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EDITORIAL

With this issue of 2008, we bring 49 proceedings of the 85, which started life as presentations at the Annual 14th International Scientific Conference "Research for Rural Development 2008" held at the Latvia University of Agriculture, in Jelgava, on 21st to 23rd May 2008.

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 357 researchers with very different backgrounds. There were 2 presentations from Czech Republic, 1 from Denmark, 1 from Poland, 1 from Sweden, 2 from Estonia, 13 from Lithuania and 65 from Latvia.

Four independent reviewers estimated each report.

The proceedings of the Annual 14th International Scientific Conference "Research for Rural Development 2008" 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.

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

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DEVELOPMENT OF ECONOMIC BASIS OF MEAT PRODUCTION IN LATVIAN AGRICULTURE

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Abstract

In this study the development of meat sector in terms of livestock population, production, farm size and reproductive material, which forms economic basis for effective meat production was analysed. The aim of the study was to investigate main tendencies of meat production sector and development of economic basis in Latvian agriculture. To achieve the set aim following objectives were defined: 1) to analyse concentration and specialization processes of pig breeding farms; 2) to describe restructuring processes of reproductive pig breeding; 3) to investigate restructuring processes of farms producing beef; 4) to characterize concentration and integration processes in poultry production. The study was based on annual statistical data, statistical bulletins covering results of the Farm Structure Survey from 2001 to 2006, scientific publications, special literature and reports of international organizations. To carry out the research adequate research methods were used. The results of this study showed that meat industry has structurally changed in recent years, where the structural change can be defined as the change in the number and size of farms in pig, cattle and poultry sectors. The results also suggested that meat production sector in Latvia has become more intensive, concentrating meat production in large and specialized farms, where this tendency can stimulate the increase of meat production. Therefore, knowledge of the current tendencies and strategies of pig, cattle and poultry sectors is a necessary precondition for the development of the meat sector.

Keywords: meat, production, livestock, population, structural, change.

Introduction

Although economically not a major player, the livestock sector, including meat production, is socially and politically very significant. The three main meat types taken together – pork, beef and poultry – account for 15% of the total value of agricultural products (Ministry of Agriculture Republic of Latvia, 2007).

According to H. Steinfeld et al. (2006a) Latvia, as previously centrally planned country and as a new European Union member state that have gone through rapid adjustments in order to prepare for accession, has experienced changes in the livestock sector. Therefore, the issue on meat sector development opportunities in Latvia has become a topical problem, where economic basis is one of the main prerequisites. In the meat production economic basis forms or consists from several components, from which the most important could be:

- Intellectual basis of entrepreneur (farmer);
- Selection of specialization direction (meat type);
- Concentration and organisation of production;
- Production capacity – number of livestock;
- Feed basis;
- Housing and feeding technologies.

Latest publications on research results let us conclude that the interest of Latvian researchers has been mainly focussed on problems of meat production organisation and economics (Ošmane et al., 2006; Auziņa, 2004; Zvirbule-Bērziņa, 2003). But information on aspects of meat production administration, management, concentration and specialization has been fragmentary published (Melece and Romanova, 2007; Jemeļjanovs and Nudiens, 2007). While developed countries, such as the United States, and international organizations, such as Food and Agriculture Organization of the United Nations, have performed broad and deep researches on meat sector development and associated problems (Steinfeld et al., 2006b; The United States Department of Agriculture, 2003).

Therefore, the aim of the study was to investigate main tendencies of meat production sector and development of economic basis in Latvian agriculture. To achieve the set aim following objectives were defined:

- To analyse concentration and specialization processes of pig breeding farms;
- To describe restructuring processes of repro-

ductive pig breeding;
- To investigate restructurization processes of farms producing beef;
- To characterize concentration and integration processes in poultry production.

The research object was Latvian meat production sector.

Materials and Methods

To meet study objectives, the following materials were used: annual statistical data, statistical bulletins covering results of the Farm Structure Survey from 2001 to 2006, scientific publications, specialized literature and reports of international organizations. Both qualitative and quantitative research methods were used in this study: analysis and synthesis, data grouping, logical and abstract constructive methods.

Results and discussion

1. Concentration and specialization processes of pig breeding farms

Pig production has taken and still takes an important role in the Latvian agriculture, which forms a significant part of the agricultural market in Latvia, such as pork, is the most popular source of meat protein in Latvia (Ministry of Agriculture Republic of Latvia, 2007). According to O. Biro and co-authors (2006), the pig breeding sector is especially sensitive to the changes in foreign markets. As a consequence of increasing input from other EU member states as well as the low level of competitiveness of Latvian meat sector the pig production in the last few years has slightly decreased. Figure 1 shows that the pork production in 2006 compared to the previous year has decreased by 2%, while imports have increased by 13%. These tendencies highlight the weak competitiveness of Latvian pig breeding sector and according to I. Gulbe (2007), the present concentration level in the sector is insufficient for providing competitive production in terms of price.

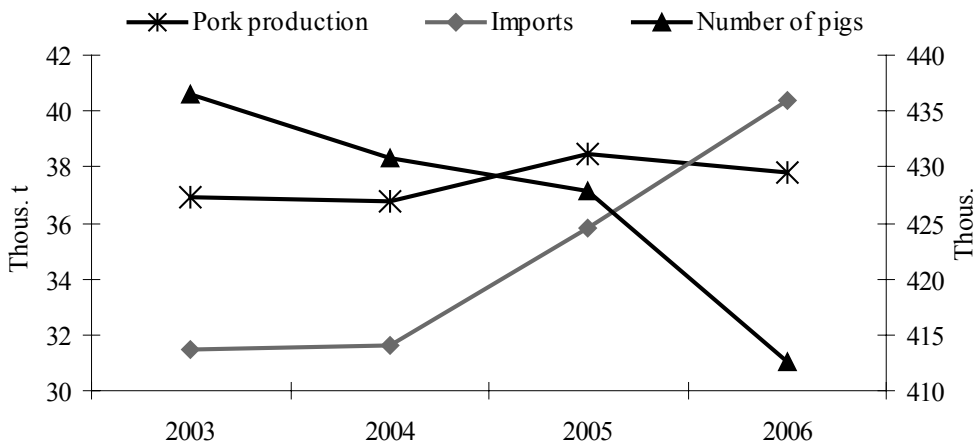

Figure 1. Dynamics of pork production (slaughter weight), imports (thous. t) and number of pigs (thous.) in Latvia, 2003 - 2006

Source: Central Statistical Bureau of Latvia, 2007

However, irrespective of above mentioned tendencies in Latvian pig sector, analysis of processes occurring in this sector has shown that structural changes are still taking place, concentrating production of pigs in the largest farms. According to H. Steinfeld et al. (2006a) this process is typically occurring in many rapidly growing economies, where the average size of operations, int. al. farms, is swiftly increasing and the numbers of livestock producers are in rapid decline: thus, carrying out production process in large production units.

As we can see from the data arranged in Table 1, the number of small-scale farms (with 9 and less pigs) in the last five years has decreased more than twice – from 51,640 to 25,327.

Table 1

Dynamics of number of farms and pigs by farm groups in Latvia, 2001 – 2006

Number of pigs on farm	2001		2002		2003		2004		2005		2006	
	Farms	Pigs	Farms	Pigs	Farms	Pigs	Farms	Pigs	Farms	Pigs	Farms	Pigs
1-2	35,051	55,747	35,470	56,828	31,598	50,648	28,725	45,140	26,350	42,295	17,690	25,239
3-9	16,589	79,484	16,146	70,165	13,160	61,807	11,559	50,431	10,259	44,011	7,637	32,101
10-99	4,438	102,615	4,393	99,843	3,440	81,224	3,086	70,390	2,512	62,876	2,013	49,177
100- 999	186	52,260	201	54,027	232	56,991	252	59,454	249	56,848	201	48,392
1000-4999	13	27,937	20	45,530	23	54,300	21	50,497	22	52,641	18	63,400
5000 and more	11	104,220	12	124,436	13	131,501	14	154,863	16	169,147	20	194,274
Total	56,288	422,453	56,242	450,829	48,467	436,471	43,657	430,775	39,408	427,918	27,589	412,583

Source: Author's calculations based on data from Central Statistical Bureau of Latvia, 2007; 2002

The number of small commercial farms that breed 10 to 99 pigs has declined sharper. Increase in number of medium-scale (100 to 4999 pigs) farms was observed until year 2004, but during the last two years it has slightly decreased. This tendency can indicate essential progress in concentration and modernization of pig sector. During 2001 and 2006 the number of the largest farms (with 5000 pigs and more) has increased and become stable. The number of large industrial pig farms in Latvia is small, but it steadily increases. More exhaustive conclusions on specialization, consolidation and concentration processes of pig breeding sector can be formed analyzing data presented in Table 1. Statistical data shows that the total number of pigs is stable but with small reduction tendency.

Analyzing division of the number of pigs by farm groups, the conclusion was that within changes in the pig farms structure, regrouping and restructuring of pig sector has occurred, and it is still taking place. In 2001 bigger share of total pigs (expressed in percentage) concentrated in farms with more than 5000 pigs (24.7%) and in farms with 10 to 99 pigs (24.2%). But in 2006 almost half of all pigs – 47.1%, were bred in the largest farms (with more than 5000 pigs) (Fig. 2). During the last six years, there has been a reduction in the number of animals on small (1 to 9 pigs per farm) and small commercial (10 to 99 pigs) farms of more than two percent points per year. At the same time, while medium-scale pig farms with 1000 to 4999 pigs per farm were reducing in number between 2005 and 2006, the number of pigs produced per farm increased by 3.1 percent. So decline in the number of pig farms could be associated with an increase in the average size of pig heard. This leads us to the conclusion that the present state of large pig farms is stable as well as their existence and development in the next years.

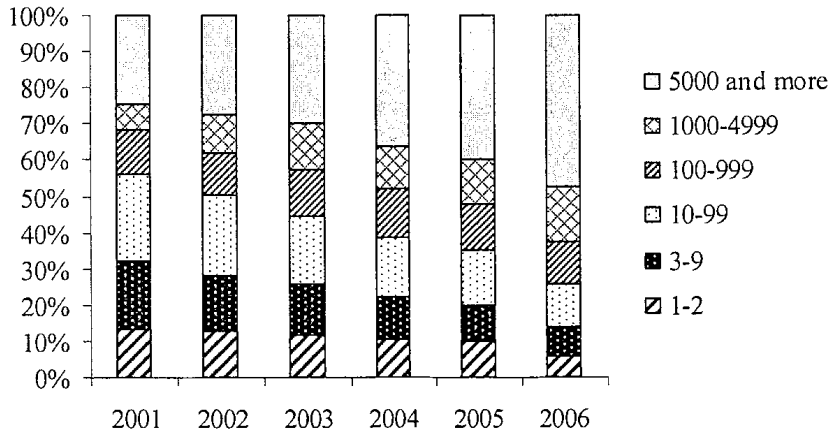

Figure 2. Distribution of total pigs by number of pigs per farm in Latvia (%), 2001 – 2006
Source: Author's calculations based on data from Central Statistical Bureau of Latvia, 2007; 2002

Generally, it was concluded that there has been a significant increase in the number of pigs per large farms, even the total pig number has slightly fallen. Thereby, the pig breeding farms have become larger or at least more concentrated in terms of their use of inputs: whereas small and medium scale farms have declined in numbers and share of total farms in Latvia. According to European Environment Agency (2001), intensification and greater specialization in livestock farms occur generally in almost all EU member states and are long-term trends that can have environmental consequences that need to be controlled to ensure the sustainability of agriculture.

Results of several studies have shown that the major factor driving these structural changes has been technology where the most important factor encouraging the development and uptake of productivity enhancing technologies has been the intense competition in the meat market and the long-term decline in real prices received by farmers, which in turn is driven by productivity improvements (Steinfeld et al., 2006b; Organisation for Economic Co-operation and Development, 2003).

2. Restructuring processes of reproductive pig breeding

For obtaining complete and unmistakable assessment of pig sector development tendencies of reproductive pig breeding were further analyzed. Data from Table 2 show that restructuring processes of reproductive pig breeding farms occur even more intensive than in pig farms. It could be explained by the fact that in larger farms it is possible to insure high specialization and technological level.

Total number of breeding sows during last five years hasn't decreased, but in comparison by years it fluctuates, where sharp increase was observed in year 2003. During 2001 and 2006 number of breeding sows in large-scale farms (with 500 and more sows) has increased almost twice the number of sows in medium-scale (with 100 to 499 sows) farms has slightly decreased, but in small-scale (with 1 to 9 sows) farms the number of sows has sharply decreased.

Table 2

Grouping of farms by number of breeding sows in Latvia, 2001 – 2006

Number of sows on farm	2001		2002		2003		2004		2005		2006	
	Farms	Sows	Farms	Sows	Farms	Sows	Farms	Sows	Farms	Sows	Farms	Sows
1-2	5,171	6,847	5,480	7,276	8,894	12,022	4,026	5,108	2,867	3,642	1,803	2,392
3-9	1,647	8,357	1,231	5,937	2,099	9,784	1,196	5,245	1,099	4,916	829	3,589
10-99	299	7,065	377	8,847	701	15,740	317	7,368	353	7,823	276	6,626
100-999	16	3,807	12	2,978	14	3,915	13	3,224	13	3,651	14	3,537
500 and more	11	11,448	12	11,102	13	13,022	15	14,502	16	15,930	20	20,076
Total	7,144	37,524	7,122	36,140	11,721	54,483	5,567	35,547	4,348	35,962	29,42	36,220

Source: Author's calculations based on data from Central Statistical Bureau of Latvia, 2007; 2002

3. Restructuring processes of farms producing beef

Although Latvia is well suited for producing beef and veal, beef production is mainly a by-product of dairy-farming. Therefore the main objective in beef cattle breeding in Latvia is to produce a high quality beef different from meat of milk cattle (Ministry of Agriculture Republic of Latvia, 2007). However in relation to pork, the consumption of beef in Latvia traditionally has been considerably lower: in 2006 consumption of beef was 20.9 thousand tonns, which was 3.6 times less than consumption of pork (74.6 thousand tons).

In 2006 compared to 2005 production of beef increased for 1.5%, but still it were less than in 2004. According to I. Gulbe (2007), the main factor that hampers development of beef sector is low purchase price. Corresponding to statistical data in 2006 price paid to the producers for cattle delivered to slaughterhouses was LVL 156.55 per 100 kg, which is almost two times lower compared to average prices in the EU (LVL 289.26 per 100 kg). Therefore, Latvian producers focus particularly on meat export, which in 2006 in comparison with previous year has increased 2.6 times (Table 3). Ministry of Agriculture Republic of Latvia (2007) points out that tendency to sell calves of milk and meat varieties cross in other member states outside the territory of Latvia could be observed in 2006, which has caused the decrease of produced meat volume in the country.

Table 3

Dynamics of beef production (slaughter weight), exports and imports in Latvia (thous. t), 2003 – 2006

	2003	2004	2005	2006
Beef production, thous. t	21.2	21.6	20.4	20.7
Imports, thous. t	7.5	5.9	5.1	6.8
Exports, thous. t	0.7	0.7	2.6	6.8
Beef consumption, thous. t	27.3	27	23.3	20.9
Total number of cattle, thous.	374.5	369.2	385.2	374.7

Source: Central Statistical Bureau of Latvia, 2007

Table 4 shows that about 87% of all cattle farms in Latvia have up to nine animals, whereas only 1% of all farms have more than 100 animals, which indicate that production resources are still not used effectively enough. Number of cattle farms has declined over the years; while in 2001 over 80 thousand cattle farms existed; in 2006 only 47,549 cattle farms were left.

Table 4

Grouping of farms by number of cattle in Latvia, 2001 – 2006

Number of cattle on farm	Number of farms grouped by number of cattle at the end of the year		
	2001	2003	2006
1-2	43,521	35,078	23,729
3-9	30,377	23,874	17,635
10-99	5,975	5,464	5,789
100-299	196	221	351
300 and more	39	43	48
Total	80,108	64,680	47,549

Source: Author's calculations based on data from Central Statistical Bureau of Latvia, 2007; 2002

However, cattle production remains economically one of the most important agricultural production forms in Latvia with large export opportunities. Generally, meat production mainly takes place in farms, household plots and private subsidiary holdings. The structure of farms producing the meat of bovine animals is still fragmented; however, the number of farms with more than 100 cattle in a heard is increasing that could be mentioned as a positive factor in further development of commercial production.

Changes in distribution of total cattle by number of cattle per farm weren't as significant as in pig sector. But still tendency shows that bigger share of total cattle concentrates in farms with 10 to 99 cattle (Fig. 3).

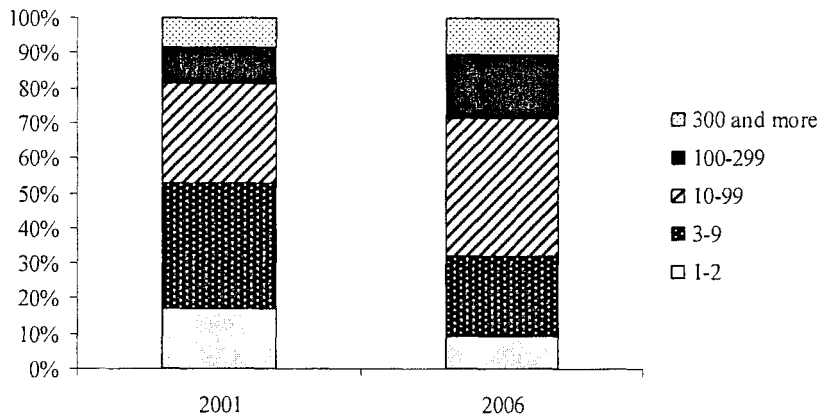

Figure 3. Distribution of total cattle by number of cattle per farm in Latvia, 2001 – 2006
Source: Author's calculations based on data from Central Statistical Bureau of Latvia, 2007; 2002

4. Concentration and integration of poultry meat production

Available data indicate that, since the 2003, poultry meat has been the fastest growing sector of animal product production and consumption in Latvia. While pork and beef production amounts annually slightly decreases, poultry meat production amount – increases. According to the results of research done by the United States Department of Agriculture (2003), key factors driving development of poultry sector include:

- Consumer demand for poultry is rising, driven by both income growth and changes in prices of poultry meat relative to other goods;
- Shift in industry structure toward integrated ownership and coordination of the input, production, and marketing operations involved in poultry production (vertical integration).

