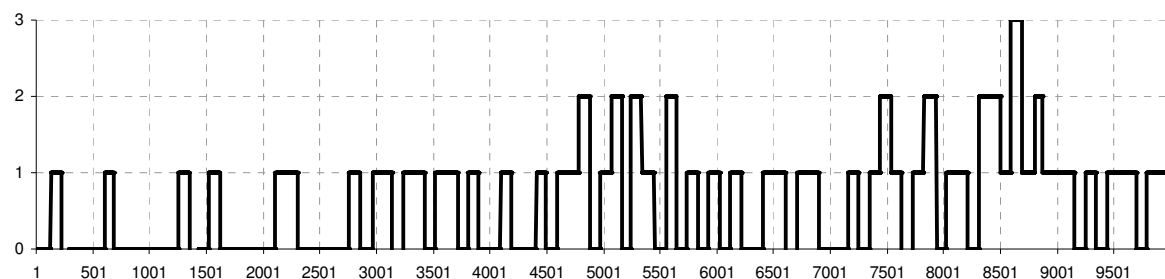Let the looked after dependence of $y = f(a, x)$ be set as a regression hash table $x_i \rightarrow f_i$, where
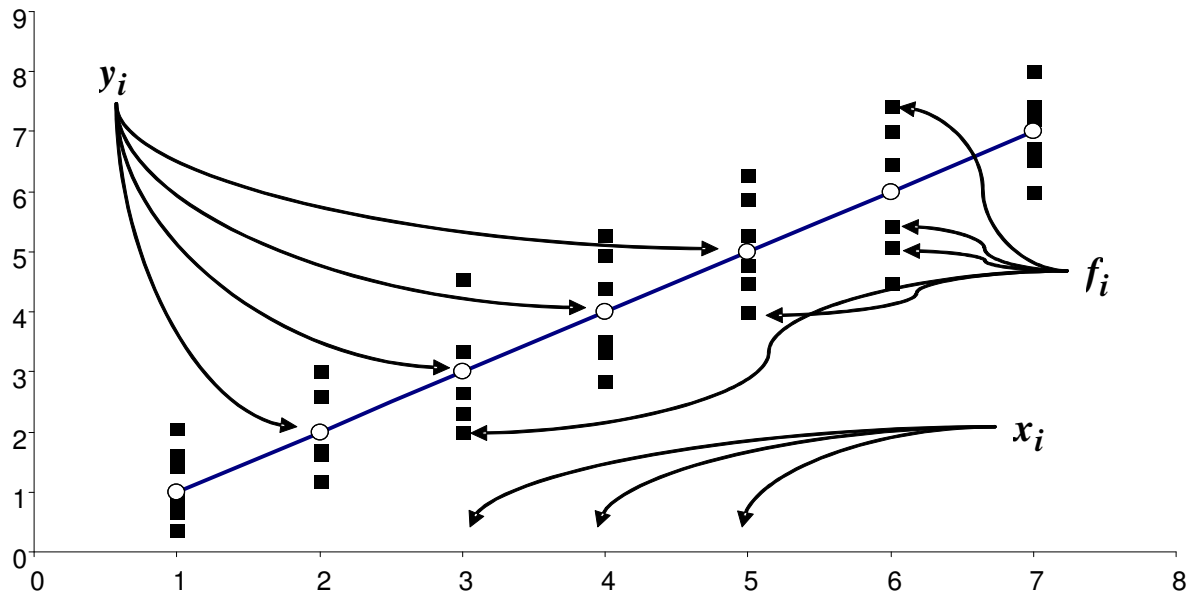

Figure 3. The digital zerro weight value.

Figure 4. LSM attributes.

xi are arguments, fi are the values, and it is necessary to find parameter a, that to estimate the got values of $y_i = f(a, x_i)$ with the best way appearance with the looked after values of f_i.

In the case of normal distribution of errors of observation Gauss grounded, that probability of the results of observation will be in an interval $(f_i - \delta_i; f_i + \delta_i)$ at small δ_i approximately equal $exp(-(f_1 - y_1)^2 - (f_2 - y_2)^2 - \ldots - (f_n - y_n)^2) \cdot \delta_1 \ldots \delta_n$. This probability will be maximal then, when sum $\Sigma(f_i - y_i)^2$ will be minimum. Consequently, by Gauss the best values of yi will be those, values which correspond the best probability of hits to the given interval. On a figure 4 the construction of straight line is represented such, that the sum of squares of errors will be minimum.

Geometrical interpretation of Least Square Method (LSM)

Geometrical essence of LSM consists of finding of minimum distance from point a view $(f1, f2, f3)$ to the variety which is given by the model of $y = f(a, b, x)$, where a,b are model parameters, and x is an argument of regression.

On a figure 5 three-dimensional space is represented, which designs the triple observation of the regression $y_i = f(a, b, x_i)$. Every dimension it is a set number of values which can adopt one of the proper observations. A point (f_1, f_2, f_3) is the got results of observations. The represented two-dimension surface is the variety of points (a', b') in functional space of lines, being linear combination of two bases of x and 1. In this case model

parameters a and b are symbolic denotations two functional dimensions and one point (a', b') on this numerical plane designates one function of $y = a'x + b'$.

A task consists of finding of such point (y_1, y_2, y_3) on the set variety, that Euclid distance between her and a point of view (f_1, f_2, f_3) was minimum. Thus, geometrical sense of LSM consists of finding of distance of a point of view to the linear variety with the set functional base. A requirement of Gauss to linearity is substantial that is why, in general case of non-linearity on parameters (but not on arguments) a question gets up about existence and uniqueness of the shortest distance to the variety.

Non-linearity of regression

The concept of linear and nonlinear regression is practically mentioned in every source on LSM. In this context it is necessary to distinguish linearity on the sought after parameters, for example $a, b, z \ldots$, from the concept of linearity on arguments, for example $x, y, z \ldots$. A mess with linearity and non-linearity of regression in the case of application of LSM is easily removed. LSM of Gauss is used for an analysis only of linear on parameters regression (Van Der Waerden, 1957). That, parameters of a,b,z... included in the model of $y = f(a, b, z \ldots, x)$ strictly linearly. As for linearity or non-linearity of incoming in a model arguments, Gauss is shown by unimportance of it for application of LSM. Thus, regression of $y = f(a, b, z \ldots, x)$ in
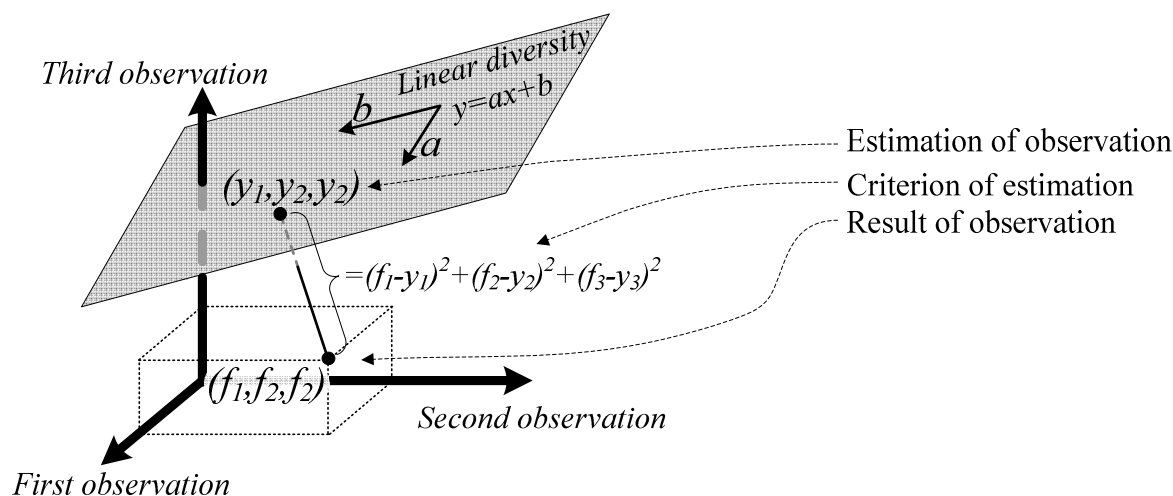
Figure 5. The geometric interpretation of LSM.

LSM must be linear combination (parameters) of linearly independent functions (of arguments).