According to statistical data in 2006, number of poultry has increased for 11% compared to 2003, consumed poultry meat has increased for 25%, poultry meat production – for 40%, but amount of

imported poultry meat has increased for 28%.

The situation in the poultry meat production sector is similar to the one in the pork production sector, and here too the large farms, which produce the largest part of the amount of poultry meat in Latvia (Fig. 4) prevail as well. Therefore, the largest part of the market products is provided by enterprises using the intensive technologies where production capacity is being used for 100%. Small farms produce mainly just for self-consumption, but the biggest farms sell some part of production to the local market (Biro et al., 2006). Research by H. Steinfeld and co-authors (2006a) showed that in commodity production, poultry is most easily mechanised, and thus shows a trend towards industrial forms of production.

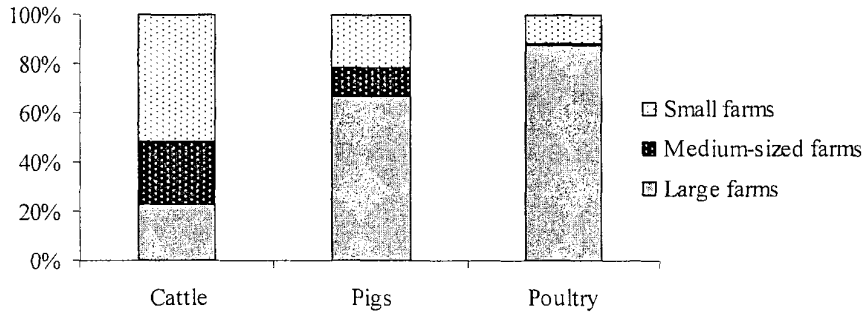

Figure 4. Number of livestock by size of farms at the end of 2006, %
Source: Central Statistical Bureau of Latvia, 2007

Looking at the meat sector together and analyzing the statistical data one could conclude that the size of production is stable and that there is still potential for increase of sales. Besides, the speed of change varies among livestock species, where the activity is being most dynamic in the pork and poultry sectors, which present an increasing challenge to the beef sector to remain competitive.

Conclusions

Structural change has been the principle characteristic of the Latvian meat industry in recent years, where structural change can be defined as changes in the number and size of farms in pig, cattle and poultry sectors.

Although the number of pig breeding farms decreased more than two times from 2001 to 2006, number of specialised pig farms (farms with 1000 and more pigs) has increased by 34%. Thereby pig breeding farms have become larger or at least more concentrated in terms of their use of inputs, whereas small and medium scale farms have declined in numbers and share of total farms in Latvia.

Restructuring processes of reproductive pig breeding farms have occurred even more intensively than in pig farms, which could be explained by the fact that in larger farms there is possible to ensure high specialization and technological level.

Although 87% of all cattle farms in Latvia have up to nine animals, the number of farms with 300 and more cattle increased by 19% between 2001 and 2006, which could be mentioned as a positive factor in further development of commercial production.

The biggest part of poultry (in 2006 – 83%) is provided by enterprises using the intensive technologies, i.e. large, specialized farms: therefore, the biggest part of the market products is provided by enterprises using the intensive technologies where production capacity is being used for 100%.

Current tendencies that can be observed in meat sector – livestock population, farm size and reproductive material, which form economic basis for effective meat production – is favourable in order to ensure the increase of meat production next years.

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THE STRUCTURE OF RURAL ECONOMY IN ZEMGALE INTRA-REGIONS

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Abstract

Zemgale planning region divides into two intra-regions (Zemgale 1 and Zemgale 2) by natural, soil and other agricultural resources. Each intra-region has different size of farms. The aim of the research was to find the structure of rural economy in different size farms or rural enterprises of Zemgale 1 and Zemgale 2 intra-regions. The research showed that very small farms dominate grow-plant sectors production. Medium size farms and enterprises have solid high proportion of grow-plant sector production in total production value. This proportion is even higher in biggest agricultural enterprises and companies (100≤250 ESU). In general author has stated that in Zemgale 1, which is the biggest agricultural production territory in Latvia, grow-plant production sectors dominate.

Key words: Zemgale, intra-regions, rural economy, structure.

Introduction

In Latvia there is one quite singular territory with its specific internal structure – Zemgale planning region (NUTS-3). In Zemgale region are included 5 districts with sharp differences taking into account agricultural resources, structure of land use and structure of agricultural sectors point of view. So, this region is interesting for researchers in agrarian economy.

Maybe it is the reason why in peer reviewed literature appeared papers about this region in the context of agrarian economy. K. Špoģis, Ž. Zaharova (2003) have proved that Zemgale region is main grow-plant production producer in Latvia. These authors defined Zemgale as consisting of Jelgava, Bauska, Dobele as well as Saldus districts, and of south-east part Tukuma district.

A. Boruks (1996) stated that for agricultural production most appropriate conditions exist in Zemgale region. J. Kaktiņš (2004) has researched farmers' forest resources in Zemgale. K. Špoģis, V. Strīķis, L. Siliņa, A. Radžele-Šulce (2004, 2005) made researches about creation of entrepreneurship environment and problems of its development in this region.

The understanding of Zemgale territory as well as definitions is very unlike. The newest normative documentations in Zemgale planning region and statistical region include not only Bauska, Dobele and Jelgava districts but also Aizkraukle and Jekabpils districts with essentially different agricultural resources and sector structure. Despite this author has accepted FADN information system (Bratka, 2007 and Drubiņa, 2006) where Zemgale planning region is divided in two intra-regions – Zemgale 1 (which includes Bauska, Dobele and Jelgava districts) and Zemgale 2 (which includes Aizkraukle and Jekabpils districts).

Described situation shows the need for special research in order to find out the agricultural production and nonagricultural sectors structure in Zemgale, as well as their development course and temp of development. The results of such research would give classified information to agricultural regional authorities and agricultural consultation service. There is ever growing demand for high qualification specialists-consultants, their knowledge and understanding for rural structural development tendencies. That proves the topicality of the theme and the subject.

The aim of the research is to clarify the structure of rural economy, including agricultural production and non agricultural sectors in Zemgale 1 and Zemgale 2 intra-regions of different economic size farms, evaluate the dynamic of production structure.

To achieve the aim, following tasks were set up:

- to study macrostructure of sector groups in different economic size farms in Zemgale 1, Zemgale 2 intra-regions;
- to study change direction of sector groups and structure in big and small agricultural enterprises and small scale farms.

Materials and Methods

SUDAT survey data as well as additional statistical data were used. Grouping, analysis and synthesis methods.

In the research were included such European size unit (ESU) farm groups:

- practically the biggest part of total amount of farms – small scale farms group (4≤8 ESU);
- medium size farms group (40≤100 ESU);
- bigger (100≤250 ESU) and biggest (>250 ESU) agricultural production farms.

Results and Discussion

Table 1

Macro-structure of production in sector groups in very small farms (4≤8 ESU) in Zemgale 1 intra-region in 2001 – 2006

Year	Production value of sector groups, LVL				Macrostructure of sector groups production value, %		
	Grow-plant	Cattle-breeding	Non-agricultural activities	Total	Grow-plant	Cattle-breeding	Non-agricultural activities
2001	4942	1646	0	6588	75.0	25.0	0.0
2002	5375	2296	0	7671	70.1	29.9	0.0
2003	2870	6765	275	9910	29.0	68.3	2.8
2004	4937	4180	64	9181	53.8	45.5	0.7
2005	6132	2966	148	9246	66.3	32.1	1.6
2006	5744	3751	172	9667	59.4	38.8	1.8

Source: SUDAT data and author's calculations

Conclusion could be made from Table 1. data and calculations:

- total value of all production in this group of farms does not grow up;
- there dominate grow-plant sector value, however its proportion shows slow decrease;
- several small farms develop non-agricultural activities, but its proportion to total amount of production value is little.

There is a place for discussion, of course, how to evaluate the stabilization of production value during last years. It could be seen as stagnation or even demand decrease in food market, either exhaustion of small scale farmers' capabilities and possibilities. In praxis I can say, that is usual phenomenon for natural and half-natural farms. Completely another situation is in production of sector groups in Zemgale 2 intra-region, which is seen in Table 2.

Table 2

Macro-structure of production in sector groups in very small farms (4≤8 ESU) in Zemgale 2 intra-region 2001 – 2006

Year	Production value of sector groups, LVL				Macrostructure of sector groups production value, %		
	Grow-plant	Cattle-breeding	Non-agricultural activities	Total	Grow-plant	Cattle-breeding	Non-agricultural activities
2001	3494	2855	33	6382	54.8	44.7	0.5
2002	4895	2740	654	8289	59.1	33.1	7.9
2003	4897	3354	112	8364	58.6	40.1	1.3
2004	4661	5431	434	10526	44.3	51.6	4.1
2005	5191	8561	922	14674	35.4	58.3	6.3
2006	5246	6980	2108	14334	36.6	48.7	14.7

Source: SUDAT data and author's calculations.

In that part of Zemgale planning region in the last years cattle-breeding and grow-plant sector experienced production value grow, nevertheless the fastest value growing shows cattle-breeding. There are radical changes in proportion of these sectors: cattle-breeding production shows greatest growing rate. It can be explained with growing milk price and financial aid to this sector.

Third feature of this region is that non-agricultural income has been essentially increased – its proportion to total value has achieved 15%. It is possible to assume that non-agricultural production is based on farmers' forestry, due to reason that Aizkraukle district is one of woodiest in Latvia. However, here develop also another non-agricultural production sectors. Aizkraukle district has almost the same forest territory (142,100 ha) as three Zemgale 1 districts in total (Bauska, Jelgava, Dobele – 15,600 ha). It is wooded by 55%, but Bauska, Jelgava and Dobele district has only 29-31% forests of all territory. Economists know that in wooded territories usually are located forestry downstream sectors – furniture, construction supplies, briquettes, charcoal production. In its turn that creates more workplaces and higher salaries. For example, low paid persons (average brute salary less than LVL 100 in month) in 2006 in Aizkraukle were 4.8%, but in Jelgava district two times more – 10%.

Non-agricultural production also attracts investments. For example in 2005 in Aizkraukle district total investment amount were LVL 59.2 mil., but in agricultural district Jelgava and Dobele only LVL 28.9-28.2 mil. In Table 3 is shown macrostructure in middle size farms, enterprises and business in both intra-regions.

Table 3

Macro-structure of production in middle size farm group (40≤100 ESU) of Zemgale 1 and Zemgale 2 intra-regions in 2001 – 2006

	Year	Production value of sector groups, LVL				Macrostructure of sector groups production value, %		
		Grow-plant	Cattle-breeding	Non-agricultural activities	Total	Grow-plant	Cattle-breeding	Non-agricultural activities
Zemgale 1	2001	59965	18756	4580	83301	72.0	22.5	5.5
	2002	64887	5978	4375	75240	86.2	8.0	5.8
	2003	74583	12584	18005	105172	70.9	12.0	17.1
	2004	86912	14811	15694	117417	74.0	12.6	13.4
	2005	75538	16749	8528	101025	74.8	16.6	8.4
	2006	83722	6614	13154	103490	80.9	6.4	12.7
Zemgale 2	2001	30325	68369	7327	106021	28.6	64.5	6.9
	2002	31809	27914	18496	78219	40.7	35.7	23.7
	2003	46284	15384	17395	79063	58.5	19.5	22.0
	2004	73174	4249	56	77479	94.4	5.5	0.1
	2005	61862	26576	2381	90819	68.1	29.3	2.6
	2006	68970	34466	6577	110013	62.7	31.3	6.0

Source: SUDAT data and author's calculations.

Sector groups' structure and their productions amount proportion in middle sized farms are very different and stable:

- Zemgale 1 intra-region during that period has high and persistent grow-plant sector production proportion, production amount in absolute number also increasing;
- cattle-breeding production value and relative proportion is insignificant and unstable, production value is fluctuating around 300%;
- non-agricultural production amount and value is relatively high (12-13%);
- there is no big progress in total production value, which during last years fluctuate from LVL 100,000 till LVL 117,000;
- in Zemgale 2 intra-region farms produce much less than Zemgale 1 and there are changes in development direction of its structure – grow-plant production proportion in last years increased, but it does not still come

close to Zemgale 1 level:

- Cattle-breeding production value is extremely unstable,
- Radical changes in politics of these farms toward non-agricultural activities, because their production value proportion in last years changed very strong.

Table 4

Macro-structure of production sectors in big agricultural business farms group (100≤250 ESU) and the biggest enterprises (>250 ESU) of Zemgales-1 intra-region in 2001 – 2006

	Year	Production value of sector groups, LVL				Macrostructure of sector groups production value, %		
		Grow-plant	Cattle-breeding	Non-agricultural activities	Total	Grow-plant	Cattle-breeding	Non-agricultural activities
100≤250 ESU	2001	135,925	18,284	17,731	171,940	79.1	10.6	10.3
	2002	166,825	43,587	22,935	233,347	71.5	18.7	9.8
	2003	189,640	28,077	37,557	255,274	74.3	11.0	14.6
	2004	223,707	36,059	32,784	292,550	76.5	12.3	11.2
	2005	241,528	33,267	40,938	315,733	76.5	10.5	13.0
	2006	209,336	39,792	20,589	269,717	77.6	14.8	7.6
>250 ESU	2001	717,465	1,188,453	302,527	2,208,249	32.5	53.8	13.7
	2002	669,399	751,835	192,403	1,613,637	41.5	46.6	11.9
	2003	709,560	1,032,465	174,380	1,916,268	37.0	53.9	9.1
	2004	686,011	717,180	152,440	1,555,513	44.1	46.1	9.8
	2005	925,576	940,781	260,528	2,126,885	43.5	44.2	12.3
	2006	717,603	562,071	192,280	1,471,954	48.8	38.2	13.1

Source: SUDAT data and author's calculations.

Interesting data can be found analyzing Zemgale 1 agricultural business groups' structural strategy (see Table 4).

Enterprises with 100≤250 ESU have strong and stable specialization in grow-plant sectors, proportion of these sectors approach 4/5 of all production value. Second - grow-plant sector tendency shows that during that period it has been increased by 60%, its chain growth rate is around 10%. Cattle-breeding and poultry keeping sectors production has no great fluctuations, however proportion of these agricultural sectors has slow decrease and during last three years proportion in total production value vary between 12-13%. In this agricultural business enterprises group important part has non-agricultural production value. Total production value dispersion during last five years is 33%, which much less in biggest agricultural enterprises.

Biggest agricultural business enterprises have different production and sector structure dynamic and changes in that period are unlike other farm groups. First of all, here risk factors have great importance, which make for sector production big fluctuations. For example, total production value dispersion during last 6 years is 50%. Nevertheless dispersions for each sector individually are different. In grow-plant sectors are greatest production stability, dispersion is 35%, which is quite close to average norm 20%. Cattle-breeding (including poultry keeping) sector has sharp fluctuations in production value: in 2001 it was 2.1 times higher than in 2006. Little lower fluctuations can be seen in non-agricultural production values.

Hypothetically and conceptually we can assume that fluctuations in production value of cattle-breeding and poultry keeping has been created by economical factor, - one of them changes in these markets not only in Latvia, but also in Europe and with it also global markets. These assumptions are based on information that in Zemgale region the biggest poultry keeping producers and agricultural complexes in Latvia are located.

During last three years, sectors 'production structure also in this group shows determined structural changes – rise of grow-plant sectors production proportion in total production value, but non-agricultural production proportion remains the same around 11-12%.

Conclusions

1. In Zemgale 1 small scale farms with certainty dominate grow-plant production value, but in Zemgale 2 macrostructure gradually changes, cattle-breeding production proportion tends to grow in total production value. Small scale farms of Zemgale 2 show increase in non-agricultural production value and this could be connected with forestry and its downstream sectors.
2. Middle sized (40-100 ESU) farms in Zemgale 1 have stable and high proportion of grow-plant production, but in Zemgale-2 goes on internal reorientation toward grow-plant production.
3. In big agricultural business farms production structure grow-plant production value takes leadership and its amount increasingly grows.
4. Among the biggest (>250 ESU) agricultural complexes and enterprises are very big cattle-breeding, and poultry meat complexes, as well as specialization in seeds and cereal growing.

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ENVIRONMENTALLY FRIENDLY ENTREPRENEURSHIP AND PROBLEMS OF ITS DEFINITION

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Abstract

Recently we have been noticing words as 'sustainable development', 'environment protection', 'environmentally friendly' etc more and more often. We understand meaning of those concepts, but there are no unambiguous definitions of these words in literature. Each of these notions include particular characterizing elements which understanding and characterizing of which make possible to detect correctness of application or context. Sustainability like entrepreneurship is a process which takes place within definite environment around it. Mutual interaction of the processes produces consequences which have to satisfy all the interested parties. Therefore, it is necessary to integrate several science branches to solve this problem- i. e. economics and ecology.

Nowadays, environment issues become part of each person, institution, policy and law. Environmental questions are integrated in different fields of economics and entrepreneurship, as well. It is hard to define environmentally friendly entrepreneurship. But there is a flexible definition that could be used in different economical spheres with great variability of economical circumstances, and it is- characterised circumstances would not be secured for a long time, yet. It is complicated to define the concept since this is a value involving process. Values which are sources for idea of sustainable development are based on need to form society satisfying human interests and unthreatening future generations, necessity to secure economical growth including moral, social and ecological aspects.

Key words: entrepreneurship, environment, and sustainability.

Introduction

These days society talks about what we want its future vision. Not only individuals but also entrepreneurs more and more often have to face planning of their activities on sustainable basis. Necessity for responsible entrepreneurship is emphasized including environmentally friendly activities. Environmentally friendly activities are needed not only at the level of enterprise management, development of visions and strategies, but also at the level of employees and consumers.

To study environmentally friendly entrepreneurship, at first, it is necessary to understand the concept. The notion 'environmentally friendly entrepreneurship' is a new compound of words which we meet more and more often in our daily lives. It consists of words from different branches - environment (ecology), and entrepreneurship (economics). These concepts merge in the context of sustainable development.

The aim of the research is to find out a definition for environmentally friendly entrepreneurship by studying related notions in literature.

The tasks are the following:

- to analyze concepts of environment protection, entrepreneurship and sustainable development;
- to define notion of environmentally friendly entrepreneurship.

Materials and Methods

In research, monographic, inductive and deductive methods are used. Characterization of environmentally friendly entrepreneurship in scientific literature and periodicals by Latvian and foreign authors are studied.

Results and Discussion

Environment, environment protection and environment quality are important for each society member who cares for balanced national and global development and wants to act towards saving natural resources for the next generations.

Concept of environment in the research is connected with 'environment protection' that is quiet a new ideology, and it is also observed also in the context of entrepreneurship. Roots of the notion 'environment protection' lie in explanation of 'nature protection' concept. People started to apply it wider in 1913 when the 1st International Nature Protection Congress took place in Switzerland. This concept was understood as a tendency to save flora and fauna representatives for scientific purposes. In the course of social processes and science development, understanding of nature protection concept has changed. It has expanded to the state, society and international enterprises system directed towards rational usage, saving and protection of natural

resources. (Liepa, 1991).

Usually all the sub- sectors of ecology are usually integrated in one common notion of ecology, but sub-sectors exploring human ecology, human relationships with environment and their interaction are joined in one- 'environment protection'. Environment protection means all the activities for human life environment saving- protection of natural resources, saving of nature diversity and self- renewal ability (Ekoloģijas un vides..., 1996). In the Law of Nature Protection, 'nature protection' is explained as 'a group of enterprises for maintenance of environment quality and securing of sustainable development of natural resources' (Vides aizsardzības likums, 2006).

One of conclusions of environment protection history is- during all the history of humanity on the planet it is hard to detect a period or a place not influenced by human action. Nature and environmental problems have existed in different times and places. But how can we imagine nature as a subject with problems? Problems are not only connected with people and their institutions, but problems are in the mind of people! Nowadays nature problems were not considered as problems. (Way to Sustainability ..., 2001).

Problems of nature protection are developed as social fact, more and more social strata become involved. Nowadays, environmental issues become a part of each person, institution, policy and law with important role of science. Generally environment protection is an actual modern problem, and it has become also a complex global problem connected with to sustainability of resource usage. Its possible solutions can be found in process of synthesis of different nature and socially economic branches of science. Environment issues are integrated in policies of forming of other branche policies and observed in common context, securing reach of common goals.

Observing environment protection concept within entrepreneurship, it is necessary to understand the notion 'entrepreneurship'.

Progress of human society is connected to continuing development of social needs and their satisfying means. Satisfied needs encourage new needs and new goals. Planned tasks for reaching goals always depend on individuals and their values in choosing the source of the means. To satisfy their numerous different needs and interesests and to reach the goal, people have to create the necessary things and service or have to manage. The highest level of managing is entrepreneurship. A.Vedļa (Vedļa, 2000) points out that entrepreneurship is simultaneously also a management but not any management is entrepreneurship. Management is work for oneself but entrepreneurship - for market to earn.

In its historical course, entrepreneurship as a science has emphasized the following aspects - property, risk, innovations, personal features of entrepreneurs, level of state non-interference (or interference), competence and methods of enterprise management. It means that in the course of time, the concept of entrepreneurship has developed and expanded. (Vedļa, 2000). It means that entrepreneurship can be perceived as:

1. economical category;
2. management method;
3. a type of thinking.

In dictionary of economics, the word 'entrepreneurship' is defined as independent and systematic activities including risk as a component by a legal entity in the sphere of goods production or service with the aim to gain some profit. (Explanatory Dictionary..., 2000)

R.Ruranedescribesentrepreneurshipasapowerful social life engine. Nature of entrepreneurship is an activity performed by a private person, enterprises or organizations in production, selling, service delivery, goods, service or money exchange. (Rurāne R., 1997)

J.Pocs declares entrepreneurship in the modern economy as a system that consists of parts and elements in mutually subordinated relations. The main goal of the system is to create real goods and services for others or for needs satisfaction in creation of the necessary means. (Počs, 2000).

Professor A. Vedļa thinks that entrepreneurship is economical activities and investment of capital which is continuous or systematic, by self - initiative and permanent; it is executed by individuals, enterprises and organizations on their own behalf, their own risk and property responsibility, and directed towards goods production, realization and work completion, sales, service or inventions with the aim to gain profit. (Vedļa, 2000)

The mentioned definitions put the main stress on production of goods and service for needs satisfaction and for profits but production of goods and service is not possible without production selling and definite production means (factors), and, as any social process, entrepreneurship is connected with risk. Like explanation of any other word, 'entrepreneurship' also includes definite elements or compounds and their characteristic features which are summarized in Table 1.

Table 1

Characteristic Elements and Features of Entrepreneurship

Element	Features
Subject	Physical or legal entity
Economic activity	Continuing, systematic, on own behalf, by self-initiative
Goal	Gain of profit, satisfaction of needs, production of goods, by service delivery
Aids	Production resources
Risk	Allowable, catastrophic

Source: by the Author

Entrepreneurship is a process with definite features of each element. It means that performing economic activities (continuous, systematic and on own behalf) the manager of entrepreneurship process (physical or legal entity) has to think also of supplement of definite means (production resources) and responsibility for the related risk.

Analysing the notion of 'entrepreneurship' within environmentally friendly context, the most important element is production resources. For satisfaction of their needs, people use things which are naturally in the state ready for use and also the ones to be processed to adjust them to human needs. To transform any natural subject into thing beneficial for needs satisfaction, there are definite conditions or resources needed - nature, work and capital. People take everything that is necessary for their existence, including supplement of entrepreneurship process, from their environment - from nature.

Academic literature presents two notions for means of entrepreneurship process - resources and factors.

Centre of Translation and Terminology explains the concept 'production resource' as production means necessary for goods production or service delivery, and the notion 'production factors' - the resources used in the production process which are divided- earth, work, capital and management (Translation and ..., 2008).

Production resources are made by people and all the things which that they **can use** to produce goods and service correspondingly to their needs. Totality of these resources is called 'production power' in economics.

And production resources, when involved into production process (meaning also service delivery), become **production factors** which are enterprise means and work techniques which **are used** for producing production or service delivery.

All facts and resources are significant in human life. Using natural resources, we have to consider needs of economical sectors and also renewal abilities of the nature itself.

Production which is realised by human society is possible because of existence of different categories of resources- natural resources, human resources and capital resources (Pelše, 2007). Natural resources supply raw materials for production process. Human resources are not only people as a labour force but also their knowledge, skills and social capital. Material resources are finance and non - finance capital. Pahomova N. (Pahamova, 2003) writes that understanding of resources in modern economic literature goes beyond the limits of traditional production factors - earth, work and capital, but also all natural resources (limited and non - limited), human knowledge and labour moral in society are included.

If we look at production process from the aspect of resource accessibility and supplement level, production is impossible without nature resources because they are source material of production process; and it is impossible to manage production process without them, dealing only with human resources and material resources. Natural basis for production development are natural resources.

With nature resources we should understand all the totality of natural circumstances of a concrete territory that people can use to satisfy their needs. Nature wealth can be expressed as (Nature protection, 2001):

1. biological diversity;
2. natural resources;
3. natural and cultural landscapes;
4. importance for recreation.

According to the Convention on Biological Diversity, which was signed by 192 states in Riodejaneiro in 1992, biological diverse means forms living organisms in all the environments, including land, sea and other water eco - systems and ecological complexes which parts of which they are; it includes diversity within species, among species and eco - systems (Pilāts, 2003). Besides those three levels of biological diversity the fourth one is also detected - landscape level. Biological diversity is secured by differences among organisms in an eco - system and ecological processes, as well as their interaction.

In the year 1989, European industrials decided to establish permanent Environment workgroup which could evaluate activities of solid waste economy, especially regarding chemical companies. Environment workgroup was given a task to analyse changes in corporate philosophy to clarify if the number of enterprises tracing influences of their products on environment from their creation to exposure is increasing. Also consumer 'the green thinking' of consumers influence participants of entrepreneurship process more and more. Consumers are offered goods, noting that they are environmentally friendly in the corresponding packiging. The same information and considered advertising have helped to gain essential advances for those producers who have made decision to diminish blight of entrepreneurship on the environment.

In the 90ies of the 20th century, there was a rise in the world entrepreneurship when production methods corresponding to sustainable development were consciously searched for. Many enterprises concluded that by diminishing resources exposure and pollution of environment, they can raise their competitiveness in market. The Business Chartes for Sustainable Development of International Chamber of Commerce validated in the year 1991, set that radical changes have to be started in entrepreneurship. It was declared that enterprises all over the world have to assume equal environmental criteria. Although, if ready for use activities plans are not set, there is no guarantee that the given principles are realized.

Introduction of different environment protection enterprises and distinct attitude of entrepreneurship subjects to them show that there are different approaches to integration of environmental issues into entrepreneurship processes. States and their enterprises have formed different management models, starting with ecological management of environment (active environment control) and competition in environmental sphere (demand by consumers and market) and to sustainable development (environment is considered as basis for corporate or common activity).

Understanding of environment management issues has changed in the society in the course of time. With development of production power, people gradually influence nature. In the ancient times, ecologically controversial tendencies were expressed for the first time in history of civilization. On the one hand, people showed their ability to change nature, to adjust it for satisfaction of their rising needs; on the other hand, response by nature common organism could follow and cause socially negative consequences after each nature transformation enterprise. During the time period of antique philosophers, the basis for rational cognition of nature law was laid, human world perception was forming. (Niedrītis, 1993)

According to science development, the antique world view was changed for other models. Pragmatic attitude to the world comes in the front - common utilitarian orientation. Nowadays it is already clear that integration of environment issues into processes of other spheres is not only a phenomenon of Western world where quality of goods quality and all the other management issues have to correspond to high demands (see Table 2).

Table 2

Historical Development of Environment Management

Criteria	To 1970	1970 – 1990	1990 and further
Common attitude	Some normative demands. Attention is focused onair emissions and water pollution.	Stricle demands are set by Law. Organizations are trying to secure the Law execution.	Complex approach to environmental issues. Organizations are trying to do more than determined by the Law.
Management philosophy	Environment is not a problem.	Decontamination of pollution after it has emerged.	Pollution avoiding in the place of its emergence. Environment management systems introduction.
Organizing structure	Special attention is not devoted to environmental issues they are not considered separately	Environment protection engineer or a group of an organization is solving environmental problems apart of other business departments. Environmental issues are not treated in complex with activities of an organization.	Environmental issues are integrated into activities of the organization.
Costs	Very small investments.	Costs are as limited as possible, mainly directed to the Law submission.	Environmental issues have strategic importance in decision making, and they tried to give investments in full scale.

Source: Belmane, Dalhammars, 2002

In the management process of each enterprise, it is necessary to control and diminish the impact on environment, as well as gain benefits from right, environmentally protective business activity. One of the ways how to deal with environmental issues in an enterprise is to introduce environment management systems; they can be formal (correspond to and be certified according to international standards) or informal (not certified).

In 1987, UNO World Environment and Development Committee started to promote the idea of 'sustainable development'. In the report 'Our Common Future' by UNO World Environment and Development Committee, the world development course is analysed and characterised. It shows that the world is going to reach deadlock if political thinking and attitude to consumption of nature resources would not be changed, as well as inequality among the world states and people would not be equalized.

The concept 'environment' is used in many different meanings. In its narrowest meaning, it characterises elements of the group of interest and their essential features. Environment in physics is explained as material surrounding, matter which contains something. In the Law on Environment Protection, understanding of notion 'environment' is explained as totality of natural, anthropogenic and social factors (Law of Environment protection, 2006).

With the concept 'environment' , it is possible to determine not only totality of natural, anthropogenic and social factors which are formed around some centre, but also objective reality, area of earth's surface with characteristic circumstances and formations, as well as combination of elements created by human. (Ecology and environment ..., 1996) Basic categories of environment are environment of land, environment of water and environment of soil. Environment is like are organism, totality of

conditions which impacts definite system and is changing itself under influence of this system.

Summarizing all the above mentioned explanations of the notion 'environment', we can say that environment serves to existence of living organisms and humans mainly. People have excluded themselves from the environment; they have included themselves in it during the long course of evolution taking all the necessary for themselves.

The environment of entrepreneurship is objective reality which is independent from human will; it is a real existence of independent economic, ecological, demographic, legal, administrative etc. conditions and processes. It is a totality of active economic subjects, objects, processes and powers which exists in respect of human environment and is in permanent interaction.

Environment of entrepreneurship is a totality of objective and subjective factors that influence situation of entrepreneurship during a set time period. (Abizāre, 2004).

Environment of entrepreneurship is the basis of prepared and made decisions by an entrepreneur for supplement of production process, and also a mechanism which limits definite activities. Its economics follows from conditions of market economics of the environment of entrepreneurship (Vasiļjeva, 1998).

These functions interact with each other and their actions take place in micro and macro levels. Macro environment includes economic, legal, political, social technological, as well as conditions of geographical actvities; micro environment- aims, structure, technologies, machines, culture, style.

Sustainable development is oriented to people and its aim is to improve human life circumstances maintaining natural resources and environment. As M.Wackernagel, V.Rees point out, the sustainable development depends on diminishing of ecological damage mainly by the energy consumption limitation in economics, on improvement of material prosperity of the poorest people in the world by vacating ecological space necessary for further economical growth in developing countries and securing that benefits go where they are needed most of all (Wackernagel, Rees, 2000).

Sustainable development is a permanent, conscious, logically managed process of social changes in the world, regional and local level based on definite principles. In spite of widely acknowledged ecological and social peculiarities of this problem, the interpretation and explanation of sustainable development notion is contradictious.

Accepting explanation of 'sustainable development' given by UNO, we understand it as materially comfortable life with peaceful coexistence within limits of means supplied by nature. In spite of imaginary simplicity, there is no unified social view on the suggested activities politics which is included by this concept. The report by UNO World Environment and Development Committee was criticised for necessity to have consumption which envisages 'faster economical increase both in industrially developed and developing countries'. Committee was looking for midway which would satisfy both debating parties. The term 'sustainability' satisfied environment protection specialists, but the term 'development' - businessmen and bankers.

Investigating explanations of concept 'sustainable development', controversial interpretations of the notion can be observed in publications by different authors. It clarifies uncertainty of the term 'sustainable development'. Composition of these two words includes the merge of two controversial words. We understand 'sustainability' as encouragement for ecological and social changes, the world with stable environment and social justice, but 'development' means increase, improvement. As Sharachchandra M. writes, 'different interpretations of sustainable development are not caused by misunderstanding but rather by ideological differences and disinclination of many people to acknowledge importance of basic idea'. (Sharachchandra, 1991). Contradiction of the concept reflects discussions of political character, but not insuperable intellectual difficulties. But Redclift M. stresses a counterargument '…if we are not ready to doubt about our consumptions on development and environment and give political power to the made conclusions, the unsustainable development will go on. (Redklift, 1987)

Ambiguity of notion of sustainable development is partly caused by disability of the society to differentiate between real development and just increase. The report by UNO World Environment and Development Committee describes the notion 'development' unclearly. This ambiguity reflects politics of authority, and it is a kind of political deal to result in wider acknowledgement of the concept. Notions 'development' and 'increase' are not differentiated. 'Development' is a qualitative concept involving ideas of improvement and progress, as well as perfection of cultural, social and economical spheres, while 'increase' is just quantitative. (Way to sustainability..., 2001)

Economist H. E. Daly defines 'increase' as volume growth resulting from accumulation, but 'development'- as realization of more complete and greater potential. (Daly, 1993) Increase means

to become bigger, but development - to become better.

H. E. Daly defines 'sustainable development' as progressive improvement not exceeding ecological capacity. Sustainability means that the capital of nature must not be exposed faster than it is renewed, although sales and technological development has given humankind the opportunity to exploit nature in increasing pace over limits of sustainability; current consumption exceeds natural income. To perform sustainability, it is necessary to diminish total energy and raw material consumption, and to give opportunity to the poor to consume more.

The goal of sustainable development, at first, is to satisfy basic needs of people. Only to the level when economical increase is efficient enough to reach this goal, it could be identified as the sustainable development. But if it appears that economical growth is not efficient enough and maybe it even starts to trouble the main aim of people, it must not be supported any more and maybe even should be given up (Basics of Sustainable..., 2001).

The concept 'sustainable development', also contains other hidden contradiction depending on context the definite term is used with. Clashes of interests, different views of the world, incompatible analyses, increasing material demands of people and fear from changes have created contradictions regarding interpretations of sustainability and ways how to reach it. It can include (Wackernagel, Rees, 2000):

- Conditions necessary for sustainable life-goals or states of existence are set;
- Socially political enterprises for reaching the aim- regarding the planning process;
- Special strategies for solving current problems- step- by- step solutions of the problems are set.

Sustainable development is orientated towards people and its goal is to improve human life circumstances by saving nature and environment; therefore, it is necessary to respect nature that supplies people with resources and all the life necessities. In such perspective, sustainable development means qualitative improvement of people life circumstances within corresponding capacity of eco- system. It orients towards people, and it is formed of individual behaviour and governmental policy which tries to satisfy both-basic needs and wish.