For example, polynomial dependence $y(x) = a_n \cdot x^n + \ldots + a_2 \cdot x^2 + a_1 \cdot x + a_0$ is linear combination of orthogonal functions $(\ldots x_n, \cdot x_2, \cdot x, 1)$ and, formal is a nonlinear function ot x. From this point of view there is only one type of linear regressions, it is $y(x) = a_1 \cdot x + a_0$ or, in the case of many variables, it is $y(x, y, z \ldots) = a_x \cdot x + a_y \cdot y + a_z \cdot z + \ldots a$. Hyperbolical dependence $y(x) = a + b/ \cdot x^2$ also named nonlinear, although is linear combination of functions $(1, 1/ \cdot x^2)$ and fully meets conditions of applicability of LSM. Periodic regression $y(x) = a_0 + a_1 \cdot sin(x) + a_2 \cdot cos(x)$ often meets in biometrics and econometrics. These can be price-waves on products or population dynamics of animals. Function y(x) nonlinear on x, but linear on the parameters of a_0, a_1, a_2 – LSM finds a synonymous decision. Thus, term "nonlinear regression" it is necessary to use and understand in the context of semantic interpretation of model, in sense of functional dependence on arguments and to try to dissociate this term from the terms of applicability of LSM (Gujarati Damodar, 1995).

Source of methodical errors of the use of LSM

Term 'nonlinear regression' generates such concept, as 'linearization of regression' (Gujarati Damodar, 1995). Usually linearization of regression has named two different approaches. First from them offers the uncomfortable from point of view functions of bases to renamed by variables and, thus, to transform a model in a linear kind. For example, 'nonlinear' regression $y(x) = a + b/ \cdot x_2$ taken to 'linear' $y(z) = a + b \cdot z$

by transformation of $z = 1/ \cdot x_2$. But from point of terms of application of LSM such transformation is not of principle and can be justified the aims of comfort of writing and, maybe, tabulations of the looked after values in a text.

The second type of regression linearization will transform not argument, but all model which usually originally nonlinear as on arguments so on the sought after parameters. For example, model $y(x) = a \cdot xb$ not only not taken to the system of Gauss normal equations but also presents certain problems of finding of decision by numeral methods. Linearization of this model consists of its taking the logarithm, which, grindings off of sight of the Gauss theory of errors, results in some paradoxical questions. To logarithm of model $log(y) = log(a) + b \cdot log(x)$ it is formal possible to apply LMS, but it is then necessary to explain not only sense of initial model and its regenerate kind but also nature of errors of observations in both models. Gauss required minimizing the sum of squares $\Sigma \delta i^2$ errors which are included in a model linearly. Indeed, if $y_i = a \cdot x_i b + \delta_i$, the criterion of minimization on LSM is $\Sigma(yi - a \cdot xib)^2 \rightarrow min$. However, if on what or from reasons, a model is taken the logarithm, formal it doing is impossible because $log(y_i) = log(a \cdot x_i b + \delta_i) \neq log(a \cdot x_i b) + log(\delta_i)$. From other side, if decision to apply LMS to logarithm of model is made all the same, it is necessary to explain linearity of errors in $log(y) = log(a) + b \cdot log(x) + log(\delta)$ and multiplicative errors of observations in the initial model of $y_i = a \cdot x_i b \cdot \delta_i$.

Very often such linearization of all model is used not in order to find the decision of

regenerated model and to interpret exactly her in terms of subject domain as it is done in classic literature, but in order that to the found decision to apply reverse transformation and obviously or non-obvious to establish optimality of the decision found thus. It methodological improperly because usually is not an answer given to the question what criterion satisfies the found decision?

It is possible to show the incorrectness by the cartographic measuring producible on a sphere and their transformations of projects on a plane. On a spherical surface the frequent measuring of distance are made between two points. A task consists of determination of the most exact distance between them. Following the method of transformation of model of regression (linearization, taking the logarithm of and other) the results of observations are orthogonally mapped to the flat card and to the regenerate results got thus LSM is used. Intuitional the clearly, that got estimation will system differ of a truth value (figure 6).

The results of such application of LMS are represented on figure 7.

The graph illustrates the values of measuring (grey groups) projected on a flat card. On a vertical line the values of distances are postponed, and on a horizontal line the numbers of measuring are postponed. Two horizontal lines are the average values of the proper supervisions on a sphere and on a plane. The method of Monte Carlo is make 35 series of experiments for 15000 imitations of measuring with the set random uniform distributed error. The results of experiments confirmed system divergence between the estimation of distance in a primary not modified model on a sphere and estimation of distance in a modified to a projection model on a plane. It is similarly possible to see on graphic arts, that distributing of error of observations on

a flat card also suffered transformation and now it already is not even and has obvious displacement toward the point of sphere which is most project remote of a card.

Estimation of growth of trees

Under a mathematical model, often understand the equation of the regression, built on the basis of experimental information. However, the coefficients of such polynomial make no rich in content sense, and regression in this case is the formal specification of experimental data. Naturally, that such mathematical models on principle make no biological sense and their value for researches is very limited, and they can be used only in strictly certain terms and taking into account the features of conducting of experiment. The basic task of our researches consisted in the construction of rich in content model the coefficients of which make clear biological sense and, which would serve as basis for the construction of theoretical pattern of growth of different types of trees in Latvia. Difficulties, arising up at the decision of this task, consist in the question about the selection of curves for description of such measuring signs which in most are biologically difficult. So, for example, if to come from supposition, that continuous fission lies in basis of growth, clearly, that the size of increase must be proportional the measured sign, that can be presented as differential equalization of $dy/dt = k \cdot y$, the decision of which looks like $y(t) = y0 \ e^{k \cdot t}$.

The most composite hypothesis consists of that the stake of the divided cages with age diminishes gradually. Speed of processes of production of new matter changes also. Therefore for growth there always are limits. Equalization of P.F.Ferhlust $dy/dt = a \cdot (1 - y/b) \cdot y$ together with death rate/birth rate coefficient a and also contains another coefficient $(1 - y/b)$, which limits
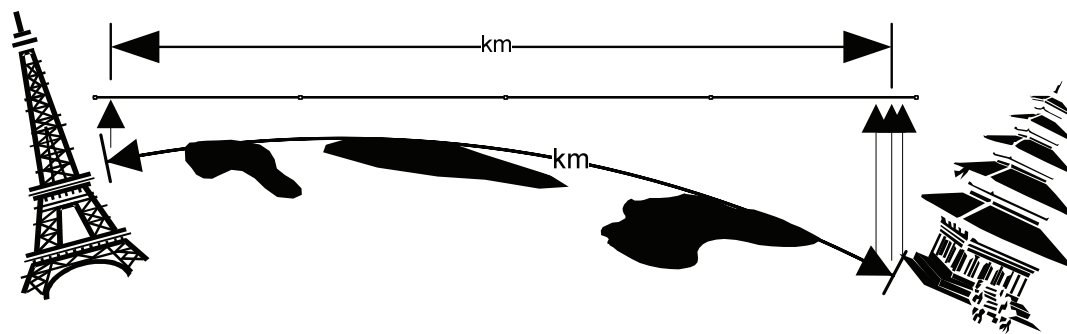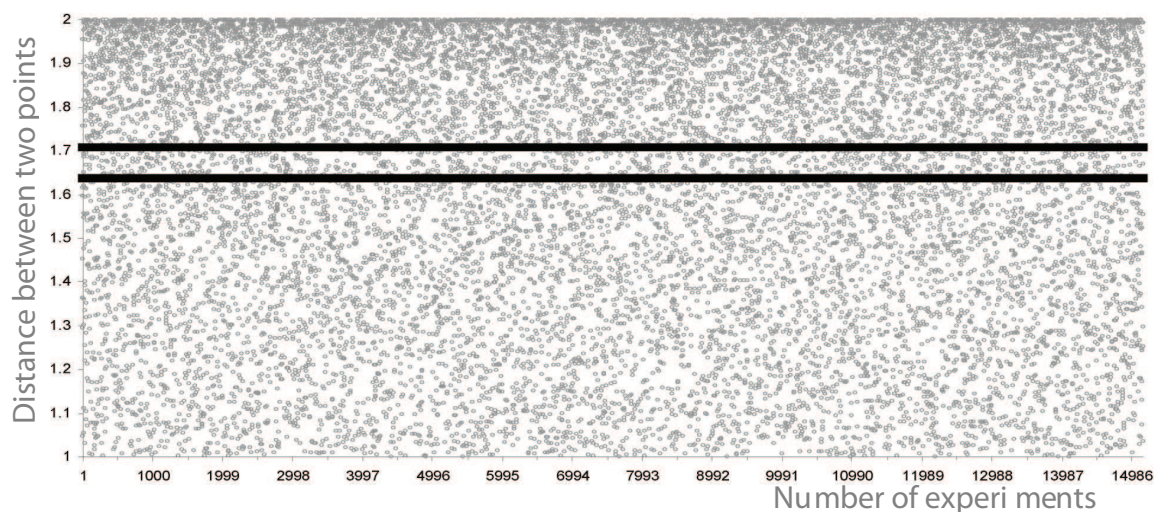

Figure 6. The measuring projecting on a flat card.