Sustainable development is a normative notion which is oriented to the behavioural and values standards to be respected, since society has to satisfy its survival demands and welfare needs. E. B. Barbier offers the following definition of sustainable development- to supply simultaneously goals of biological (genetic diversity, endurance, biological productivity), economic (satisfaction of basic needs, rise of objectivity and equality, increase of quantity of the necessary goods and service) and social (cultural diversity, organizational sustainability, social equality, participation systems. (Barbier, 1987). The definition reflects the fact that values system of society stays remains but the list of environmental values could have additions with time.

It means that growth and next generations tended sustainability has to include issues of social environment, economical achievements and the sphere of environment itself. Sustainability is a process which involves social, economic and environment protection factors.

Definition of concept of environmentally friendly entrepreneurship can be found in research 'Environmentally Friendly Entrepreneurship in Latvia' by D.Kaužēna (Kaužēna, 2001). It is defined as the entrepreneurship totality of activities and each step separately taken consider conditions of sustainable development by all the main factors influencing its activities and corresponding environmental indicators.

Therefore, these are economic activities which are carried out in positive connection with environment, e. i. environmentally friendly, diminishing the load on environment, promoting the improvement of environment quality. **Environmentally friendly entrepreneurship is economic activity whose process considers supplementing all factors for environmental protection and sustainable development.**

Conclusions

1. Different authors have different views on characterization and definition of the notions in different literature sources, but they all include the same characterizing features.
2. Sustainable development is human oriented and its aim is to improve life circumstances of people by saving nature and environment, therefore, it is necessary to respect nature which supplies people with resources and all the necessary for life. In such perspective, sustainable development means qualitative improvement of human life circumstances within corresponding capacity of eco- system.
3. Environment serves existence of living organisms and mainly- people. People have excluded themselves from environment where they have beer for many years in the course of evolution taking all they need.
4. Entrepreneurship is a process where each ele-

ment as a set of features. It means that besides gaining profit (producing goods or delivering service), the manager of the entrepreneurship process (physical or legal entity) has to consider also supplement of production resources and readiness to undertake related risk as well.

5. Environmentally friendly entrepreneurship is economic activity whose process considers supplementing all factors for environment protection and sustainable development.

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TRANSACTION COSTS OF AGRI-ENVIRONMENTAL POLICY MEASURES: THE EXTREME BOUNDS ANALYSIS APPLIED TO PERMANENT GRASSLANDS

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Abstract

It has been shown in previous studies that transaction costs (TC) of agri-environmental policy measures often are very large both in absolute terms and as a share of payments. As agri-environmental policy measures make up an increasingly large share of agricultural policies, not least within the European Union, it is becoming ever more important to improve the knowledge about the factors determining the level of transaction costs. This paper investigates the TC determinants of one Swedish agri-environmental policy measure. More specifically, it aims to investigate if the level of TC is attributable to economic factors, such as pasture density and distances, or if political factors, such as lobby groups and political majorities at the county level, influence the costs. To evaluate if the results are robust with respect to alterations in model specifications, a version of the extreme bounds analysis is applied. Although initial results indicate that political parties influence the level of transaction costs, the extreme bounds analysis reveals that those results are fragile. It shows that five of the economic variables are robust with respect to model specifications, but none of the political variables is.

Keywords: extreme bounds analysis, agri-environmental policy measures, pasture, transaction costs.

Introduction

In the last couple of decades, there has been an increasing number of articles devoted to the study of transaction cost economics. Although most of the articles have studied the issue analytically or discussing the sources and implications of transaction costs (TC) in general terms, lately there has also been an increasing number of empirical studies related to agriculture and the environment (see Nilsson (2007) for an ample supply of references to relevant studies). The magnitudes of transaction costs may be important for the development and implementation of environmental policy measures. Although traditional price and income support programs generally carry relatively small administrative costs, often between 1% and 5% of the total costs, the level of transaction costs has tended to increase as programs have become more focused on supporting positive externalities. Since the results of previous studies indicate that transaction costs may be sizeable, it is important to gain a further understanding of the size and determinants of transaction costs. As noted by other authors, non-negligible transaction costs will affect the optimal design of policy instruments as well as the optimal level of payments. Interestingly, despite the importance of developing efficient policy measures, relatively little attention has been given to the cost-effectiveness of conservation policies

The agri-environmental policy measures are of increasing importance, not least in the European Union with the ongoing transfer from commodity related support to area payments complemented by payments for non-commodity outputs. Consequently, transaction costs are becoming increasingly important to study if efficient policy measures are strived for. This paper aims to increase the understanding of what determines the level of transaction costs by analyzing how some economic and political factors influence the level of transaction costs. It investigates the transaction costs of the Swedish agri-environmental policy measure that aims to support the qualities of semi-natural pastures. More specifically, it investigates the determinants of the county authorities' costs for setting up maintenance plans for the permanent pastures that participate in the system. Although to some extent fulfilling an educational function, the costs of creating the maintenance plans could essentially be classified as pure transaction costs. The costs per plan vary substantially between the 21 Swedish counties. Since no apparent reason for the divergence in costs can be easily found, the purpose of this paper is to shed further light on the sources of the transaction costs: It aims to investigate if the cost divergences could be attributable to reasonably objective economic factors, such as pasture density or distance, or if other factors, such as political majorities at the county level, influence the costs.

Since very little empirical research has been performed on the determinants of transaction costs for agri-environmental policy measures, this paper is exploratory by nature. Thus, solid foundations for which variables that should be included in the specifications have not always been possible to find. This implies that the foundation for the inclusion of the different variables vary. In some cases there are previous studies available, indicating that variables such as membership in conservation organizations could be expected to have an influence. In other cases there is more of an intuitive reasoning arguing why the variables are to be included. The exploratory nature of this paper is one reason for the inclusion of the Extreme Bounds Analysis (EBA). The essence of the EBA will be further discussed in the empirical section but it could be stated here that it is a suitable method to check if the independent variables are robustly related to the dependent variable, or if they are fragile and depend on certain specifications to be significant. The method has previously mainly been applied to growth studies.

The Swedish county administrative boards essentially consist of administrators that are appointed by the central government. Their main task is to function as the central government's administrator at the local level, handling the implementation of national policies in the counties including administration of agri-environmental policy measures. Since the county administrative boards are not elected but centrally appointed, they should not be influenced by local political majorities or preference formations at the county level. Neither should they be affected by the influence of interest groups since any implementation of policy that diverges from the norm decided by the central government would imply a breach with the boards' mandate. In essence, the boards should fulfill the tasks given to them by the central government efficiently and fairly. In Sweden, the holders of semi-natural pastures can apply for compensation to maintain the pastures' specific qualities. There is one basic payment that all semi-natural pastures are granted as long as some basic measures are fulfilled. If the pastures are deemed to be of special importance from a biological or cultural point of view, the holders may apply for an additional payment. In order to get that payment, the pasture has to be maintained in accordance with certain site-specific conditions. When a farmer has applied for the payment, an expert from the country administrative board visits the farmer, investigates the pastures and sets up a maintenance plan for the pasture. The maintenance plan is thus a prerequisite for the implementation of the desired policy measure. The maintenance plan contains certain stipulated conditions regarding the maintenance of the pasture that the farmer has to fulfill or he risks losing the payment. The plan can be quite detailed with respect not only to the types of objects that are included in the plan but also to how detailed the directives for each object are. It is therefore possible that two experts that each visits a randomly chosen farmer could produce somewhat different plans. Consequently, it is also possible that some county administrative board experts generally produce more costly plans than others.

The costs of creating the maintenance plans could reasonably be considered a relatively pure transaction cost. Usefully for our purposes, between the years 2000 and 2003 the county administrative boards did not have to commit resources from their ordinary budgets for the creation of the maintenance plans. Rather, during these years the Boards could request funds from the project KULM to cover their expenses. This procedure has two major implications. Firstly, it implies that explicit data is accessible regarding the costs for the creations of the maintenance plans. Secondly, it also implies that the local Boards did not necessarily have strong incentives to keep down the costs for the Plans as they were reimbursed for their expenses anyway. The Boards could thus to some extent follow agendas other than those decided by the government. The Boards could for example encourage the administrators to spend additional time on the plans and with the farmers in order to improve networks, increase farmer knowledge or simply make the plans more detailed in order to increase pasture performance. As has been shown in previous studies, bureaucrats sometimes influence the policy process (e.g. Miller, 2004). It has for example been suggested that local labour market conditions and unemployment levels influence regulators strategies (e.g. Dion et al., 1998) and that membership levels in conservation organizations affect enforcement decisions (Firestone, 2002). Then, if the administrative costs of a particular choice of the administrator do not influence the administrators' budgetary expenses, it would be even more reasonable that the bureaucrats utilize their potential powers.

Materials and methods

In the previous discussion, it has been argued that transaction costs *should* depend on factors that are unavoidable and *may* depend on factors that should not influence the level of transaction costs. An example of the latter is a common preference formation at the local level that induces administrators to spend resources on activities that the central administrators have not previously planned for. That may result in different levels of transaction costs spending between counties. In the following, the unavoidable factors that reasonably should affect transaction costs will be referred to as economic factors whereas the factors that should not affect the level of transaction costs will be referred to as political factors. For clarity, the description of variables begins with the economic variables and then continues with the political variables.

Naturally, total transaction costs should increase with the number of maintenance plans created by the Boards. However, it is also reasonable to expect some efficiencies of scale in the number of plans that are created. If many plans are created in a given county, it may be possible to use resources more efficiently as slack could be avoided. Likewise, it is probable that if many plans are created, the people creating the plans become more efficient. These assumptions would imply that an increasing number of maintenance plans created would increase total transaction costs but decrease transaction costs per plan. These effects are captured by data on the number of maintenance plans created (PLAN) and the same variable squared (PLAN2). These assumptions would imply that the variable PLAN would be positive as TC increase with increasing number of plans, but that PLAN2 would be negative because of efficiencies of scale. The creation of maintenance plans necessarily implies some physical visits of the county boards' administrators to the farmers applying for the payments. Thus, some of the costs for the creation of the maintenance plans will be related to costs of transportation. Large distances contribute to transaction costs not only by the pure travel costs, but also through the cost increases incurred by time being spent on transportation rather than productive work. Since there are large differences in size between the Swedish counties, the effect of transportation costs could possibly explain some of the differences in TC, an effect that should be possible to capture through an indicator on the size of a county (CSIZE). A variable that should work in the opposite direction of CSIZE is the variable PGNO that measures the number of pastures in a county. The argument is that the presence of many pastures in a county implies that they are closer to one another than they are if there are few pastures. Thus, many pastures in a specific county could decrease transaction costs by lowering the time spent on transportation between pastures. An important aspect that should effect the magnitude of the transaction costs is the actual size of the pastures. Basically, the larger the pastures, the higher transaction costs could be expected to be. The argument is simply that larger pastures tend to consume more of the Boards' staff time as it will take longer time to accurately investigate the qualities of the pastures and set up the maintenance plans. Two alternative indicators are used as to capture the effect, the average size per pasture, aPSIZE, and the total county pasture size, PSIZE. The share of total pasture area that is deemed to be of high quality, QUAL, is used as a proxy for the quality of the land. The effect could work in two directions. One effect of high quality land could be that costs increase since the plans need to be more elaborate in order to account for the richness and complexities of the lands. On the other hand, the effect of poor quality lands could be an increase in costs since the previous degradation of the lands implies that the plans need to be more elaborate. The reason for this is that the plans have to be more detailed in order to specify the maintenance works that need to be fulfilled for the pastures the fulfill the requirements. Finally, it should be expected that transaction costs are affected by a time factor. With time, efficiency should increase as the administrators get more accustomed to their tasks. Thus, it is reasonable to expect time to have a negative effect on the level of transaction costs. The time effect of organizational learning that is expected to occur in the Boards is captured by the three time dummies y2001, y2002 and y2003.

As for political variables, a large population, POP, in a county could imply that there is a high demand for public goods. If that is the case, it may be the case that additional time is devoted to the maintenance plans in order to make the pastures more aesthetically attractive from a user perspective. Such efforts should then increase costs. It could however be the case that the population size per se has a minor affect, but that the population density POPDEN, is important. Local politics could possibly influence the transaction costs because of unemployment levels. Since someone else pays for the staff, the Boards may have incentives to hire more people than necessary to fulfill the task in an attempt to improve the employment situation. The indicator used for employment is share of working age population that is unemployed, UNEMP.

Drawing on the environmental Kuznets curve literature, a test is performed to see if income, INC, has some kind of effect on the transaction costs. The link could then be that with increasing income beyond a certain level, increasing demand for public goods leads to more resources being devoted to the creation of maintenance plants in order to improve the performance of pastures. Two variables that sometimes capture the same effect, the average age of the population, AGE, and the education level (measured as the share of the population that has at least three years of university education) EDU are also included in the data set. The literature on lobby groups and their influence on policy outcome is now substantial, and it is undeniably so that lobby groups sometimes manage to affect the policy process. In this study, the question of interest is whether lobby groups influence the implementation of policy. The argument in this context is that the stronger the lobby group in the county, the higher the expressed demand for public goods. The share of the population that is a member of Swedish Society for Nature Conservation (SSNC), LOBBY, is used as an indictor for lobby influence. If a high share of the population is member of SSNC, there may be high demands on the efforts of the Boards to create thorough plans. That would in turn increase the transaction costs. Occasionally, the population expresses their preferences through the procedure of voting at the municipality level. Even though local politics should not affect the county administrative boards, it is still possible that there is some link and influence between the composition of political parties in a county and the policy process. Local political configurations could affect the transaction costs by influencing the atmospheres in the counties and displaying implicit demands on the Boards' activities. That could especially be expected to be the case for two types of parties. Firstly, there are the parties that claim to be more environmentally friendly than others. A higher influence of those parties could increase costs as the Boards devote more time to the maintenance plans. In Sweden, the liberal Center Party (CP) and the left wing Green Party (MP) are the two parties that traditionally are associated with environmental friendliness. Secondly, there are the parties that follow a fairly conservative agenda, in the case of Sweden the Christian Democrats (KD). A conservative agenda could in the framework of agriculture be a preference for traditional pastoral landscapes. As the semi-natural pastures that the maintenance plans aim to promote are important aspects of these landscapes; one hypothesis is that conservatives wish to promote resources to the maintenance plans. The above mentioned parties could be expected to have an effect on the policy implementation at the margin in a county. In addition to the above mentioned parties, the party configurations left wing block (LWB) and right wing block (RWB) are also tested for influence. The variables for political influence are defined as the share of voters favoring a particular party or party configuration.

The econometric estimates in this paper rely on the availability of panel data for all 21 Swedish counties. The transaction cost estimates are data from the Swedish Board of Agriculture, which is the institution from where the County administrative boards retrieve the money used for the creation of the maintenance plans. The data on the area of high quality pastures that is used in the indicator QUAL is from Swedish Board of Agriculture. The data on membership in the non-government organization Swedish Society for Nature Conservation has been received from its central office in Stockholm. All other data have been retrieved from Statistics Sweden. The data covers the four year period 2000-2003 and the data is balanced, implying that there is a total of 84 observations. Data is continuous for the dependent variable and the variables PLAN, PLAN2, POP, POPDEN, UNEMP, INC, AGE. The remaining variables, except for time dummies and election results, are assumed constant over the period but in reality may the variables PSIZE, aPSIZE, PGNO and EDU have experienced some minor changes. Likewise, the variable LOBBY is not constant in reality as the number of members in SSNC is likely to have varied to some extent over the years. Data for this variable is however available only for 2002 and since changes over the period are likely to be relatively small, the variable is assumed constant in this paper. The indicator for landscape quality, QUAL, is also assumed constant event though some minor changes may have occurred over the period. The pastures were surveyed with respect to quality in the period 2002 – 2003. The period 2000 - 2003 covers two election periods as there was one election in 1998 and one in 2002. This implies that the result of the first election expresses preferences covering the period 2000 - 2001 and the second election the years 2002 - 2003. The election data is municipality votes that are aggregated to the county level.

If the administrators at the county administrative boards were indeed some kind of ideal bureaucrats in the Weberian sense, transaction costs would be expected to be a function of a set of economic factors. They would thus be a function of the number of maintenance plans, the size of the county, the size of the pastures and the quality of the pastures

in addition to other economic factors. A more realistic administrator may possibly be affected by political factors in addition to the economic factors. Examples of such factors may be lobby groups and local politics. An adjusted function for transaction costs would thus include those behavioral aspects and a complete econometric specification takes the following form:

$$TC_{i,t} = \alpha_{i,t} + \beta_{i,t} \cdot \mathbf{x}_{i,t} + \eta_i \cdot \mathbf{z}_i + \varepsilon_{i,t}$$

i=1,…,21 t=2000,…,2003 (1)

where $\mathbf{x}_{i,t}$ is a vector of the independent variables that vary in both time and space, and $\mathbf{z}_i$ is a vector of independent variables that are constant over the years but vary between counties. Since the data consists of a short panel (T=4) with relatively few observations in space (N=21), it is not possible to estimate all coefficients. Now, since all Swedish counties are investigated, a natural first suggestion for the empirical analysis would be to utilize the fixed effects model. The objection to that approach is however that it is necessary to incorporate the variables that are constant over time in the estimation, and thus the fixed effects model cannot be utilized. A less obvious estimation procedure is to utilize the random effects model. Although it may seem unlikely that the random effects model would be an appropriate model since the investigated counties cover all Swedish counties, the model could still be appropriate due to omitted variables in the error component. Bresuch and Pagan (1980) present a Lagrange multiplier test for the random effects model based on the OLS residuals to find out if it is an appropriate model despite the presumptions that it is not. Regardless of which independent variables that are included in the analysis, the results of the tests indicate that the random effects model is not appropriate. Another possible method that could be used to perform the estimation would be the between effects model. In that case though, the data for each county is averaged over the years and the estimation results can thus not describe any changes over time. Even if it is deemed suitable to ignore possible changes over time, the between effects model still produces relatively poor results and thus does not present a feasible estimation alternative.