Figure 7. The simulation results of measuring projecting on a flat card.

growth at y. Indeed, when poplation is at the beginning of the development and value of $y \sim y0$ close to the initial value, then a coefficient $(1-y/b)$ does not have strong influence on speed of change of poplation volume and law of growth described by the equation $dy/dt \sim a \cdot (1 - y0) \cdot y = a'y$. Thus, the volume of population at the beginning grows exponentially. However, when population approaches the value of $y \sim b$, then coefficient $(1 - y/b) \sim (1 - b/b) = 0$ becomes very small and halts speed of growth of population of $dy/dt \sim 0$.

Thus, in time speed of growth of population falls practically to the zero and its volume aspires to the certain size. By the decision of differential equation of $dy/dt = a \cdot (1 - y/b) \cdot y$ there is a function
$y(t) = (y_0 \cdot b \cdot e^{a \cdot t})/(b - y_0 + y_0 \cdot e^{a \cdot t})$, which describes an initial exponential change the quantity of population and further stabilizing of its volume well. In the case of model of Ferklust population is expected by the synonymous stabilizing. Depending on the size of initial volume, population will be raise, if volume is less the value of b prescribed by model $y_0 < b$, to diminish in the case of $y_0 > b$, and be in the stable state, if $y_0 = b$.

The analysis of these demographic trees showed in Latvia, that the initial stage of their growth did not answer the model of Ferkhlust, however slowed growth of trees is in time and their height does not change in future. On a figure 8 it is possible to see distributing of middle heights of pine-trees depending on their age, beginning of 10 years and concluding 140 summer age, when growth is practically halted.

This information are the statistical measuring of middle heights of pine-trees which sprout in identical regional and bonitate terms. The values of heights of pine-tree are grouped on the groups of ages with a difference 10 years and imposed on the graphs of decision of equalization of Ferklust with the initial condition of $y_0 = 1$ meter and limit on a height $b = 25$ meters. Visual comparison and numeral experiment on searching for an optimum coefficient a showed that divergences between the sheets of facts and approximated function did not have casual character, but are regular. In an initial period many information is substantially below than theoretical curve, and farther more actual values are excelled by the proper values of approximation.

Thus, it is necessary once again to analyze and revise the variable coefficient of increase in equation of growth. In the case of trees, it is possible that the initial period of growth differs of exponential dependence. Therefore by analogy with approach of Ferklust, it is necessary to pick up such coefficient of growth, that the height of tree did not change with age, that at the coefficient of growth biological sense would have mathematical appearance and, that divergences between normally distributed characters would be taken in ideal case information and got dependence.

In research a model is explored $y(x) = ax^k/(b + x^k)$ approximations of dependence of height of tree y of his age of x. Information was grouped in relation to the type of trees, region of sprouting and bonitates. Riga and Ogres district forest taxation data are used execute of
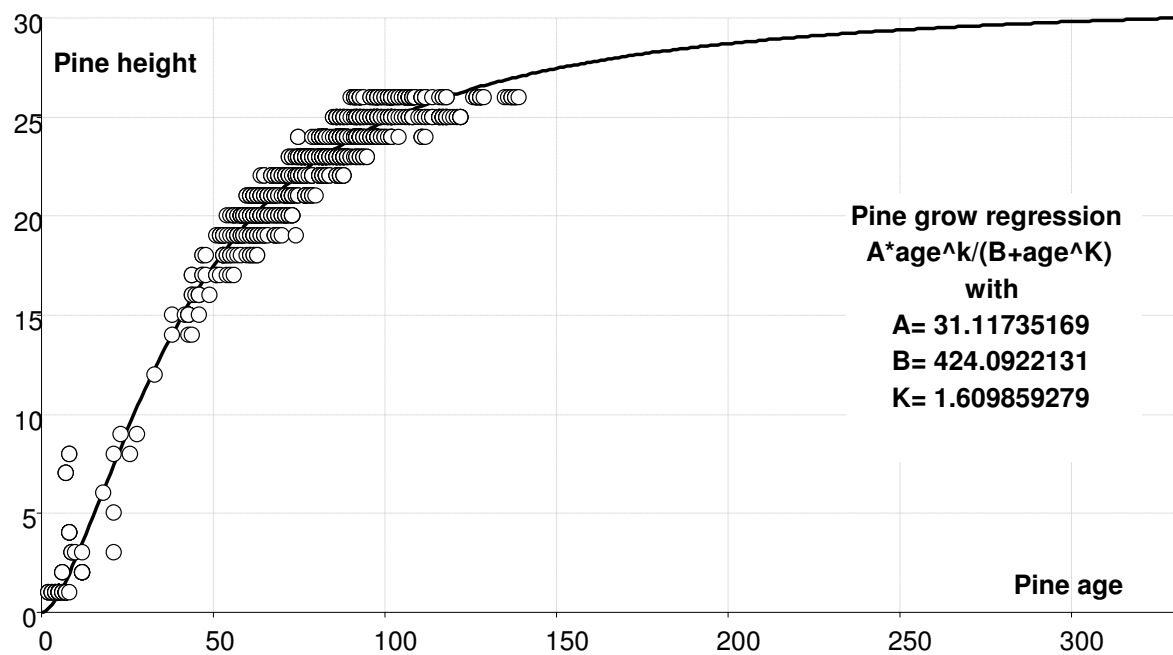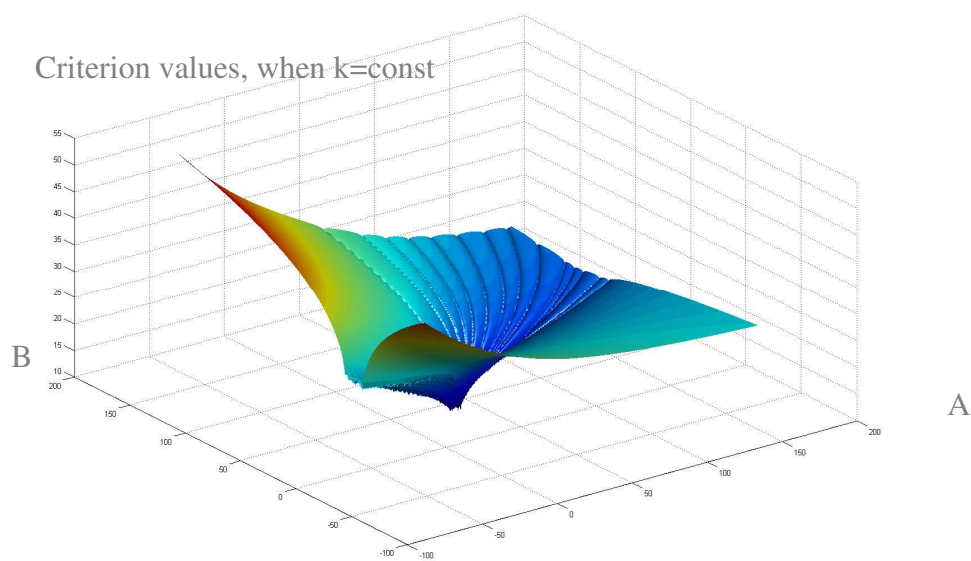
Figure 8. Estimation of pine grow.

Figure 9. Graph of estimation criterion.

experiments, which is fixed the price in a time period from 1999-2005 year. Data is are analyzed from 10840 areas, which general area is 20724 hectares.

Regression $y(x) = ax^k/(b + x^k)$, which is the decision of equation of $dy/dx = ay^2/x^k$ give satisfactory approximation. Three parameters of a,b,k give very good approximation, they have biological sense. A decision is given by a limit on monotonous growth of tree. Optimization of model a least-squares method gives a semi analytical decision, what can not be attained with the model of Ferklust. Thus this model becomes an applicant on the use in the system of estimation of growth of trees. On a figure 9 the real information of observations of heights of pine-trees and regression is combined got formal application of LMS.