A remaining option is to pool the data and perform a simple OLS analysis. In doing so, it is possible to test if time affects the transaction costs by implementing time dummies. The empirical specification then takes the form:

$$TC_{i,t} = \alpha + \beta \cdot \mathbf{x}_{i,t} + \eta \cdot \mathbf{z}_i + \gamma_1 \cdot D_{2001} + \gamma_2 \cdot D_{2002} + \gamma_3 \cdot D_{2003} + \varepsilon_{i,t}$$

i=1,…,21 t=2000,…,2003 (2)

Where, as previously, α is a constant, $\boldsymbol{x}_{i,t}$ is a vector of independent variables that vary with time and over space, $\boldsymbol{z}_i$ is a vector of independent variables that are constant over time but vary between countries and D_t are dummies capturing the learning process occurring over time. Initially, the Breusch-Pagan (Breusch and Pagan, 1979) test is performed to test for heteroscedasticity in the sample and the test reveals that there is heteroscedasticity in the sample. Thus, the regressions need to be adjusted for heteroscedasticity, something that in the following is done by applying the weighted least squares procedure and using the variable PLAN as weight. Since this paper is exploratory, it is desirable to establish if the parameters are robust with respect to model specifications. Therefore, in order to improve the strength of the results and especially establish if the significant variables are robust, an extreme bounds analysis will be performed.

The EBA version originating with Leamer (1978) will be utilized. Previous applications of the EBA have been related to growth theory, corruption studies, determinants of intra industry trade, foreign direct investment and trade creation in the presence of regional trade arrangements (for extensive references, see Nilsson (2007). Common to all studies is that there is a discussion in the research community whether or not various factors influence the dependent variable in a certain direction. In the growth literature, for example, a very wide range of factors have been suggested to contribute to, or damage, economic growth. In short, the central difficulty, which also applies to this study, is that many different models may seem reasonable given the data but yield different, or even opposite, conclusions about the parameters of interest. The basic idea laying the foundation for the extreme bounds analysis is that the researcher has an idea on some variables that definitely should be included in an analysis. These variables are commonly called *free* variables. The reason why the researcher believes those variables should be included in the regressions could for example be due to prior empirical consensus in the research community or

a solid theoretical foundation. In addition to the free variables there are also some variables that the researcher considers to be doubtful. One reason why the variables may be doubtful is that prior empirical investigations have shown inconclusive results. In our case, the EBA then uses an econometric specification of the following form:

$$TC = \alpha_j + \omega_j \cdot M + \beta_j \cdot F + \gamma_j \cdot Z_j + \mu \tag{3}$$

Where the dependent variable *TC* is, as previously, transaction costs, *M* is the variable that always is included in the regressions, in our case the number of maintenance plans created (PLAN), *F* is the variable of interest and $Z_j \subset N$ is a vector of up to three doubtful variables taken from the pool *N* of doubtful variables that may be related to the dependent variable, and μ is the error term. To apply the EBA, the specification is regressed for all possible combinations of $Z_j \subset N$ resulting in a total number of 1140 combinations. The extreme bounds test is applied on the variable *F* and for each model *j* one finds an estimate β_j and a standard deviation σ_j. The EBA criteria are as follows: If the *lower extreme bound* for β, which is equal to the lowest value for β_j achieved in any of the regressions *minus* two standard deviations (minβ_j-2σ_j), is negative, whereas the *upper extreme bound* for β, which is equal to the highest value for β_j achieved in any of the regressions *plus* two standard deviations (maxβ_j+2σ_j), is positive, then the variable *F* is considered to be fragile, i.e. not robustly related to *TC*. If, on the other hand, the lower extreme bound and the upper extreme bound share the same sign, then the variable *F* is considered to be robust. Henceforth, this criterion will be referred to as the *strong* EBA criterion. The criterion above is indeed very stringent as it implies that if there is *one* regression where the sign of the coefficient β changes, then the variable *F* is not considered to be robust. The criterion has been the focus of e.g. Sala-i-Martin (1994 i.a.) and Granger and Uhlig (1990) who both criticize the criterion on the grounds that it is too stringent. The main criticism by Granger and Uhlig is that the extreme values may come from combinations of variables that most economists would find unreasonable. They consider this problem by defining R^2-max as the R^2-value that is achieved by running a regression using all the free and doubtful variables at the same time. Then, it might be the case that the extreme bounds arise from variable combinations that achieve R^2-values very much lower than R^2-max and that those combination may be considered irrelevant because of the poor goodness-of-fit. Their suggestion is to rank the R^2-values achieved and include the rank in the presented statistics, thereby allowing a continuum of choices between Leamer's extreme bounds (any R^2) and classical econometrics (R^2-max). Sala-i-Martin's suggestion is similar insofar as he also suggests that it may be unreasonable to discard variables just because a single regression (out of possibly hundreds) fails to be significant with the right sign. Instead, he suggests that the variables of interest *F* should be ranked according to the share of variable combinations of *Z* that display significant regression results. Then one could set a weaker criterion allowing less than 100% of the regressions being significant with the right sign. This suggestion will be taken into account by following e.g. Fölster and Henrekson (2001) and Serra (2006) and presenting the fraction of regressions that are significant at the 5% level. Henceforth, this criterion will be referred to as the *weak* EBA criterion. Before starting with the EBA analysis, it should be noted that there is a high degree of correlation between some particular variables. For example, the correlation between QUAL and PGSIZE is 0.65. Often, a high level of correlation tends to decrease the robustness of the relationship between the independent and dependent variables when additional independent variables that are (highly) correlated with the dependent variable are included. In order to decrease the multicollinearity problem, I follow the suggestion by Beugelsdijk *et al*. (2004) and condition the *F* variables by a 0.5 correlation criterion and rerun the EBA. Thus, for each *F* variable, the *Z* variables that have an (absolute) correlation higher than 0.5 with the *F* variable are discarded.

Results and Discussion

Several pooled data OLS regression have been performed and the economic variables PGSIZE, PLAN, QUAL and the dummies for 2002 and 2003 are significant regardless of which other variables that are included in the regression. The two variables PGSIZE and PLAN have the expected signs: clearly, transaction costs increase with the number of plans that are created. Likewise, it appears that larger pastures imply higher transaction costs. Regarding the variable QUAL, it was previously argued that the standard of the landscape could drive costs in either direction. It does appear though that transaction costs are lower where the share of semi-

natural pastures is large in relation to the share of cultivated pastures, implying that a high quality of pastures decrease the costs. In addition to the three aforementioned variables, the time dummies for 2002 and 2003 are highly significant. The variables are large and negative, indicating that the county administrative boards do become more efficient over time, resulting in reduced transaction costs. The intercept is significant in four cases, all of which are positive. Regarding the political variables, four of the variables are significant at the five or one percent level. It appears as if the Christian Democrats, the Left Wing Block and the Right Wing Block increase transaction costs, whereas the Green party decreases transaction costs. That a high presence of votes for the environmental party decreases transaction costs is rather surprising as the opposite would have been expected. Although the results are interesting, not particularly inconclusive and the regressions evidently capturing a large share of the variability (the adjusted R^2 is 0.93 – 0.94 in all regressions), the EBA will be used to investigate if the results are robust.

Table 1

Results of Extreme Bounds Analysis

F var	Coef	t	p	Z	Excluded		Sign	R/F
Min	3547.6	18.6	0.00	aPGSIZE Y2002 Y2003		-	0	
PLAN					PLAN2, PGSIZE, y2001	Σ	100	R
Max	4509.2	22.0	0.00	PGNO C LWB		+	100	
Min	1.92	10.7	0.00	PGSIZE Y2002 Y2003		-	0	
PLAN2					PLAN,	Σ	100	R
Max	3.37	13.8	0.00	PGNO POP Y2001		+	100	
Min	17.84	2.84	0.01	PLAN2 LOBBY MP		-	0	
PSIZE					PLAN, aPGSIZE PGNO	Σ	100	R
Max	85.42	9.13	0.00	C KD RWB	QUAL	+	100	
Min	4.78E+04	1.27	0.21	UNEMP LOBBY MP		-	0	
aPSIZE					PGSIZE	Σ	99.9	R
Max	2.24E+05	6.40	0.00	LWB AGE EDU		+	99.9	
Min	-80.13	5.78	0.00	CSIZE C 2001		-	97.5	
PGNO					PGSIZE QUAL	Σ	97.5	R
Max	-8.58	0.70	0.48	aPGSIZE KD CSIZE		+	0	
Min	-1.26E+06	3.64	0.00	aPGSIZE C LWB		-	31.9	
QUAL					PGSIZE PGNO	Σ	31.9	F
Max	2.56E+05	0.56	0.58	CSIZE KD RWB		+	0	

Table 1 displays the results for the *F* variables of the EBA analysis that are robust plus one example of a non-robust variable. Only five of the regressions could be classified as robust. As a matter of fact, only three of the variables fulfill the strong EBA criterion and only 2 of the variables satisfy the weak EBA criterion. Starting with the variables that pass the strong criterion, the first one is the *M* variable PLAN. This one should of course be significant or we would have some serious problems. The other two are PLAN2 and PGSIZE, which are both positive. The implication of PGSIZE is that if the average pasture size in a county is large, then the transaction costs increase, essentially implying that cost per plan increases when average pasture size increases. The finding that PLAN2 is positive is somewhat surprising though. On the other hand, the coefficient is very low (the upper extreme bound has a value of only 3.4). The two variables that pass the weak EBA criterion are aPGSIZE and PGNO. aPGSIZE is positive and significant in 99.9 of the regressions run. It essentially captures the same effect as PGSIZE, i.e. the larger the pastures the higher the transaction costs per plan. The other variable that passes the weak EBA criterion is PGNO with 97.5% of the regressions being negative and significant. It thus does appear that if there are many pastures in a county, transaction costs decrease. The reason for this should be that if pastures are close to one another, staff transportation costs will decrease. A very important final result, contrasting strongly to the OLS regressions, is that none of the political variables is significant. To summarize the EBA results, the extreme bounds analysis does not verify the robustness of all the variables that came out as significant in the initial analysis. Indeed, all

the political variables are fragile according to both the strong and weak EBA criterion. In addition to that, the variable measuring the general quality of pastures, QUAL, is not robust. Likewise, it appears as if the organizational learning process captured by the time dummies was only apparent. When the EBA analysis is performed, the time dummies become fragile.

Conclusions

This paper has investigated the determinants of the transaction cost related to the Swedish agri-environmental policy measure for maintenance of pastures. The originating hypothesis was that two different set of factors influence transaction costs, *economic* factors and *political* factors. It was argued that the economic factors should influence transaction costs as these are factors that the administrators cannot really affect. It was also argued that, given the large variation in costs between countries, there may be other, political, factors that influence the transaction costs although they should not. In order to test the hypotheses, heteroscedasticity adjusted OLS regressions of various specifications were initially performed. These preliminary results indicated *inter alia* that political configurations at the local level might influence the level of transaction costs. It appeared for example that counties where a relatively large fraction of voters voted on the Green party had lower transaction costs than those where a large fraction voted on either the Christian Democrats, the left wing block or the right wing block.

In order to test if these results were robust or not, a modified extreme bounds analysis was performed. In the EBA, all the political variables came out fragile, leaving only a set of five economic variables robust. The results showed that the free variable, i.e. the number of maintenance plans created, clearly influenced the level of transaction costs. In addition to that, the size of the pastures had the expected influence; the larger the pastures, the higher the level of transaction costs. One of the economic variables, the number of existing pastures in a county, contributed to decreases in transaction costs. An explanation for this could be that if there are many pastures in a county, the pastures tend to be closer to one another, thus reducing transaction costs.

To conclude, it appears as if the level of the transaction costs investigated in this paper is not related to political factors but only to economic factors, and that administrators at the county levels are not unduly affected by local politics and public preferences. As far as is possible to tell from this study, the county administrators seem to behave as Weber's ideal bureaucrats. The reader should finally be reminded that it is a very specific share of the total transaction costs of the agri-environmental policy measures related to pasture maintenance that has been investigated in this paper. Although being highly important for implementation purposes and cost-efficiency, the entire chain of transaction costs should preferably be investigated. That task is however left to later research.

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RELATIONSHIP BETWEEN CORRUPTION LEVEL CHANGES AND ECONOMIC GROWTH IN THE WORLD AND EUROPE

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Abstract

The present article reviews part of a research paper on regional differences in evaluating economic growth and the various aspects that influence it.

In this publication, the relationship between changes in corruption level and economic growth is analyzed, paying close regard to all countries of the world and taking Europe separately as a region with relatively consistent economic and social development levels. The author analyzes the average values and changes in gross domestic product (GDP) per capita based on purchasing-power-parity valuation (in US dollars) for 1998 – 2005 and the corruption perception index (CPI) of 1998 – 2007.

When looking at data from all countries of the world and European countries, no interrelation can be observed between changes in CPI and GDP per capita. These values fluctuate independently of each other. The obtained results give rise to doubt whether CPI is a suitable indicator for determining the corruption level. The author concludes that assertions of negative (or positive) influence that corruption is said to have on GDP increase should be taken very critically.

Key words: corruption perception index, gross domestic product (GDP) per capita, linear regression.

Introduction

In previous 15 years, as seen in scientific studies, understanding of the influence that corruption has on economic growth has witnessed a revolution of a kind.

Mauro (1995) discovered that corruption has a significant negative influence on the amount of investment. Many researchers (Pellegrini & Gerlagh, 2006; Desta, 2006 and others) have assumed that negative influence of corruption on investment automatically produces a negative influence of corruption on economic growth. Drury et al. (2006) have proclaimed that corruption has a negative influence on economic growth, if all other factors are held constant.

However, as early as 2001, Getz and Volkema (2001) indicated that research on the influence of corruption on economic growth has produced controversial results, demonstrating both a positive and a negative influence on economic growth.

Revina's (2005) research on the influence of corruption produced quite peculiar results. Influence of corruption on economic growth had a determinative coefficient of only 0.17. However, if in the regression of economic growth investment, education, openness and political stability are included, while the corruption indicator is excluded, the determinative coefficient is 0.62 (Revina, 2005); and the greatest influence on growth is that of education (determinative coefficient being 0.69) (Revina, 2005).

Inconsistency of the above results promoted the formation of the research hypothesis, namely, that changes (specifically, reduction) in corruption levels have a positive correlation with economic growth, and invited to test this hypothesis by means of a quantitative analysis.

The present article reviews part of a research paper on regional differences in evaluating economic growth and its influence by various aspects.

In this publication, the relationship between changes in corruption level and economic growth is analyzed, paying close regard to all countries of the world and taking Europe separately as a region with relatively consistent economic and social development levels.

Aim of the present paper is to analyze relationship between corruption level and economic growth and possible impact to each other. The following objectives were defined in order to meet the aim of the paper:

1. To evaluate the relations of annual changes of corruption level and annual changes of GDP per capita with different years data sets.

2. To evaluate relation between long term corruption level and indicator of economic development GDP per capita.

Materials and methods

Before carrying out the research, quantitative data that would reflect changes in corruption levels, as well as data on economic growth levels had to be selected.

For quantitative analysis of the data set, the corruption perception index (CPI) created by Transparency International was selected. The main reason for selecting CPI data was an extensive availability of data for 1998 – 2007 (Corruption Perceptions Index, 2007). Moreover, as pointed out by Doug et al., (2006), CPI is the most widely cited corruption indicator. CPI has been widely used in scientific research when analyzing the influence of corruption on various spheres (Grigorescu, 2006; Khondker, 2006; Pellegrini & Gerlagh, 2006; Shen &Williamson, 2005).

In research where territorial development level must be assessed, the determinative indicator GDP growth rate per capita was used by Echevarría & Iza, (2006); Maasoumi et al., (2007); Hasler et al., (2006). Hence for this research annual changes in gross domestic product (GDP) per capita, based on purchasing-power-parity (PPP) valuation, were selected as an indicator, using International Monetary Fund World Economic and Financial Surveys obtained from the World Economic Outlook Database (World Economic Outlook Database, 2007), Gross domestic product (GDP) per capita: annual changes based on purchasing-power-parity (PPP) valuation.

Data on changes in percent in GDP per capita (in US dollars) are available in the database of IMF; these data were not altered. Changes in CPI were calculated according to the formula

$$C_{(\%)} = \frac{(C_2 - C_1)}{C_1} \times 100$$

where

$C_{(\%)}$ - changes in CPI, percent per base year

C_1 - CPI in previous year

C_2 - CPI in base year

To inquire into the relationship between CPI and GDP per capita, average data for the respective period (1998 – 2007 for CPI and 1998 – 2005 for GDP per capita) were used, calculations carried out by the formula

$$G_v = \frac{\sum_1^n G_n}{n}$$

where

G_v - average GDP per capita in time period *n*

G_n - GDP per capita in a specific year

n – number of observations included in calculations of the average value

Average CPI was calculated by the same method replacing GDP per capita with CPI.

The data set to undergo correlation and regression analysis between change in percent in CPI and change in percent in GDP per capita was formed by grouping changes in pairs. Changes of C in *n* years were verified, subjecting them to a regression and correlation analysis with GDP changes in the respective year (n), as well as in years (n-1), (n-2), (n-3) and years (n+1), (n+2), (n+3).