The lack of this approach consists of method of finding of decision of model. Regression is nonlinear on the parameters of b,k and LSM in this case applied formal, that needs further ground. On a figure 9 a two-dimension surface is shown built as the graph of criterion $C(b, k) = \Sigma(f_i - a(b, k)x_i^k/(b + x_i^k))2$, where the parameter of $a = a(b, k)$ is expressed through the other two parameters.

It can be done to equal zero the derivation of LSM criterion by a. The analysis of surface of criterion of minimization shows the features of investigation, that the criterion of minimization is nonlinear on the parameters of a,b,k.

Conclusions

The application of LSM allows the students to obtain clear interpretation of the statistical models as well as to help them better understand the transformed models parameters interpretation. Students get clear explanation about the LSM field of usage in the tasks of nonlinear regression, as well the concepts about the statistical properties of transformed models. The preceding analysis demonstrates for students the properties of the stochastic residual term that enters these transformed models.

References

1. Van Der Waerden (1957) Mathematische Statistik, Springer-Verlag, 431 p.
2. Gujarati Damodar N. (1995) Basic Econometrics. McGraw-Hill, Inc. 838 p.
3. Statistical Yearbook of Latvia, 2005 (2006) Riga: Central Statistical Bureau of Latvia. 105 p.

EDUCATIONAL SCIENCES

ACTIVE CLASS - WORK FORMS VERSUS STUDENT PASSIVITY

Ingrida Augustaitiene
Lithuanian University of Agriculture
E-mail: ka@lzuu.lt

Abstract

Recently, the graduates should not only be technically competent, but also they should be skilled in communication and team work, have social and global awareness, be self directed and prepared for life-long learning. Knowing of languages contributes to student personal development. However, passivity of the students in the English classroom is among the factors limiting not only active engagement in academic tasks, acquisition of communicative skills but also soft skills needed for future profession. Therefore, at Lithuanian University of Agriculture, where student-active teaching and learning has been applied the study of the most acceptable class work forms for breaking passivity and improving students' motivation in the classroom for learning English as a foreign language was performed. The most persistent problem for the passive students who are afraid of speaking is the inability to find right words to express themselves (31%), and the fear of making mistakes, criticism, and sounding foolish (almost 55%). The application of the active class-work forms seems to behave well over fighting the passivity and enabling acquisition of the most important skills both for foreign language acquisition and becoming perspective future employees. Team work in created by a teacher relaxed atmosphere in the fitted classroom was found to be one the ways for breaking silence and passivity of the students in the English class room.

Keywords: class work forms, student passivity, contributing factors, abilities.

Introduction

Challenging economic times have greatly increased pressure on society and higher education, in particular. Recently, an opinion has been predominant that teaching and learning must meet professional needs, be critical and innovative, make appropriate use of contemporary technologies, use teaching/learning experience and resources to support good practice. Consequently, the graduates should not only be technically competent, but also they should be skilled in communication and team work, have social and global awareness, be self directed and prepared for life-long learning. In this context, knowing languages means greater participation in social, economic, cultural and political life, to say the least of the effective contribution to personal development (Forrest, 2004).

With the growing involvement of Lithuania in international business and the increasingly multinational character of foreign languages in nearly every kind of occupation is evident. Generally, Lithuanian business firms and service organizations are not likely to hire employees based on their language skills alone. But a substantial number of them, except for the willingness to learn, commitment, reliability, self-motivation, ability to work in a team, oral and written command of the native tongue, and co-operation, have not only come to recognize the specific needs for foreign languages, but also most of them foresee a growth in the need for foreign language skills, both in their own particular businesses and in the global employment market. Besides, people who are able to speak foreign languages have increased earning power and have greater career advancement possibilities. However, in Lithuania we are confronted with the sad fact that the majority of students entering higher education with the experience of eight or more years of the instruction in English at the secondary school use the version of English which is not accurate, meagre and insufficiently fluent to stand up the demands placed on it outside the classroom. Moreover, some of the students seem to be completely negative about their learning they have no clear conception of their future needs with the foreign language and the possible reason for this might be low students' motivation leading to indifference and passivity.

Recent advancements in foreign language teaching indicate a trend towards the development of the communicative competence (Allwright, 1987; Littlewood, 1991; Harmer, 1991). Lots of student-active class work forms including discussion and debate, communication games, team work, pair work, problem solving, role play are designed to provoke spoken communication between students and/or between the teacher

and the students. However, many teachers can be heard complaining that their students have nothing to say: they complain, for example, that they have no opinions, are not interested in or are not prepared to discuss anything. In this setting encouraging communicative classroom participation is one of the greatest challenges for English foreign language (EFL) teachers.

Research aim: to analyse the class work forms helping to break student passivity and improve their motivation to learn English as a foreign language.

Research objectives:

1. to analyse the causative factors of passivity in the classroom;
2. to discuss the class work forms helping in fighting passivity;
3. to reveal the influence of secure and relaxed atmosphere.

Research object: the role of the class work forms in fighting student silence and passivity.

Materials and Methods

The research was conducted at Lithuanian University of Agriculture by way of questioning 55 students in the spring of 2003 and 66 students in the spring of 2005. They represented 4 groups of the first and second year students from 2 faculties: the Faculty of Economics, and the Faculty of Forestry.

Different class work forms including: discussions, presentation making, pair work, and team work were applied to teach EFL. The application of these forms in the English classes enabled to establish the role of the class work forms in fighting student silence and passivity and reveal the main reasons of the passivity.

To collect data necessary for the research students were asked to complete a questionnaire.

The questionnaire was constructed seeking to find out the reasons of passivity in the English classes and the role of the class work forms in fighting it at Lithuanian University of Agriculture.

The questionnaire was anonymous and contained the following questions:

1. What is the atmosphere like in the English class?
2. Are you passive in your English class?
3. What class work forms are most stimulating?
4. What abilities have you developed in your English classes?

Data analysis, correlation and interpretation were analysed with the help of EXCEL software.

Results and Discussion

The reasons of passivity in the class room

The research revealed that 56% of the first year students from the Faculty of Economics and 78% of the first year students from the Forestry Faculty considered themselves passive in the English classroom. It follows from Figure 1 that the most persistent problem for the students is inability to find right words to express themselves (31%) followed closely by the fear to make mistakes (21%). Significantly lower are the effects of fear of criticism (18%) and sounding foolish (17%). The least important reason of why the students remain silent and passive is the lack of common knowledge (13%).

The development of the communicative skills requires learning atmosphere which gives students a sense of security. Figure 2 indicates that active students enjoy being in their English classes and in most cases find the atmosphere there relaxed or quite relaxed (60% of active students). Those who considered themselves passive in the English classroom did not enjoy being in their
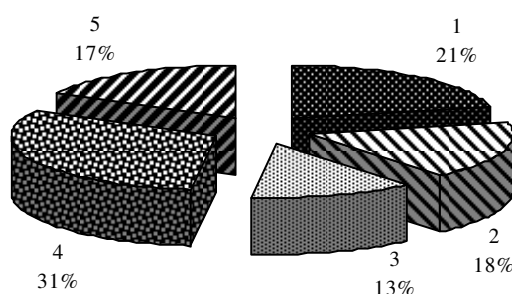

Figure 1. The reasons of passivity in the class room. (1. Fear of making mistakes; 2. Fear of criticism; 3. Lack of common knowledge; 4. Inability to find right words to express thoughts; 5. Fear of sounding foolish).
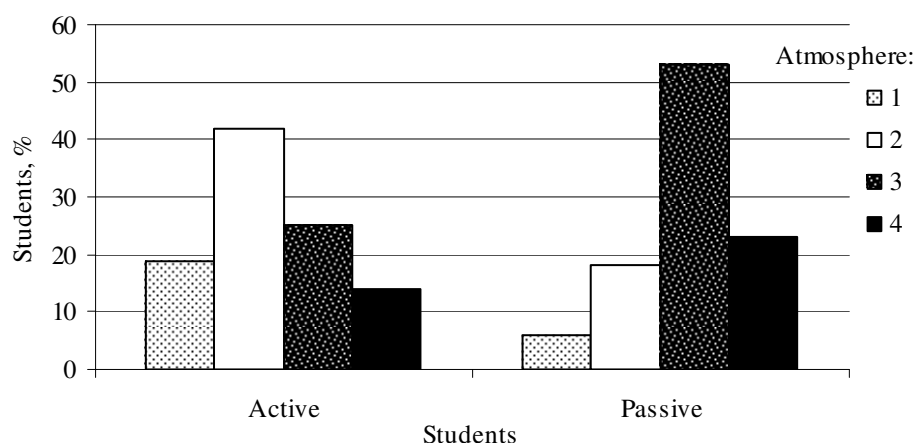
Figure 2. Assessment of the atmosphere in the classroom by active and passive students. (The atmosphere in the classroom: 1. Relaxed; 2. Quite relaxed; 3. Stressful; 4. Quite stressful).