The author believes that, in the case of CPI and GDP, certain statistical indications are to be observed that reflect events or phenomena for which it is hard to distinguish between causes and effects. Krastiņš (2003) suggests that, in such cases, dependent and independent variables should be selected according to their qualitative attributes. When examining changes in percent for one year, changes in GDP per capita in the year in question were taken to be the variable indication, but changes in CPI in the year in question – as the resultant indication. In other cases, earlier data in terms of time (e.g., year *n*) were taken as the variable indication, while later data (e.g., year *n*+1, *n*+2 etc.) – as the resultant indication. Following the standard used by Frolova (2005), the zero hypothesis – namely, that the resultant indication is not influenced by the factorial indication of the regression – was tested for regression models, checking whether zero was included in the credibility interval of the regression coefficient. If zero appeared in the credibility interval of the respective coefficients of the regression variables in the regression equation, the factor in question was excluded from the equation.

In data matching, heed was paid to the fact that the CPI data timeline is irregular. In 1998, data on 86 countries and territories were available, in 2001 – on 92, but in 2007 – on 181 countries and territories (Corruption Perceptions Index, 2007). For GDP per capita, however, a full data timeline is available for almost all countries with only minor exceptions – such as data on Afganistan during the Talib rule, etc. (World Economic Outlook Database, 2007). This means that in the data analysis, only those years could be included for which both CPI and GDP were available. This in turn means that for each data set there was a different number of observations.

Results and discussion

Data on all world countries

Taking CPI changes of the respective year as the variable indication, and GDP per capita changes after three years – as the resultant indication, 442 observations were made. The determinative coefficient was 0.0001. The regression coefficient, in turn, was -0.00438. The lower and upper limits of the regression coefficient were -0.0389 and 0.0301 respectively, which indicates that the zero hypothesis cannot be rejected, as the regression coefficient with a probability of 95% does not differ from zero.

Taking CPI changes of the respective year as the variable indication, and GDP per capita changes after two years – as the resultant indication, 572 observations were made. The determinative coefficient was 0.0003. The regression coefficient, in turn, was 0.0060. The lower and upper limits of the regression coefficient were -0.0248 and 0.0368 respectively, which indicates that the zero hypothesis cannot be rejected, as the regression coefficient with a probability of 95% does not differ from zero.

Taking CPI changes of the respective year as the variable indication, and GDP per capita changes after one year – as the resultant indication, 715 observations were made. The determinative coefficient was 0.0007. The regression coefficient, in turn, was 0.0099. The lower and upper limits of the regression coefficient were -0.0182 and 0.0380 respectively, which indicates that the zero hypothesis cannot be rejected, as the regression coefficient with a probability of 95% does not differ from zero.

Taking GDP per capita changes of the respective year as the variable indication, and CPI changes in the respective year – as the resultant indication, 867 observations were made. The determinative coefficient was 0.0015. The regression coefficient, in turn, was 0.0972. The lower and upper limits of the regression coefficient were -0.0713 and 0.2658 respectively, which indicates that the zero hypothesis cannot be rejected, as the regression coefficient with a probability of 95% does not differ from zero.

Taking GDP per capita changes of the prior years as the variable indication, and CPI changes in the respective year – as the resultant indication, 1026 observations were made (Fig. 1). The determinative coefficient was 0.0032. The regression coefficient, in turn, was 0.1345. The lower and upper limits of the regression coefficient were -0.0108 and 0.2797 respectively, which indicates that the zero hypothesis cannot be rejected, as the regression coefficient with a probability of 95% does not differ from zero. Figure 1 shows that data are distributed almost symmetrically in relation to the axes of the graph, which indicates that their position resembles that of a random dispersion.

Taking GDP per capita changes of two prior years as the variable indication, and CPI changes in the respective year – as the resultant indication, 1026 observations were made. The determinative coefficient was 0.0013. The regression coefficient, in turn, was 0.0818. The lower and upper limits of the regression coefficient were -0.0588 and 0.2224 respectively, which indicates that the zero hypothesis cannot be rejected, as the regression coefficient with a probability of 95% does not differ from zero.

Taking GDP per capita changes of three prior years as the variable indication, and CPI changes in the respective year – as the resultant indication, 1026 observations were made. The determinative coefficient was 0.0001. The regression coefficient, in turn, was 0.0237. The lower and upper limits of the regression coefficient were -0.1163 and 0.1636 respectively, which indicates that the zero hypothesis cannot be rejected, as the regression coefficient with a probability of 95% does not differ from zero.

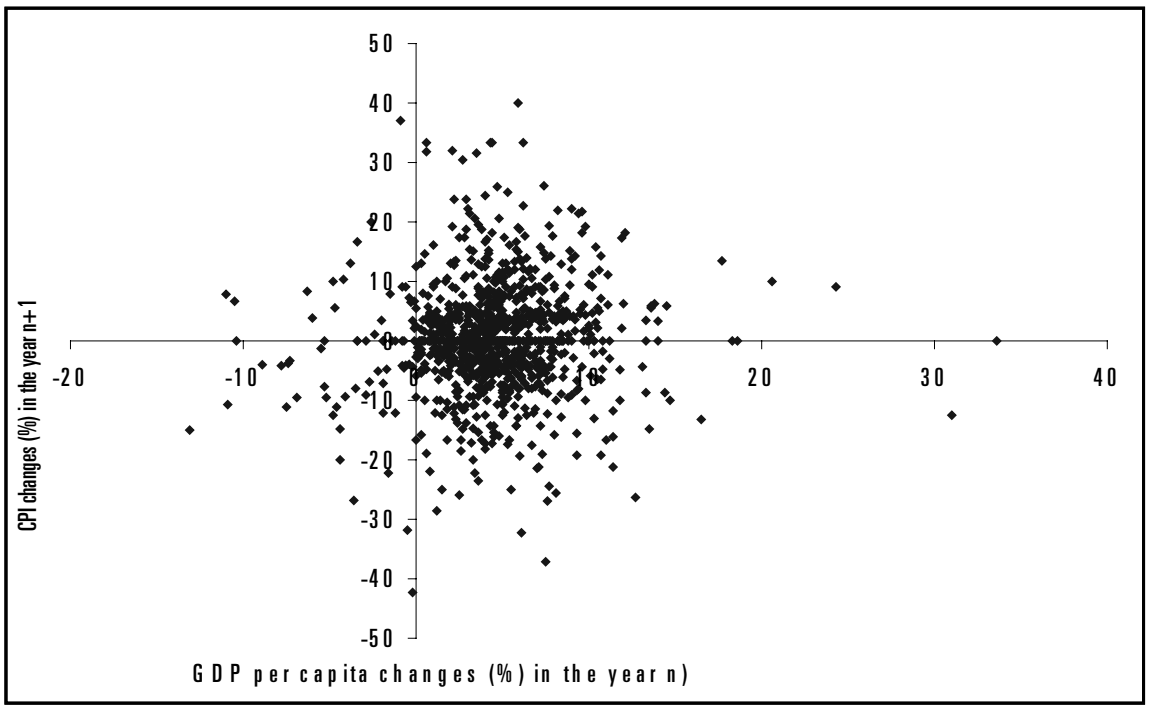

Fig. 1. GDP per capita changes (%) for all countries of the world in the respective year as the variable indication, on the horizontal axis; CPI changes (%) for the next year as the resultant indication, on the vertical axis.

Observing data for all countries in the woeld, no interrelationship can be spotted between changes in CPI and changes in GDP per capita. It must be concluded that these indicators fluctuate independently of each other. Using the determinative coefficient as a criterion, the best results appear in the connection between GDP per capita changes in the year before and CPI changes in the year in question. However, the determinative coefficient was only 0.0032, and GDP changes would explain only 0.32% of all dispersion of CPI changes (Fig.1). In this case also, the zero hypothesis that there is no regression cannot be rejected.

When tracing this lack of interrelationship between all countries of the world, a legitimate question may arise – that is, are the results similar when analyzing data from different regions? Moreover, Sah (2007) has reached a conclusion that corruption indicators are better used for comparing countries of the same region, but less effective when comparing countries from different regions. To test this hypothesis, data on European countries were separated from the data set on the world countries, and subjected to the same regression analysis as data on allcountries in the world.

Data on European countries

Taking CPI changes of the respective year as the variable indication, and GDP per capita changes three years later– as the resultant indication, 160 observations were made. The determinative coefficient was 0.0030. The regression coefficient, in turn, was 0.0167. The lower and upper limits of the regression coefficient were -0.0313 and 0.0647 respectively, which indicates that the zero hypothesis cannot be rejected, as the regression coefficient with a probability of 95% does not differ from zero.

Taking CPI changes of the respective year as the variable indication, and GDP per capita changes after two years – as the resultant indication, 197 observations were made. The determinative coefficient was 0.0168. The regression coefficient, in turn, was 0.0405. The lower and upper limits of the regression coefficient were -0.0032 and 0.0843 respectively, which indicates that the zero hypothesis cannot be rejected, as the regression coefficient with a probability of 95% does not differ from zero.

Taking CPI changes of the respective year as the variable indication, and GDP per capita changes after one year – as the resultant indication, 235 observations were made. The determinative coefficient was less than 0.0000. The regression coefficient, in turn, was -0.0020. The lower and upper limits of the regression coefficient were -0.0428 and 0.0389 respectively, which indicates that the zero hypothesis cannot be rejected, as the regression coefficient with a probability of 95% does not differ from zero.

Taking GDP per capita changes of the respective year as the variable indication, and CPI changes in the respective year – as the resultant indication, 273 observations were made. The determinative coefficient was less than 0.0000. The regression coefficient, in turn, was -0.0013. The lower and upper limits of the regression coefficient were -0.3680 and 0.3654 respectively, which indicates that the zero hypothesis cannot be rejected, as the regression coefficient with a probability of 95% does not differ from zero.

Taking GDP per capita changes of the year before as the variable indication, and CPI changes in the respective year – as the resultant indication, 311 observations were made. The determinative coefficient was 0.0017. The regression coefficient, in turn, was 0.1201. The lower and upper limits of the regression coefficient were -0.2093 and 0.4494 respectively, which indicates that the zero hypothesis cannot be rejected, as the regression coefficient with a probability of 95% does not differ from zero. Taking GDP per capita changes of two prior years as the variable indication, and CPI changes in the respective year – as the resultant indication, 311 observations were made. The determinative coefficient was 0.0028. The regression coefficient, in turn, was 0.1440. The lower and upper limits of the regression coefficient were -0.1610 and 0.4490 respectively, which indicates that the zero hypothesis cannot be rejected, as the regression coefficient with a probability of 95% does not differ from zero.

Taking GDP per capita changes of three prior years as the variable indication, and CPI changes in the respective year – as the resultant indication, 311 observations were made. The determinative coefficient was 0.0085. The regression coefficient, in turn, was 0.2382. The lower and upper limits of the regression coefficient were -0.0490 and 0.5254 respectively, which indicates that the zero hypothesis cannot be rejected, as the regression coefficient with a probability of 95% does not differ from zero.

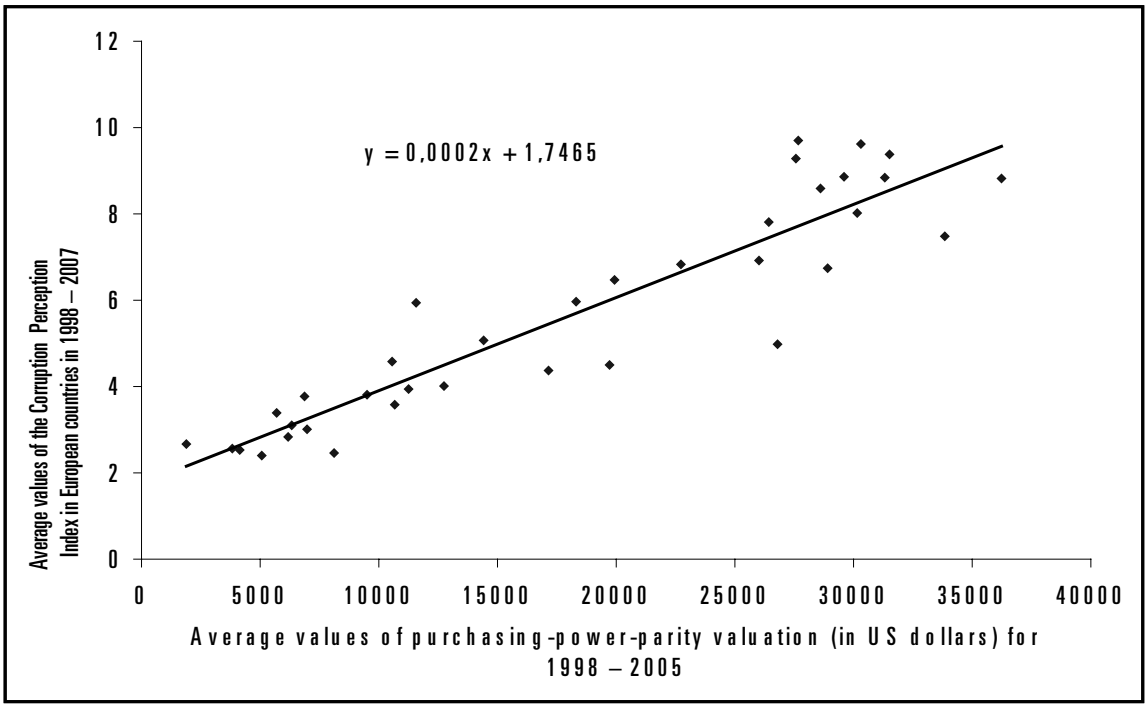

Fig. 2. Linear regression between gross domestic product per capita, based on average values of purchasing-power-parity valuation (in US dollars) for 1998 – 2005 (horizontal axis) and average values of the Corruption Perception Index in European countries in 1998 – 2007 (vertical axis).

Observing data for European countries, no interrelationship can be spotted between changes in CPI and changes in GDP per capita. It must be concluded that these indicators fluctuate independently of each other. Taking the determinative coefficient as a criterion, the result, when evaluating connectedness between GDP per capita changes and CPI changes in the respective year or the year before or after, is less than 0.002. The data are distributed almost symmetrically in relation to the axes of the graph, which indicates that their position resembles that of a random dispersion.

However, when looking at the average values in

European countries of average GDP per capita of a decade, and average CPI of a decade, a surprising similarity is observable in the spatial placement of these indicators. GDP per capita and synchronically CPI are high in the Nord and the West part of Europe and low in the East Europe. Regression analysis of these indicators (Fig.2) also shows a high connectedness between the two. The interconnection is almost functional.

Looking at gross domestic product per capita, based on purchasing-power-parity valuation (in US dollars) for 1998 – 2005, as the variable indication, and the average values of corruption perception index in European countries between 1998 – 2007, in the respective year as the resultant indication, 38 observations were made. The determinative coefficient was 0.7259. In turn, the regression coefficient was 0.000165. The upper and lower limits of the regression coefficient were 0.00013 and 0.00020, respectively, which indicates that the zero hypothesis can be rejected, as the regression coefficient differs from zero with a very high probability.

When analyzing European countries, a very high correlation can be observed between the average values of gross domestic product per capita, based on purchasing-power-parity valuation (in US dollars) for 1998 – 2005, and the corruption perception index in European countries for 1998 – 2007.

In political debates within Latvia it is often claimed that, in order to attain a certain goal, the value of another parameter must be influenced. Rather paradoxically, it was stated that a smaller level of corruption is cause for greater economic growth (one of Latvian political leaders and member of Latvian parliament, Aigars Štokenbergs in an interview to the daily newspaper "Diena" , (Štokenbergs et al., 2008)) or that a successful combating of corruption will result in a decrease in inflation (keynote announcement of Latvian political leaders and members of Latvian parliament Sandra Kalniete and Einars Repše before the parliamentary election (Repše & Kalniete, 2006)).

Problems often arise in Latvia when it is attempted to materialize political ideas dictated by the political situation through a specific economic policy.

In this sense, results obtained in this paper are an attempt to test by statistically measurable methods exactly how great the chances are of improving the quantitative indicators of one phenomenon – growth – by influencing the quantitative indicators of another – corruption.

In this sense, the obtained results are practically useful for creating a scientifically grounded system of measures that would stimulate economic growth.

The obtained results are controversial; a tight, almost functional connectedness is observable between the average values of GDP per capita and CPI, along with a total lack of connection between annual changes in these values, either synchronously or with an offset of one, two or three years.

Such results can possibly be interpreted by the methodological deficiencies of CPI.

Here it must be stressed that, according to Sajo (2003), corruption perception indexes are good for stirring up public interest, but the dynamics of these indexes depend on the political diary and create a sort of a *competition* between countries. One of the strongest points against over-reliance on CPI is that in many countries corruption of a high level is not taken notice of, and this creates a deformed perception of what corruption is (Sajo, 2003). It has been stressed that there is a methodical problem in adapting indexes by different agencies, because, ideally, the indexes of the same methodology and the same dimension should be used (Knack, 2007). Hwang et al. (2005), in turn, point out that the perception of corruption is too closely connected with the satisfaction of the people with government policies, hence the index can reflect the level of satisfaction or dissatisfaction with the government. Seligson (2006) criticized perception-type indicators from a different aspect, stating that corruption perception indexes are of a national level, but do not reveal problems of individual corruption. Moreover, Dreher et al. (2007) have concluded that perception-based indicators are not good in evaluating the actual corruption level of a country.

It is impossible to come to a practically unequivocal conclusion on the interrelationship between corruption and economic growth only from the obtained results. It is highly possible that, due to its methodological deficiencies, CPI cannot be used as an indicator, measuring the prevalence of corruption, that in the long term this indicator reflects the satisfaction level of the population with the economical situation in the country and that this would explain the almost functional interconnection between CPI and GDP per capita in Europe. Obviously, satisfaction with economical and general living conditions is higher in richer countries (Nordic and Central Europe) and lower – in poorer countries of Europe (Baltic, Balkans and former USSS area). Meanwhile, changes in short-term CPI and GDP depend on completely different factors.