English classes, because in most cases found the atmosphere there stressful or quite stressful (75% of passive students). These results indicated that atmosphere in classroom could be attributed to key factors contributing to student passivity. In stressful or quite stressful atmosphere such students are afraid of different things (making mistakes, criticism and sounding foolish) that explained more than 50% of the reasons of their passivity (Fig. 1). Thus, to ensure active and productive student participation in order to develop their English skills a teacher should create relaxed atmosphere in the classroom applying the most acceptable class work forms.

Too big group, unfit classroom, group mates, and even incompetence of a teacher were mentioned among the factors contributing to student passivity. No class work form will help to break silence and passivity of the students if classrooms are unfit for learning. This factor was indicated by more than 60% of respondents, irrespective of their behaviour in class. Over 20% of the students as a factor contributing to passivity mentioned too big groups, and over 10% - incompetence of the teachers (Fig. 3). The latter factor was pointed out by the passive first year students, and most probably resulted from the confrontation with new class-work forms. Second year students did not question the competence of the teachers.

Influence of class-work forms on activity.

The results obtained on the class-work forms proved the efficacy of the forms in fighting the passivity. Four class-work forms: discussion, team-work, pair work and presentation were under investigation. We attempted at identifying which of them contributed most to the promotion of
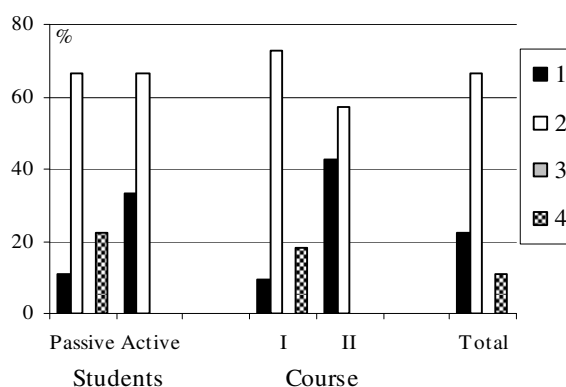

Figure 3. Factors contributing to student passivity. (1 – too big group; 2 – unfit classroom; 3 – group mates, 4 – incompetence of teacher).

student activity. The results of the questioning indicated that there was no considerable difference between Faculties or years. Data presented in Fig. 4 revealed that the worst forms of learning for the passive students were presentation making and discussion most probably due to the fact that these forms of learning require much effort on their part and are contrary to their habit – to be passive in the classroom. The main aim of these students was most likely to hide behind the backs of the active students and expect not to be noticed.

The most preferred for the passive students appeared to be team work that should be taken into account while teaching passive students.

The application of the considered class-work forms not only ensures better acquisition of the English language, but also transforms listless and disinterested students into more active thinkers and participators.

Abilities developed in the English classes

In the analysis of the abilities developed by the students in the English classes the most important were the answers of the second year students as their English course is almost completed, though the answers of the first year students were taken into account. The findings of the study indicated that the ability to communicate was rated as the most important by approximately 48% of the passive students, whereas approximately 44% of the active students indicated that they learned to express their ideas (Fig. 5). They also developed the ability to work in a team and ability to communicate 23% and 21%, respectively. In contrast to the passive students they also admitted that they learned to think critically – 12% of the respondents. Responsibility for monitoring the quality of teaching and learning lies with University faculties and departments that are responsible for the teaching and learning quality. Quality assurance in teaching resides with teachers whose qualification and its development is an important factor that determines their ability to organise classes, provide appropriate instruction and motivate students to succeed. Quality assurance in learning resides with the students who together with the teachers are considered to be equal partners in the educative process, and thus are expected to be largely responsible for their own learning and learning outcomes. Material resource basis at Universities is the last but not the least factor to be taken into account as proper classrooms and their equipment, computer and computer programme use possibilities, abundance of books and diversity of library resources and possibilities to use them surely guarantees better quality in studies.

Many a teacher face a problem of students who are not attending the classes, who don't complete assignments on time and if present they say they are not interested, they have no opinions or they have nothing to say in other words they are simply passive (Corria, 1999; Balato, 1996). There are many factors that might affect students' commitment to study. Many things – perhaps most – are beyond our control as language teachers home background, physical tiredness, events in their personal life, health, personality, etc. are just some factors that can have temporary influence on the activity of the students and make them silent. Differential success in foreign language learning has been attributed to individual differences such as intelligence, aptitude, personality, motivation, and anxiety (Rossiter, 2001). However, in general, silence is related to fear of saying the wrong thing, of showing emotions, fear of the judgement not only
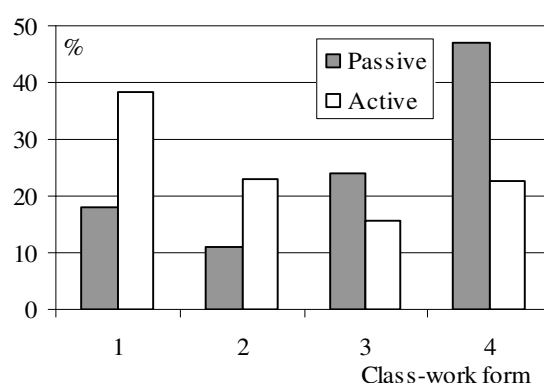

Figure 4. Class-work forms contributing to activity of the students. (Class-work forms: 1 – discussions, 2 – presentation making, 3 – pair work, 4 – team work).
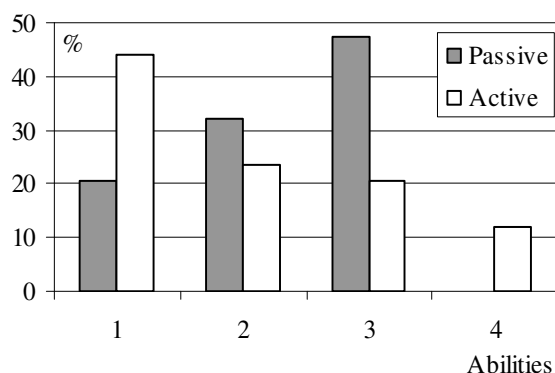
Figure 5. Abilities developed in the English classes. (1 – to express one's ideas; 2 – to work in the team; 3 – to communicate; 4 – to think critically).

of the teacher, but also of the fellow students, it may also be a way to avoid taking risks or getting involved (Thorne, 1989).

In our research we attempted to identify the main reasons for this kind of behaviour. The obtained data indicated that more than a half of the first year students from both faculties were passive. This percentage slightly decreased in the second year (by approximately 10%). As the key reasons for this kind of behaviour were indicated: fear of making mistakes, criticism and sounding foolish and inability to find right words to express themselves or poor vocabulary. This state of affairs made us think that the problem might stem from the school where typical form of interaction is: the teacher always initiates, the learner only responds, what greatly limits the communicative functions that learners need to use and interactional abilities they need to practice (Littlewood, 1991)

Lots of communicative activities and class-work forms are designed to provoke spoken communication and stimulate students' involvement as well as deal with the problem of student participation. (Holec, 1979; Little, 1991; Ohta, 2001; Saville-Troike, 1988)

The results obtained from our survey indicated that for the active students the most acceptable class-work form was discussion followed by presentation and team work. They also indicated that through these class-work forms they learned to express themselves, to work in a team and improved their communication abilities. Meanwhile the passive students indicated that discussion and presentation were the worst forms of the class-work most probably due to the fact that most of them are afraid of making mistakes, criticism or sounding foolish. However, these

class-work forms made them change and the majority of them indicated that they improved their ability to communicate.

It seems generally to be assumed that effective learning of a foreign language requires a supportive atmosphere. In order to learn the students need the environment in which they do not feel intimidated or frustrated and they need to feel they will be heard. J.Shrum and E.Glisan (1995) note that 'competition in language learning may result in feelings of anxiety, inadequacy, hostility, fear of failure, guilt and too strong a desire for approval'. The above mentioned class-work forms seem to be conductive to building self-esteem and increasing motivation when the atmosphere in the classroom is relaxed.

Such issues as infrastructure and limited school budgets have not received much attention in EFL books and articles yet seem to contribute to the outcome of the educational process as more than a half of students indicated that unfit classrooms contribute to their behaviour in the classroom.

The detected complex of factors contributing to student passivity, and suggested means of breaking silence and passivity, should help to achieve a degree of communicative competence in a number of languages (plurilingualism) on a lifelong basis, in the interests of better personal mobility, information in a multilingual and multicultural Europe what has been proportioned by The Council of Europe in modern language learning and teaching (Trim, 2001).

Conclusions

The most persistent problem for the students who are afraid of speaking is the inability to find right words to express themselves (31%), and the

fear of making mistakes, criticism, and sounding foolish (almost 55%).

To ensure active and productive student participation in order to develop their communicative competence a teacher should create relaxed atmosphere in the classroom.

Among the class-work forms applied in the English classes team-work help in acquiring better abilities in communication. The application of the active class-work forms seemed to behave well over fighting the passivity and enabling acquisition of the most important abilities both for foreign language acquisition and as of the perspective future employees.

References

1. Allwright R. (1987) Language learning through communication practice. In: C.J. Brumfit and R.Johnson (eds.) The communicative approach to language teaching, Oxford Yniversity press, pp. 167-182.
2. Baloto F. (1996) How to Motivate Learners of English. Forum, 34/1, pp. 31-32.
3. Corria I.L. (1999) Motivating EFL Learners. Forum, 37/2, pp. 17-18.
4. Forrest A. (2004) The challenge of languages in Europe, Hendrik Brugmans memorial lecture, available at: http://www.madariaga.coleurop.be/docs/speech99.pdf, 01.10.2004
5. Harmer J. (1991) The practice of the English language teaching: Longman group UK limited, 151 p.
6. Holec H. (1979) Autonomy and foreign language learning. Strasbourg: Council of Europe.
7. Little D. (1991) Lerner autonomy 1: definitors, issues and problems. Dublin, Authentic. http://www.lang. ltsn.ac.uk/resources/goodpractice.aspx?resourceid=1409, 30.04.2006
8. Littlewwod W. (1991) Communicative language teaching. An introduction. Cambridge University press, 124 pp.
9. Ohta A.S. (2001) Second language acquisition in the classroom. Mahwan, NJ: Lawrence Erlbaum Associates. Available at: http://tesl-ej.org/ej19/r13.html, 30.04.2007.
10. Rossiter M.J. (2001) The Effects of Affective Strategy Training in the ESL Classroom. University of Alberta. Available at: http://www-writing.berkeley.edu/TESL-EJ/ej26/a2.html, 30.04.2007.
11. Sawile-Troike M. (1988) Private speech: Evidence for second language learning strategies during the silence period. Chaild Language, 15, pp. 567-590.
12. Shrum J.L. Glisan E.W. (1995) Teacher's Handbook: Contextualized Language Instruction, 1st ed.), Boston, Heinle and Heinle Publishers, 360 pp.
13. Thorne B. (1989) Rethinking the ways we teach. In: Educating the majority: Women challenge tradition in higher education. Mac Willan, pp. 311-325.
14. Trim J. (2001) The Work of the Council of Europe in the field of Modern Languages, 1957 – 2001. European Day of Languages - 26 September 2001 at the premises of the European Centre for Modern Languages. Available at: http://www.ecml.at/efsz/files/Trim.pdf, 30.04.2007.

THE MODEL OF STUDENTS' PATRIOTIC ATTITUDE DEVELOPMENT DURING THE STUDY COURSE 'RURAL TOURISM'

Ināra Dunska, Nora Lūse
Latvia University of Agriculture
E-mail: inara_dunska@hotmail.com; luseno@llu.lv

Abstract

The migration of many rural youngsters to bigger cities and other countries in order to find a place for better life and job is not only economic but also educational and up-bringing problem nowadays. The development of the Latvian countryside is closely connected with the investment of educated young people in the long-term creative development of the native country. Latvia University of Agriculture students consider that one of the reasons of leaving their native land rather easily is because they were not purposefully brought up in the field of the patriotism and the feelings of belonging to their native country. Higher educational establishments apply different study models dependent mainly on the aims of educational institutions. The aim of this work is to develop a study model of 'Rural tourisms' taking into account that the study course 'Rural Tourism' has its up-bringing potential which can help to increase the development of students' patriotic attitude during the acquisition of Latvian cultural and historic inheritance. The priority of the study course 'Rural Tourism' in Latvian higher educational establishments is supposed to contribute to the development of students' entrepreneurial skills but this direction does not increase the development of students' patriotism. The above mentioned developed study model is based mainly on the dynamics of the relationship between the study program and the development of students' patriotism.

Keywords: study model, patriotism, regional studies.

Introduction

One of students' training forms is the study model including mutual students' and lecturer's level of freedom in the area of study relations which complies with the chosen learning task. The process of learning and up-bringing is not fully voluntary for students, because 'a stone does not ask a sculptor to put it into a shape'. Each new study model gives birth for a corresponding problem-solving situation in this process. Kant declared that the aim of up-bringing is not to adapt humans to a definite situation, but it should be an universal one, and should move to the humans' development all over the world; thus, the aim of up-bringing in many countries will be the same (Kant, 2002). One should understand that the issue is about values common to all mankind but they differ depending on the interest of each ethnical community and one's own particular way in education. The questions of up-bringing patriotic attitude are urgent in modern pedagogy. The education of–today has a rather practical feature and modern higher educational establishments tend to limit students' personal cultural development in definite borders. In future after finishing their educational establishments students will produce, create in their own field, but they will be only consumers for others (Kons, 1982). Patriotism and society are closely interdependent, as a social phenomenon. It mainly depends on the peculiarities of the historical development of a state and society. In the period of Soviet occupation in the conditions of reglamentational functioning Soviet social system patriotism was one of ideological fundamentals used as the main direction in the area of upbringing youth. Later, at the end of 60s and beginning of 80s patriotism was investigated as an intellectual phenomenon of society in different fields of science, especially, in philosophy. From the middle of 80s the trend to realise patriotism as one of the phenomenon of the social intellectual life became dominant (Bader, 2006). As the subject of the students' patriotic attitude one can consider the state, the native land that could be understood as having a predisposition to share national goals, interests that is the priority compared to any other personal interests. A state and one's native land are the highest values and the object of major high personal patriotic feelings and purposes. Patriotism and the patriotic attitude can strengthen a state and facilitate its development (Hēgelis, 1981).

The study model in higher educational establishment is intended to help students obtain

knowledge which will be useful in their future life and education, and support students' own opinion about their development of knowledge and skills. Our aim is to work out a study model of the study course 'Rural Tourism' so it is necessary to observe already existed didactic models used in high schools and implement such a study model which will allow students to develop further their patriotic attitude, obtain Latvian cultural and historical values during study in high school.

Many different didactic models are used in higher educational establishments. The aim of the Pragmatic – Practical Model is to reach a practical result and develop a student's personality based on his/her individual characteristic features. Students' practical skills are developed; they obtain knowledge about social culture and cultural values. A student can realise his/her working approach and develop his/her own characteristic features in the frame of this model. Students develop their group work skills; collaborate in models of groups, teams (Žogla, 2001). Contrary to this model, the idealistic theoretical model represents the theory which can't be used in the real life. The aim of the Individual Model is to incorporate the development of students' entrepreneurial skills that intend to work in future with presidents of the firms or top managers. The main focus is on the individual needs in this model comparing to the common social needs in the previous one.

One can notice that a student is often perceived as a potential university client who pays for the chosen program. Thus, market relations are implemented at universities and one thinks less about intellectual values as well as patriotic upbringing (Westheimer, 2006). From the very beginning, different popular models were developed in each state differently, but these models were available in other states. Behaviouristic, cognitive, lingvodidactic, activities-based, motivational models interdependently enrich and supplement each other. The task of learning environment at universities is to develop an individuality, to hasten students' accumulating and constructing knowledge and skills under the guidance of a high school lecturer. The educational process helps students to obtain socializing skills as well as other skills and methods which are necessary in their future professional work. Cultural values are acquired during the process of learning because these values are included in the contents of the study course (Žogla, 2001).

While working out the study model 'Rural Tourism' the following hypothesis is taken into account:

The development of students' patriotic attitude occurs more successfully if:

- students are connected with the research of cultural, historical and natural heritage of their native land, and emotional experience significantly personal for each student takes place during it;
- the contents of the study course 'Rural Tourism' is oriented to the development of students' patriotic attitude to the native land and its cultivation.