Practically, there exist two probabilities. One is that CPI cannot be used as an indicator of corruption levels. The other suggests that statements asserting a positive or a negative influence of corruption on GDP growth should be taken very critically, and the argument stands that changes in corruption do not influence GDP per capita changes in any way.

To obtain more specific conclusions, similar quantitative research should be carried out, using other corruption indicators.

Conclusions

1. Observing data for all world countries, no interrelationship can be spotted between changes in CPI and changes in GDP per capita. These indicators fluctuate independently of each other.
2. Using the determinative coefficient as a criterion, the closest connection appears between GDP per capita changes in the year before and CPI changes in the year in question, with a determinative coefficient of 0.0032.
3. Observing data for European countries, no interrelationship can be spotted between changes in CPI and changes in GDP per capita. These indicators fluctuate independently of each other.
4. When analyzing European countries, a very high correlation can be observed between the average values of gross domestic product per capita, based on purchasing-power-parity valuation (in US dollars) for 1998 – 2005, and the corruption perception index in European countries for 1998 – 2007.
5. The obtained results give rise to doubt whether CPI is a suitable indicator for determining the corruption level. Statements proclaiming a negative (or positive) influence of corruption on GDP growth should be taken very critically.

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ENSURING OF TAX REVENUE BUDGET PLAN

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Abstract

The concept of the state fiscal policy is developed by the Ministry of Finance and the Ministry of Economics. The State Revenue Service (hereinafter - SRS) is the administrative body carrying out the fiscal policy in Latvia.

Ensuring of tax revenue is the main operational task of the SRS. Based on the consideration that the tax revenue plan for the regions is drafted correctly, i.e. by taking into account the macroeconomic situation in the country and the research contains calculations of the regional budget revenue plan performance indicators which prove that the regional tax revenue planning method is efficient thus efficient tax administration is one of the main factors influencing tax revenue.

Considerable part of the research is devoted to the role of the SRS and its operation in order to improve the tax administration efficiency. Polls concerning satisfaction of the SRS clients are carried out for this purpose. By evaluating the poll results it has been stated that by organising seminars for taxpayers the specific character of business in any particular region should be taken into account. It would be useful to organise thematic seminars about applying taxes in specific business areas. In Kurzeme region and Riga it would be efficient to organise seminars on applying of taxes for businesses dealing with international transportation by sea and businesses supplying goods and rendering services for ships which are used for navigation in international waters.

Key words: tax policy, tax administration, tax revenue, SRS clients' consultations.

Introduction

Fiscal policy is one of the methods how the state can influence the economy. Fiscal Policy finds its practical manifestation in the state budget - government revenue and expenditure estimate which is approved by Saeima as a government law. Changes in the state budget require for voting by the Saeima. Tax revenues, in their turn, form the main source of government revenue.

Successful tax revenue collection is influenced by efficient tax administration and economic growth of the country.

Taking into consideration that the amount of voluntarily paid taxes form the greatest part of the taxes collected, for instance, in the year 2007 it constitutes 97.5 per cent, but only 2.5 per cent have been additionally calculated as the result of audits, it is very important to facilitate voluntary tax compliance.

Ensuring of budget revenues in regions is selected as the research object. Subject of the research: tax revenues in the regions. Hypothesis of the present research: selection of efficient tax revenue planning is the decisive factor for performance of the regional action plans. The objective of the research is evaluation of the tax revenue planning method and development of proposals for improvement of consultations.

In order to achieve the objective the following tasks have been solved: study and evaluation of the characteristic indicators of the tax revenue plan fulfilment by the regions, poll of SRS clients satisfaction as been carried out and evaluated and development of proposals for improvement of the quality of consultations.

Due to the limited volume of this article, it presents only the main research results.

Evaluation of tax revenue planning method effectiveness is a novelty.

Materials and Methods

Data about tax revenue collection for the years 2005-2007 in SRS Riga, Kurzemes, Latgales, Vidzemes and Zemgale regions, characteristics of macroeconomic strategy developed by the Ministry of Finance for the years 2005-2007, laws on the state budget, The Administrative Offences Code, Law of the Republic of Latvia 'On Value added Tax', research on the satisfaction of SRS clients (SRS, 2007), SRS tax administration tax control work results for the years 2005-2007 (SRS NTB, 2005, SRS NBT, 2006, SRS NTB , 2007). Analysis of variation indicators and analysis of the polls for SRS clients are used as the research methods.

Results and Discussion

SRS is a government institution that operates under the supervision of the Ministry of Finance and ensures recording of taxpayers, collection of state taxes, fees and other state mandatory payments in the territory of the Republic of Latvia and at the customs border, as well as carries out customs policy and deals with customs matters.

According to the definition provided in SRS strategy (2004) 'SRS Tax Administration Strategy for the Years 2005-2009', tax administration is an aggregate of all mutually related processes the objective of which is to ensure complete, timely and fair collection of taxes in accordance with the tax laws including registration of taxpayers, recording of tax revenue, tax control, tax enforcement and consultation of taxpayers.

During the recent years many scientists have studied the problems of improving tax administration efficiency in Latvia (Filipoviča, Lāce, 2004; Kauliņa, 2007). Filipoviča, Lāce (2004), in their article 'The Problem of Formulating the Objectives of Tax Administration' express their view that the basic objective of tax administration cannot be limited only to collection of tax revenue. According to the opinion of the author, compliance with the national tax legislation should be more important than ensuring of tax revenue, since it ensures fulfilment of the fiscal and economic function of taxes, as well as compliance with the bookkeeping rules. According to Filipoviča and Lāce (2004) the concept of tax administration could be formulated as follows: 'Tax administration is coordinated action aimed at ensuring tax legislation'. This opinion is disputable. Compliance with bookkeeping legislation cannot end in itself. For instance, if the taxpayer of the Latvian value added tax (hereinafter - VAT) carrying out VAT taxable transactions and purchasing goods in Finland, without importing them to Latvia, immediately sends them to Russia, then VAT of 0% is applied to this transaction and it is shown on VAT declaration. But according to the tax legislation in VAT area the norms of the law 'On Value Added Tax' are not applicable to this transaction. In this case the tax legislation has not been observed, but it will influence tax calculations. Thus in the aforementioned case and similar cases it is not efficient to load the tax administration system with extra expenses for the purpose of achieving compliance with the tax legislation. In this case there are no signs of administrative offence, as according to Article 9 of the Administrative Offences Code (Supreme Council of the LSSR, 1984) and administrative offence is an unlawful, blameable (done deliberately or through carelessness) action or inaction which jeopardizes the state or public order, property, rights of citizens or the government order and which falls under the law as administrative responsibility.

Filipoviča and Lāce (2004) in the aforementioned article suggest formulating the main objective of tax administration as facilitation of voluntary compliance of a taxpayer with the tax legislation requirements. Of course, this suggestion is not disputable, as voluntary tax payments form the most part of tax revenues.

It should be noted that in the SRS development strategy for the years 2007-2009 the objective to ensure voluntary tax and customs liabilities has been set as the first strategic objective.

For comparison, in Latvia the collected tax revenue in 2007 constituted 4,312.36 million lats, but the amount calculated as the result of audits – 105.9 million lats. The amounts to be paid has been reduced by 1.8 million lats as the result of taxpayers' claims against the decisions made by the SRS officials. Thus the calculated additional tax payments to the budget after the appeals constitute 104.1 million lats (SRS, 2008). Consequently, the voluntarily paid tax revenue in the year 2007 constitute 97.5%.

Tax administration problems have been studies also by Joppe (2008) in her promotion paper "Improvement of Tax Administration". Definition of tax administration conception on the basis of analysis of scientific articles is one of the scientific novelties of the present paper. Joppe in her research has found two approaches to the tax administration definition. One of them - which tax administration, is an action by the tax administration controlling compliance with legislation and the other - that tax administration is management of tax system. Joppe doesn't agree with the viewpoint that tax administration istax control. In her paper Joppe expresses the point that tax administration is part of management of state tax system.

The author agrees to the approach of Joppe, as in Latvia tax adminsitartion functions are separated from tax policy functions and they are carried out by two institutions - SRS and the Ministry of Finance. But the management of tax system includes both functions.

Mr.Kalniņš in his article "VAT - value added or lost tax"(2006) writes about tax administration problems related to tax fraud and points out that the situation has improved in comparison to the year 2000, however it is not perfect.

Of course, one could agree to this opinion that the situation is not ideal. However I would like to

admit that it is not possible to fight against tax fraud only by way of improving tax administration. First of all, several amendments to the legislative acts should be made for this purpose, which would enforce responsibility for fraud in the tax area and would reduce the possibilities to carry out fraudulent activities.

Solid increase of tax revenue is observed in comparison with the previous period.

Table 1

Total budget revenue administered by SRS for the years 2002-2007 in Latvia (million Ls)

Year	Tax revenue	Increase, compared to the previous period, million Ls
2002	1,634.54	-
2003	1,823.20	188.66
2004	2,111.12	287.92
2005	2,657.07	545.95
2006	3,436.16	779.09
2007	4,312.36	876.20

Source: SRS (2002-2007) data

After the approval of the current state budget the SRS receives an order issued by the Ministry of Finance for the annual tax revenue plan. Then the SRS central administration approves tax revenue plan for the regional offices.

In order to reduce the tax planning risks for the regions, it is efficient to use information about the object indicators in the previous periods, as such data will include all functioning and development qualities of an object, as well as to consider other factors of influence. Those factors which influence the economic situation in the country, and, thus also the tax revenue are important, for instance, such factor as the economic growth in the country, which influences the tax revenue in proportion to the tax base is considered when the Ministry of Finance develops the forecast of macroeconomic situation for the current year on the basis of which the state budget is approved. Besides, when carrying out the tax revenue planning for the regions, the migration of businesses from one SRS regional office to other is considered this factor has considerable impact on the tax revenue in the regions. Thus, when drafting the tax revenue plans for the regions the results for the previous year and the migration of the businesses are taken into consideration. The present research contains data of tax revenue performance of 5 SRS regional offices (Riga, Kurzeme, Vidzeme, Latgale and Zemgale) considering the similarity of functions in the regions and the structure of taxpayers (data from SRS Large Taxpayers Department, Excise Goods department and Riga Customs House). The study has been carried out on the basis of SRS data.

Table 2

Information on the Fulfilment of the Action Plan of SRS Regional Offices in Latvia, 2005 (thous. Ls)

SRS regional office	Plan	Actual	Fulfilment %
Riga Regional Office	1,058,652.3	1,139,341.1	107.6
Kurzeme Regional Office	91,988.2	98,210.6	106.8
Latgale Regional Office	75,857.1	80,310.3	105.9
Vidzeme Regional Office	71,168.1	72,927.1	102.5
Zemgale Regional Office	95,151.4	99,604.4	104.7

Source: SRS data

In order to evaluate tax revenue plan fulfilment results, calculation of the standard deviation and variation coefficient of the plan performance percentage was carried out.

Standard deviation is defined as the square root from dispersion (Krastiņš, 1998), and it is identified by the symbol *s*.

$$s = \sqrt{\frac{\sum_{i=1}^{n}(X_i - \overline{X})^2}{n}} \qquad (1)$$

Table 3

Information on the Fulfilment of the Action Plan of SRS Regional Offices in Latvia, 2006 (thous. Ls)

SRS regional office	Plan	Actual	Fulfilment %
Riga Regional Office	1,542,614.46	1,604,019.2	104.0
Kurzeme Regional Office	119,946.05	124,834.5	104.1
Latgale Regional Office	97,629.38	102,883.7	105.4
Vidzeme Regional Office	92,176.56	96,610.1	104.8
Zemgale Regional Office	126,935.7	133,512.8	105.2

Source: SRS data

By putting the respective figures in the formula (1) and calculating *s* from the data in tables 2, 3 and 4, we get that the value of *s* concerning the results of 2005 equals 1.78%, of 2006 – 0.72%, of 2007 – 2.79%.

Table 4

Information on the Fulfilment of the Action Plan of SRS Regional Offices in Latvia, 2007 (thous. Ls)

SRS regional office	Plan	Actual	Fulfilment %
Riga Regional Office	1,917,976.25	2,219,160.3	115.70
Kurzeme Regional Office	147,123.97	181,108.04	123.10
Latgale Regional Office	118,465.76	141,659.0	119.58
Vidzeme Regional Office	117,043.51	135,620.3	115.87
Zemgale Regional Office	155,296.53	181,783.3	117.05

Source: SRS data

Also, the relative variation indicator is calculated, which is an unnamed figure and does not depend neither on the unit of the studied feature, nor on its average value. The relative value of the variation is characterized by the variation coefficient, which is calculated by dividing the standard deviation by the arithmetical average (Krastiņš, 1998) and it is identified by *V*.

$$V = \frac{s}{\overline{X}} \times 100 \qquad (2)$$

By making the calculations by formula (2), we get that *V* for the year 2005 equals 1.69%, 2006 – 0.69%, 2007 – 2.36%.

Therefore, the standard deviation of the tax revenue plan implementation of five regions, as well as the variation coefficient does not exceed 3%. This allows making the statement that the selected regional tax revenue planning method of the regions is very effective.

Assuming that the regional tax revenue plan has been drafted correctly, that is, macroeconomic situation in the country has been taken into consideration and, as proved before the regional tax revenue planning methods are effective, then one of the main factors which will influence tax revenue is effective tax administration. Taking into account that voluntary paid tax revenues form about 98 per cent of the tax revenue and the fact that audit inspections are carried out only for a small part of taxpayers, for example, in 2007 in the country 950 legal persons were

audited, that is, 0.7% of the total number of legal persons registered in the taxpayers register (SRS National Tax Board, 2007), it is clear that is important to facilitate voluntary paid tax revenue, and one of the main factors, facilitating the voluntary tax payment, is consulting and educating taxpayers.

SRS in 2007 (SRS, 2007) has carried out a research on the client satisfaction about SRS services; the questionnaire included also questions concerning the evaluation of consultations.

During the survey, the respondents were given 2249 questionnaires, but the total number of respondents the opinion of whom will be analyzed further, is 2017.

The cluster of the client questionnaire respondents was divided into 3 groups – self-employed persons, natural persons and legal persons. In the given research the evaluation of SRS consultations is expressed as a separate factor of the client satisfaction, as it unlike other services, is of great significance in cooperation with a client. The client knowledge about the fulfilment of liabilities set by the state, the client action, loyalty and further cooperation greatly depend on the quality of consultations.

To indicate the factor, two questions by the help of which the client has to evaluate the quality of consultations in tax and customs matters, as well as one question whether SRS in correspondence with the client uses simple and understandable language are used. The evaluated coefficient of each client satisfaction factor is determined as an average value from all the answers used to indicate the factor (evaluated coefficients). The numerical value of each question is calculated as a coefficient within the range from 0 to 1. A positive answer inclines toward 1, a negative one – towards 0 (the value depends on the selected answer), and the answer of the respondent 'difficult to say' or 'average' is assigned a coefficient 0.5. The total question coefficient is gained by calculating the average value of all the given answers.

In general SRS clients are satisfied with SRS consultations. By looking at the table below, it can be concluded that SRS consultations in tax administration are highly valued. The coefficients of client satisfaction factor are relatively high – within the range of 0.7 – 0.8, which means that mathematically they are much closer to 1 (absolute client satisfaction value) than to zero (absolute client dissatisfaction value).

Table 5

'Consultations evaluation' for the questions included in the SRS satisfaction factor

Question number	Questionnaire question	Evaluated question coefficient
1	Consultations (taxes)	0.803
2	Consultations (customs)	0.725
3	SRS in the correspondence with the client uses simple and understandable language	0.730
SRS client satisfaction factor''SRS client consulting' assessed coefficient		0.753

Source: Research of the SRS (2007) client satisfaction of 2007

According to the results of the SRS research, significant sources of information for clients are free seminars and consultations, since the awareness of the rights and liabilities of the clients as well as normative enactment requirements to great extent depend on the quality of these services. Services to great extent depends on the awareness of the clients of their rights and liabilities, as well as of the. However, clients, who are aware of their right and liabilities and are satisfied with the quality and rapidity of SRS services, most frequently note that they are loyal towards the state regarding the payment of the state taxes, thus qualitative SRS work promotes client loyalty. The research proved that the most popular are consultations provided at SRS offices and by phone. Least used are electronic consultations. Most of the clients as the most appropriate means of consultation choose on the spot consultations which require most from SRS specialists and, as well as form queues in the client service halls. Taking into consideration that also free seminars for taxpayers make a significant source of information, special attention should be paid to organization of seminars for taxpayers, which could allow reducing the load of tax administration employees.

As the author is a lecturer in the seminars on the application of the value added tax organized for accountancy employees taking place in different regions of Latvia, the author has observed that when organizing seminars for taxpayers attention should be paid to the business specifics of the particular

region. Thus, for example, in Liepaja (Kurzeme region) the value added tax application matters upon conducting marine goods international carriages, as well as for supplies of goods for ships, which are utilised for navigation in international waters are especially important. In Riga, in its turn, issues on the value added tax application in transactions with real estate, also in transactions related to supplies to these ships, international transport carriages, supplies and acquisition of goods in the territory of the European Union, financial transactions are more important. In Latgale region there are more questions about the application of the value added tax to services of goods transport, services rendered by processing companies, export and import transactions.