Our task is to develop students' patriotic attitude to the native country in higher educational establishments during the time of acquisition of the study course 'Rural Tourism'. The aim of this work is to develop a study model of 'Rural tourisms' taking into account that the study course 'Rural Tourism' has its up-bringing potential which can help to increase the development of students' patriotic attitude during the acquisition of Latvian cultural and historic inheritance. In the frames of the study course 'Rural Tourism' we have the real possibility to develop students' patriotic attitude and the sense of belonging to the native land and understanding that she/he is a component of the whole, by implementing cultural and natural treasures of the native land. Our country has its own ethnic and cultural peculiarities which will be handed down to the next generation and these endeavours also can be developed during the process of education. The possibility of practical implementation of acquired knowledge, skills, and its accordance to the needs of the modern world, students' ability to widen their knowledge independently, were also taken into account. The ideas of constructivism are put as a base of developing the study model of the course. Students were given the possibility to work out their own approach to obtaining knowledge, which will become personally significant in their future working time. Students' obtained knowledge, skills, and their conformity to modern reality are considered to be important. Acquiring knowledge and skills occur in collaboration, thus social experiences are obtained. Students' and high school lecturers' mutual team work could facilitate the development of a future specialist's professional skills as well as each student's individuality. The Hermeneutic approach to understanding traditions, history and cultural values of a native land were taken into account

during the study course acquisition. Such an approach could allow discovering a goal but not constructing it. It is also important to appreciate the student's way to self-investigation, understanding his own place in this world, explaining himself who he is in connection with himself as a personality (Ksenofonts, 2005).

Materials and Methods

Patriotism is a multidimensional phenomenon including complicated characteristic features which reflect different levels of functioning varied social systems in many ways. The level of LUA students' patriotic attitude may be considered as one of the structural components of his/her personality, and may be added to the strongest feelings and stable personal peculiarities (value, confidence, norms of behaviour, and valuable criteria of social phenomenon). The essence of the patriotic attitude as a student's complicated individual integral model includes love un faithfulness to the native country; the identification of one's own interests with the interests of the native land, the connection of his/her fortune with the life of the native state; students' patriotic feelings which are the components of human spiritual structure; the active civil position, readiness to protect the interests of the native land and work for its prosperity; pride for the national culture and achievements of their countrymen, the respectful attitude to the Past, national traditions, and critical evaluation of them simultaneously (Koltzova and Sosnin, 2005). Consequently, LUA students' patriotic attitude are honest, correct and respectful to the native land. The aim of patriotic upbringing is to create a sense of responsibility for the native country; a need to take care about cultural and historical values of the native land; a necessity to collaborate in the cultural and historical life of the native country; a willingness to work actively, self-actualisation in practical life for welfare of the native state.

We need to facilitate patriotic upbringing because students' patriotic attitude is real only when it becomes an persistent emotion, and if a student is conscious of the necessity of the patriotic activities and its practical implementation. Comprehending the life of the native state through his/her emotional experience a student acquires spiritual values of the native state.

The model of the study course 'Rural Tourism' is based on the following methodical principles:

- the conformity to nature;
- the conformity to culture (Dunska, 2006);
- and the main - investigation of the native land.

The tasks of forming LUA student's patriotic attitude follows the above mentioned: overcoming selfishness and being aware of civil duties; raising human pride of the native land and respect to it; preserving and resuming national traditions; openness to new ideas and strengthening efficient love to the native land. Modern LUA students should have the ability to adapt themselves to changeable environments, implement opportunities for mobility as well as using the advantages of national values. A student's patriotic upbringing is the development of the attitude and it cannot be seen separately from themselves, a family, and a state. An important role is given to a family where young people would develop their love to the native land and patriotism. LUA students from the countryside and provincial towns are more brought in Latvian cultural traditions. The development of comprehension of the motherland starts from the very childhood, from a child's emotional experience during working activities.

LUA students express such a standpoint in discussions that patriotism is mainly the matter of a family. Tactics of citizenship upbringing is developed in the family, and working habits are adopted also in the family. The basic principles of the generation genetic links, patriotic mentality with original ethnic peculiarities, customs and traditions of rural yards are considered in continuum. A young man acquires the fundamentals of love of his microsocium- The Small Motherland- only in his family. The definite professional direction of LUA students also occurs here. Thus, higher educational establishment should do its best in order to develop LUA students' patriotic attitude to the native land. Knowledge should not be contrary to students' attitudes, emotional experience, and disturb the acquisition of the study course contents. Student's emotions, understanding, and listening can be improved during the study process.

It is possible using the local lore method. Principles of regional studies which is taught during 'Rural tourism' course. Local lore method (research work carried on the native land) could be treated as a specific LUA students' activity form which is realized in scientific circles which are expanded through upbringing students' ecological culture, the development of all spheres

of human personality and students' inclination to acquire the surrounding world, as well as the attitudes to the world, society, and the ability for self-investigation. Local lore method of 'Rural Tourism' course consists of the following: target identification; finding out environmental epistomological spiral; cycle; social role mastering; student ethics development (Буковска, 2002). The definition of the aim determines such a development of scientific work connected with rural tourism activities which allows realizing students' upbringing, education, to develop the emotional, moral and intellectual sphere. The realisation of the block 'The epistomological spiral of cognition of the environment' defines the gradual acquaintance of the world: from the close to the more distant, at the very beginning students acquire, then investigate. The acquisitions of different social roles acquaint students with professions of rural tourism and scientific investigation of routes of rural tourism during the time of presentation, when there is a possibility to feel themselves in a new role. This recurrence defines the theoretical preparation of the tour of rural tourism, the defence and practical realization. Students' ethic preparation includes norms connected with the relationship with nature, society and Self. These norms are the moral fundamentals of the scientific ecological activities connected with the native land and rural tourism. Such an organization of scientific work connected with tourism and the native land ensures students' complex approach to patriotic upbringing. This method is interpreted as the impact on students' consciousness, feelings and behaviour in the whole. The revelation of history and facts of culture challenges students' positive feelings, joy of discovery, forms love and pride for 'The Little Motherland'. Students implement many cultural values during the time of activities of their life, very often it occurs unconscientiously. The image of the small native district, town stays from the very childhood in a student's memory. This image is a micro model of the surrounding world on which a young man depends on acquiring the surrounding world. The historical and regional studies proved its pedagogical efficiency many years ago. The process of youth upbringing is more efficient if the local images and regional components are implemented (Ноженкина, 2005).

The aspect of historical and regional studies in LUA gives the possibility to change an aspect of Latvia rural region, and understand its uniqueness and the place in the world cultural space. The native land can't preserve its originality if people change their living places without any feelings of responsibility. LUA students are able to keep in touch with local traditions and originality; thus, higher school can up bring the students' feeling of responsibility and patriotic attitude.

Results and Discussion

Experts who collaborate with young people in the area of rural tourism believe that patriotic upbringing is finished in primary school, and there is not a continuation in secondary and higher educational establishments (Rungule, 2005). Rural schools have organizations for boys-scouts, small hobby-groups, for girls'- guides. Young people in the countryside are much more conscious of their native land, because they comprehend that native land is the family' capital. But still many young people leave the countryside because there are no possibilities of studying and finding a job. Sometimes young people are involved in the cultural life of the native land during the time of learning in higher school, but it does not last long only till they establish their own families.

Forming the model of the study course 'Rural Tourism' to develop the patriotic attitude the following didactic postulates were implemented:

- the process of LUA students' cognition is activated during the research activities;
- self-evaluation of the patriotic attitude makes LUA students be based on worked out criteria.

We have taken into account the fundamentals of the study process are LUA student's deliberated activities, a student's and a higher school lecturer's collaboration. The study subject 'Rural Tourism' is the subject of learning for students, but it is the teaching aid for higher school lecturers. The theoretical material of the contents of the study model should be in accordance with the didactic stages of the process of acquisition: information of facts, events and occurrences. We have taken into account the working elements such as tasks oriented to LUA students' practical work should also be included. The model contains the emotional element which is included in the contents of the study course 'Rural tourism' (photos, video and ethnograpical materials, posters). We created the final test for determining the patriotic at the end of the course 'Rural Tourism'. This test includes questions for self-evaluation based on critical thinking closely connected with self-control.

The structure of the model of the study course 'Rural Tourism' is based on the idea that the theory, activities, emotions, mind, will and feelings are marked as well. All these components are developed as reasons followed because the results will appear in the students' patriotic attitude. We based on two concepts in this model:

- self-upbringing, and
- self-education.

Self-upbringing is included in the contents of the study course 'Rural Tourism'. It is LUA student's responsibility and duty to develop, to save, make progress and take care about the native land. According to the Latvian educated .Students, true upbringing is self-upbringing (Students, 1998). Self-education is student's education during the course of rural tourism, dipping into the culture and history of the native land, it is self-education using intellectual activities. LUA student should be oriented to self-activities, because he/she should enrich knowledge and skills obtained at university. Student's attitudes to the world could be divided into two parts. The first one is connected with research activities when the development of causation constantly takes place. But the second one is connected with the answer 'what', and 'how', not 'why' (Schopenhauer, 1994).

Authors created the model that represents the unity of upbringing and learning in order to develop a students' new quality - the patriotic attitude and the highest stage of that - civil maturity. In the centre of the model there is a student, during the study process his/her intellect, feelings and will are developed. During the research activities the patriotic attitude and further civil maturity start to develop. The principles of history, culture, accordance to activities, work connected with the native land are implemented during the study course. The study model was worked out taking into account modern changes in the state and society. The model develops a students' patriotic attitude as well as strengthens the development of students' professional skills. The fundamentals of the study models are the following: the acquisition of historical and cultural values of the native land; the development of the patriotic attitude. This model motivates students' research activities connect with the real life, develops the exact emotional attitude to the cultural environment, raises patriotism and civil maturity. According to the criteria of patriotic attitudes: the attitude to oneself, the state and society, work, the nation of the native land, culture and nature, the didactic model provides: acquisition of knowledge and skills of the native land and the attitude to the changes of the native land (Špona, 2000). In the study contents of the course 'Rural Tourism' methods and themes developing the patriotic attitude, in which the cultural environment of the Latvian state is implemented, are included. Professional education and patriotic upbringing in higher educational establishments is the joint purposeful process of the development of young personality. One cannot separate patriotic upbringing and professional training and isolate from the conditions and possibilities of the personal development.
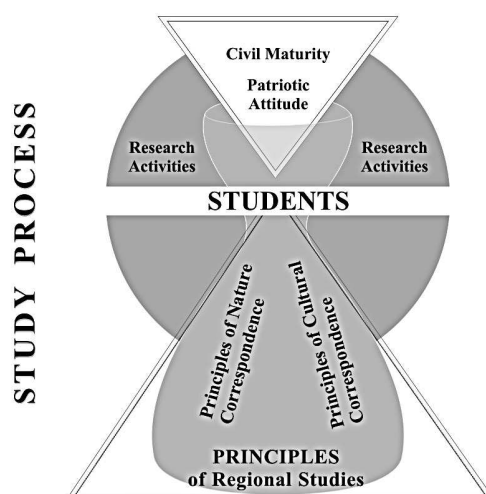

Figure 1. The study model of the development of the patriotic attitude.

The native land gives us a lot: it conducts our cultural life, the closest link with the motherland is language, it gives us the treasures of history and nature. A student's duty is to respect and love all these things. One should upbring Latvian patriotism, patriotism to the native land, respect to traditions and cultural values of the Past. Then a student will have the feeling of responsibility for the native land and civil maturity will be developed. Study of local history, culture is a students' tool of patriotic upbringing. This knowledge develops great ethic values which teach to respect the natural treasures and inheritance of former generations a lot, and encourages the development of a student civil maturity. The aim of the national plan of the development inspires optimism because there is a point about the efficient implementation of human resourses and the development of lasting and attractive living environment for human job, rest and life (Stratēģiskās analīzes komisija, 2005).

The attitude of an individual is formed in collaboration with the social environment, but higher school is only a small part of this environment. The efficiency of the educational process at universities depends greatly on the prevailing attitude in the society. Students should develop emotional intelligence during the educational process, but the staff of higher educational establishment could offer 'the patriotic components' in the contents of the study course. Acquiring the study course 'Rural Tourism' students investigate the history of their native land, nature and historical monuments, and all of these matters become closer, more understandable and loved by them. Rural tourism and study of local history, culture is very important for students' education and socialization, as well as implementing students' sensible forms of their spare time. The study course 'Rural Tourism' has a great pedagogical value, because it inspires the patriotic students' attitude and their refinement that is why this study model is created.

Conclusions

It is important what exactly students feelings and what is their exact attitude towards their native land. Students usually do not think so much about the benefit of the native region; they mainly concentrate on their own family and their studies. Students' stable civil consciousness can not be developed without the continuation of rural

traditions, observing facts and events. A students' patriotic attitude means that he/she facilitates the existence of the native region not only in words but also with his/her work. Young people determine the fortune of their native region, state, that is why it is important to continue the patriotic upbringing work at university level. One needs the support from the state that is why many states accept patriotic upbringing programs for young people on the state level. All attention in the practice of higher educational establishments is paid to wide directions of study work, neglecting upbringing feelings and will, expressing emotional spheres. The premises of universities should be open to moral civil ideas and the ideas of citizenship nowadays. During the educational study one can upbring students and change their attitude to the native region, because of the critical situation in Latvia nowadays. The absence of the patriotic upbringing proves that there is crisis in the state and society. One should not forget that patriotism develops the following important functions: it is the internal reserve and moral force of the social development, which starts to develop cultural potential and national forces joining them into the cultural and social unit.

Thus, patriotism helps to unite the state and develops sense of preserving people as a cultural, economic, territorial, political unity. One can make the following statements:

- patriotism adjusts behaviour and secures mobilization of the social forces in critical situations;
- it develops sense of preserving cultural traditions and their development;
- patriotism has a trend to increase forces, possibilities, potential of the development of the social community, and it is the progressive source of it;
- patriotism ensures the spiritual links of an individual with culture, history, and in such a way ensures the development of historical social diversity etc.

Patriotism is an important factor of determining human behaviour, civil positions, the development of social responsibilities and activities. Thus, one can surely conclude that patriotic upbringing is an objective necessity, because it ensures social existence, the development of society and its productive functioning, and strengthens its creative and spiritual potential.

References

1. Bader M. (2006) The psychology of patriotism. Phi Delta Kappan. NewYork. 572 p.
2. Dunska I. (2006) The Possibilities of Upbringing Students' Patriotic Attitudes During the Acquisition of the Course of Studies Rural Tourism. Research for Rural Development 2006, pp. 296-303.
3. Hēgelis G.V.F. (1981) Filozofijas zinātņu enciklopēdija (Encyclopedia of Philosophical Science). Rīga, Zvaigzne, 116 p. (in Latvian).
4. Kant I. (2002) From Kant to Levi-Strauss. The Background to Contemporary Critical Theory, Edinburg Un-ty Press, Edinburg, 256 p.
5. Koltzova V., Sosnin V. (2005) Social-psychological Problems of Patriotism and Features of its Education. Психологический журнал, 4, pp. 89-97.
6. Kons I. (1982) 'Es' atklāšana (Self-openness). Rīga, Avots, 334 p. (in Latvian).
7. Ksenofonts (2005) Atmiņas par Sokratu (Memories about Sokrates). Rīga, Zinātne, 251 p. (in Latvian).
8. Students J. (1998) Visparīgā paidagoģija (General Education). Rīga, RaKa, 329 p. (in Latvian).
9. Rungule R. (2005) Jauniešu identitātes veidošanās un līdzdalība (Youth identity formation and collaboration). Rīga, Latvijas Universitātes Filozofijas un socioloģijas institūts, 115 p. (in Latvian).
10. Schopenhauer A. (1994) Philosophical writings. New York, Continuum, 300 p.
11. Stratēģiskās analīzes komisija (2007) Stratēģiskās analīzes komisijas ziņojumi (Strategic Komission's Reports). Rīga, Zinātne, 214 p. (in Latvian).
12. Špona A. (2000) Audzināšanas process teorijā un praksē (The Theory and Practice of Upbringing). Rīga, RaKa, 211 p. (in Latvian).
13. Westheimer J. (2006) Patriotism and Education. New York, Basic Books, 147 p.
14. Žogla I. (2001) Didaktiskie modeļi augstskolā (The Didactic Models at the Higher Education Establishments). Skolotājs, 6, pp. 19-26. (in Latvian).
15. Буковская Г.В. (2002) Воспитание экологической культуры в системе туристко-краеведческой деятельности (Upbringing Ecological Culture in the System of Tour-regional Activities). Педагогика, 5, стр. 48-51. (in Russian).
16. Ноженкина О. (2005) Культурная символика в контексте лингвокраеведческой работы (Cultural Symbolics in the Context of Lingvoregional Activities). Педагогика, 5, стр. 118-199. (in Russian).