Conclusions

1. The tax revenue plan for regions during the study period, i.e. the years 2005-2007 is fulfilled with surplus. The standard deviation from the tax revenue plan for regions, as well as the variation coefficient does not exceed 3%. This allows to declare that the selected tax revenue planning method for the regions is very efficient. Thus the hypothesis advanced for the present study is proven to be true.
2. Assuming that the tax revenue plan for regions has been drafted correctly, that is, taking into account the macroeconomic situation in the country and the results of the research show that the regional tax revenue planning method is effective one of the main factors which will influence tax revenue will be effective tax administration.
3. Voluntary paid tax revenues constitute the basic part of the total tax revenue. Besides, taxpayers consulting and education are one of the most important factors facilitating voluntary tax payments. Thus special attention should be paid to improvement of taxpayers consulting and education in order to increase the effectiveness of tax administration.
4. Clients, who are aware of their rights and are satisfied with the quality and speed of SRS services, more frequently note that they are loyal towards the state in regard to the payment of state taxes, thus qualitative SRS work promotes client loyalty.
5. The most popular are consultations at SRS offices, however, they require from SRS employees most of the time, as well as form queues in the client service halls. Taking into consideration that free seminars for taxpayers also form a significant source of information, one should pay particular attention to their organization, which at the same time would allow reducing the load of tax administration employees.
6. When organizing seminars for taxpayers one must take into account the business specifics of the particular region. In Kurzeme and Riga it would be useful to organize seminars on tax application to companies dealing with international sea carriages and companies, supplying goods and rendering services to ships, which are used for navigation in international waters.

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PRIMARY ENERGY RESOURCE CONSUMPTION

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Abstract

Primary energy resource consumption in the world is surveyed in the work and oil yield, production and consumption evaluated on the world level, also showing its density in the view of several states. Oil reserves are evaluated and the states with biggest oil reserves stated. The research proves consumption of primary energy oil in the world is increasing continuously. There are primary energy resources to be acquired in Latvia evaluated and primary energy resources in means of final consumption divided between types of energy estimated.

Key words: energy, oil, energy, production, consumption, proved reserves.

Introduction

Adequacy of energy in the state is the question of the state economic development, provision of life quality and state security. The aim of development of energetic is to secure balanced, quality, safe and sustainable provision of national economy and inhabitants with energy. Nowadays the mankind cannot be visualized without usage of energy in all spheres of national economy. Energy is mainly contracted from primary energy resources.

In the nearest decades people will face the problem that can be serious or even dramatic: the main source of primary energy – fossil fuels and oil in particular is dissolving.

Scientists of many countries have investigated oil reserves in bowels of the earth and elaborated adequate models to foresee extraction as for non-renewable energy resource.

Hotelling created the first model of mineral economy in his classical document (Hotelling, 1931). Later dissolving of the planet resources was modelled by Forrester/Meadow in 1972. He studied "limitations of increase" (Meadows et al.,1972) Hubbert created another approach – he modelled raw oil production in the USA in 1960ies (Hubbert, 1962). He used empirical approach based on a bell-shaped schedule/curve. The model planned culmination of production in the USA in 48 states, after that – drape.

Recntly other authors used Hubbert `s curve to foresee raw oil production evolution on the level of the planet (Deffeys, 2001; Bentley, 2002; Campbell and Laherre, 1998). Characteristic trait of this modelling is – gradual resource diminishing (we can even say – production / extraction does not go to zero Houthakker, 2002) That is why production culmination point is the most serious event in the history of oil extraction. It will be turning point that will mark epochal changes from cheap oil to expensive oil (Campbell and Laherre, 1998) Following Hubbert production culmination point will be "in the middle" that is when approximately half of the reserves – of the primary renewable resources – will be depleted. Different evaluations show that there are almost one trillion barrels extracted out of the contingent two trillion barrels of oil. (Campbell, 2003).

Although Hubert's model describes models of local resource diminishing, it is not possible to describe global resources and their condition with the help of it. Hubert's symmetric curve differs from Forrester/Meadows models (Meadows, 1972) that are equally asymmetric with diminishing, reduction of extraction; much sharper with increase.

Some models exist that are described in literature and give the beginning for a bell-shaped curve of non-renewable resources. This basic approach can be considered the classic 'Lotka-Valterra' model that is known since 1925 (Lotka, 1925), known also as "foxes and rabbits" model. This model can be attributed also to extraction of non-renewable resources.

In recent years Reinolds (1999) offered approach to mineral economy that reproduces the bell-shaped Hubert's curve. Reinhold's model is described as "Robinson Crusoe's hardtack" method. Let's assume there are no more shipwrecks in the world and there are only hardtacks left from the previous ship wrecks –dug in the ground. Hardtack tins can be considered to be non-renewable resources. Depending on how many tins of hardtacks are dug in the ground and how will Robinson Crusoe be able to find them – either he will die old with many tins of hardtacks still in the ground, or he will live very short.

Delusive assumption that the resources will last forever can lead to wrong way. One day the resources will be over and the mankind will not know what to do.

In Latvia there are researches done on investigation of renewable energy resources and their usage. Academic and member of Latvian Bio-fuel Association Arnis Kalniņš (Kalniņš, 2005, 2006) has done feasibility study and research on the existent situation and bio-fuel production possibilities in Latvia. Research material is made as the future economy strategy foreseeing development tendencies – agriculture plant possible practical usage as a renewable energy porter for fuel production.

Under guidance of Vilnis Gulbis, professor of the Institute of Power Machinery of the Faculty of Engineering, Latvia University of Agriculture actual research on qualities of bio-diesel and influence of different type of bio-fuel and their mixtures on operation of means of transport was done and possibilities of their development (Gulbis, Birzietis, 2006) were mentioned.

To do research on consumption of energy resources in Latvian agriculture, it is essential to know consumption of primary energy on global level – in the world, especially oil – the main resource in gasoline extraction and production. That is why the author has investigated the world primary energy consumption in the world, oil extraction and consumption, also proved oil reserves.

Hypothesis of the research – consumption of primary energy increases that would increase resource dynamics in Latvia and the world.

Aim of the work – to do research on consumption of primary energy.

Nominated tasks for reaching the aim:

1. Do research on primary energy consumption in the world.
2. Investigate oil extraction and production in the world.
3. Investigate oil consumption in the world.
4. Evaluate oil resource proved reserves in the world.
5. Investigate primary energy resources extractable in Latvia.
6. Investigate Latvia `s biggest primary energy resources in final consumption – split in types of energy.

Materials and Methods

Calculation constructive method, comparison, monographic, graphic methods are used for data and research processing.

The research is based on the author `s theoretical and practical knowledge and investigation connected with execution of the promotion work theme.

Scientific literature, data from Central Statistic Board, Internet materials, publications in press are used in elaboration of the work.

Results and Discussion

The world is rich in different energy resources. Technically possible extractable and acquirable resources in the world constitute comparatively small part against theoretical energy resources. Out of non-renewable energy resources gas with 22.5% is the biggest technically acquirable energy resource. From renewable energy resources it is technically possible to acquire comparatively more energy out of organic waste 49.2% and hydro energy from big water flows 44.9%.

In the first table we see that total consumption of primary energy in the world has a tendency to grow – in 2006 chain increase tempo was 3.0% and base increase tempo – 29.5% compared to 1995.

Energy chain starts with energy gathering and extraction in its primary form. Crude oil takes the leading role in the field of energetic resources. Density of crude oil products is growing continuously among energy resource types: 3% - in 1900, 5% - during World War I (1914 – 1918), 17.5% - during World War II (1939 – 1945), 24% - in 1950.

In table 1 we can see that in the world: consumption of crude oil is increasing with years and its density is the highest out of all used energy types. But density of crude oil consumption in total consumption of primary energy in the period from 2000 until 2006 has decreased by 2.8%.

Density of natural gas energy consumption in the world in the period from 2000 until 2006 has increased by 0.6%. The highest base and base increase tempo is in 2006 respectively: 4.5% and 38.5%.

Coal energy consumption density in the world has got a growing tendency in recent years in the range of 24.4% until 26.6% in 2006. The highest chain increase tempo for coal is 4.8% and base increase tempo is 26.6% in 2006.

In the world hydroelectric energy consumption grows: base increase tempo in 2006 reached 16.3 %, but density of its consumption in the world has decreased: in 2006 – 6.2 %, but in 1995 – it was 6.9%.

Atom electric energy (nuclear energy) in 2006 has got the highest base and chain increase tempo: 1.4% and 17.0%. Consumption has decreased during the years. Density in total consumption in 2006 constitutes 5.8%.

Table 1

Primary energy resource consumption in the world 1995 – 2006 (quadrillions British Thermal Units)

Title	Unit	1995	2000	2001	2002	2003	2004	2005	2006
Crude oil	Btu	142.4	155.4	156.8	158.1	161.5	167.5	169.7	171.2
Specific weight total consumption,	%	38.9	38.9	38.9	38.6	37.9	37.5	36.9	36.1
Base increase tempo	%	0	9.1	10.1	11.0	13.4	17.6	19.2	20.2
Atom electric energy	Btu	23.3	25.7	26.4	26.7	26.4	27.5	27.5	27.7
Specific weight in total consumption	%	6.4	6.4	6.5	6.5	6.2	6.2	6.0	5.8
Base increase tempo	%	0	10.3	13.4	14.7	13.7	18.1	15.4	17.0
Natural Gas	Btu	81.1	91.4	92.8	96.1	99.6	103.4	107.6	112.4
Specific weight in total consumption	%	22.2	22.9	23.0	23.5	23.4	23.2	23.4	23.7
Base increase tempo	%	0	12.6	14.4	18.4	22.8	27.4	32.6	38.5
Renewable energy	Btu	4.5	5.2	5.1	5.4	5.7	6.0	6.4	6.8
Specific weight in total consumption	%	1.2	1.3	1.3	1.3	1.3	1.3	1.4	1.4
Base increase tempo	%	0	15.6	13.3	20.0	26.7	33.3	42.2	51.1
Hydroelectric energy	Btu	25.3	27.0	26.4	26.4	26.8	27.5	28.5	29.5
Specific weight in total consumption	%	6.9	6.8	6.5	6.5	6.3	6.2	6.2	6.2
Base increase tempo	%	0	6.6	4.1	4.4	5.9	8.6	12.7	16.3
Coal	Btu	89.1	94.9	96.1	97.0	105.6	114.5	120.3	126.1
Specific weight in total consumption	%	24.4	23.8	23.8	23.7	24.8	25.6	26.2	26.6
Base increase tempo	%	0	6.6	7.8	8.9	18.6	28.6	35.1	41.6
Sum total	Btu	365.7	399.6	403.5	409.7	425.7	446.4	460.0	473.7
Chain increase tempo	%	0	9.3	1.0	1.5	3.9	4.9	4.0	3.0
Base increase tempo	%	0	9.3	10.3	12.0	16.4	22.1	26.9	29.5

Source: author `s table following International Energy Agency 2006.

In usage of renewable energy resources in the world increase is noticed from 4.5 quadrillion Btu in 1995 to 6.8 quadrillion Btu in 2006. Renewable energy resources are the real future resources because fossil energy resources are subsiding. Base increase tempo in 2006 is 51.1% and chain increase tempo – 6.3 %.

Total primary energy consumption during recent eleven years increases gradually. Renewable energy has got the fastest consumption growth during 11 years – 51.1%. State financial and political support for usage of renewable energy has promoted it. Coal consumption has got the second fastest increase – 41.6%, because coal usage in China, India, Germany, USA and Russia is increasing.

The least energy consumption within 11 years growth is with hydro energy – 16.3% and atom electric energy – 17.0%. Many countries do not build nuclear power stations because of radiation danger, and it is not possible to reach rapid growth of nuclear energy. The largest nuclear energy consumers are the USA, Canada, and Japan.

The mankind knows crude oil since the beginning of our era (Соколов 1970). There are several known places on the Earth where crude oil and natural gas is discharged from mountain springs.

60ies of the last century are characteristic of rapid extraction of crude oil that reached 2 billion tons per year. Search for new and new oil deposit fields was done. In 1967 the USA took the first place in the world in extraction of crude oil (approximately 400 million tons a year), the second place was taken by the USSR (288 million tons a year), Venezuela took the third position. Wider usage of natural gas started.

While doing more detailed evaluation of crude oil extraction in the world, we see (table 2) that the

tendency for crude oil extraction is to grow: base increase tempo in 2006 was 16.9%. The highest chain increase tempo in 2003 with 4.1% and smallest chain increase tempo in 2002 was negative -0.6%.

In Oil producer and exporter organization (OPEC) crude oil extraction density in 2006 was 41.9%, which is for 1.1% more than in 1995.

In European Union oil extraction / production diminishes every year because oil reserves become less. In 2006 chain increase tempo was -9.0% and base increase tempo -27.5%.

Saudi Arabia is the biggest oil producer country in the world. It has been this way for the last 11 years that have been analysed. Density of the country in total crude oil extraction in 2006 constitutes 13.3%.

Table 2

Crude Oil production in the World 1995- 2006

Title	1995	2000	2001	2002	2003	2004	2005	2006
OPEC, thousand barrels per day	28472	31512	30857	29031	30884	33175	34068	34202
Specific weight total consumption, %	40.8	42.0	41.2	39.0	40.1	41.3	41.9	41.9
Chain increase tempo,%	0	10.7	-2.1	-5,9	6.4	7.4	2.7	0.4
Base increase tempo,%	0	10.7	8.4	2.0	8.5	16.5	19.7	20.1
EU, thousand barrels per day	3325	3486	3278	3331	3119	2893	2649	2412
Specific weight in total consumption, %	4.8	4.6	4.4	4.5	4.0	3.6	3.3	3.0
Chain increase tempo,%	0	4.9	-6.0	1.6	-6.4	-7.2	-8.4	-9.0
Base increase tempo,%	0	4.9	-1.4	0.2	-6.2	-13.0	-20.3	-27.5
Total world, thousand barrels per day	69830	75033	74932	74496	77056	80244	81250	81663
Chain increase tempo,%	0	7.4	7.3	-0.6	3.4	4.1	1.3	0.5
Base increase tempo,%	0	7.4	7.3	6.7	10…3	14.9	16.4	16.9

Source: author `s table following BP Statistical Review of World Energy2006, 2007. Oil: Production

The next comes Russia as the second biggest oil producer country with density in common production market of 12.0%, but the third position is taken by the USA with density in the world oil production of 8.4%. Norway is the main country in Europe in production of crude oil. It constituted 3.5 % in density of common oil production in the world in 2006.

Oil consumption in the world among regions is very different. The biggest consumption is in North America with density of consumption in 2006 – 28.9% and Asia – 29.0%, Europe & Eurasia 24.9%, the smallest consumption was in Africa – 3.4% from total world consumption.

Total base increase tempo for crude oil (table 3) in 2006 was 20.4%. Chain increase tempo in years is in the range from 0.8% to 9.7%.

Table 3

Oil Consumption in the World 1995 – 2006 (thousand barrels per day)

Title	1995	2000	2001	2002	2003	2004	2005	2006
EU, thousand barrels per day	13766	14402	14553	14471	14546	14686	14861	14865
Base increase tempo,%	0	4.6	5.7	5.1	5.7	6.7	8.0	8.0
Total world, thousand barrels per day	69506	76280	76828	77737	79158	81898	83080	83719
Chain increase tempo,%	0	9.7	0.7	1.2	1.8	3.5	1.4	0.8
Base increase tempo,%	0	9.7	10.5	11.8	13.9	17.8	19.5	20.4

Source: author `s table following BP Statistical Review of World Energy 2006, 2007. Oil: Consumption

The biggest in the world consumption of oil is in the United States of America (USA). In 2006 oil consumption from the total consumption was 24.1%

China is the second biggest oil consumer state in the world with density of 9.0% in 2006.

Japan is the third biggest oil consumer with density of 6.0% in 2006.

The rest of countries with highest density of oil consumption are in the range between 2.2 and 3.3%. In EU oil consumption base increase tempo in 2006 was 8.0%, but the biggest chain increase tempo in 2005 was 1.2%. Oil consumption density in 2006 constituted 17.8% from total oil consumption.

Table 4

Countries with the Biggest Oil Reserves 1995 - 2006 (thousand million barrels)

Title	1995	2000	2006	Specific weight total consumtion %	2000/1995 %	2006/ 2000, %	Ratio: proved reserves 2006 / production 2006
Saudi Arabia	261.5	262.8	264.3	21.9	0.5	0.6	65.6
Iran	93.7	99.5	137.5	11.4	6.2	38.1	93.0
Iraq	100.0	112.5	115.0	9.5	12,5	15.0	x
Kuwait	96.5	96.5	101.5	8.4	0.0	5.2	x
United Arab Emirates	98.1	97.8	97.8	8.1	-0.3	0.0	97.4
Venezuela	66.3	76.8	80.0	6.6	15.9	4.1	72.6
Russian Federation	x	59.6	79.5	6.0	x	33.4	21.4
Libya	29.5	36.0	41.5	3.4	22.0	15.2	63.0
Nigeria	20.8	29.0	36.2	3.0	39.4	24.9	38.0
USA	29.8	30.4	29.9	2.5	2.0	-1.5	11.8
China	16.3	17.9	16.3	1.3	10.1	-9.3	12.1
Total world	1027.0	1108.2	1208.2	100.0	7.9	9.0	40.6

Source: author `s table following BP Statistical Review of World Energy 2006, 007. Oil: Proved. Reserves

According to evaluation of 2006, the biggest crude oil reserves are in Saudi Arabia (table 4) where the reserve constitutes 21.9% out of all crude oil reserves of the world. There are 11.4% in Iran and 9.5% in Iraq. Another big oil production reserve is oil tar sand. Reserve of it is situated in Canada – 178.8 gig barrels.

As seen from the table 4, oil reserves in the world increased in 2006 compared to 1995 – for 17.6%, but there are less new fields discovered in the recent years. Proportion – proved reserves 2006 / extraction in 2006 show for how many years' oil reserves are enough for consumption following the pervious tempo. We divide proportion calculation residue reserves by extracted oil amount during the year. Crude oil is left for 40 years in the world. That means that future belongs to renewable energy and the nominated hypothesis is approved.

Table 5

Primary energy resource production in Latvia 1995 – 2006

Years	1995	2000	2001	2002	2003	2004	2005	2006
Peat and peat briquettes,TJ	3685	714	708	1427	80	131	121	141
Specific weight total consumption, %	6.1	1.2	1.1	2.1	0.1	0.2	0.2	0.2
Base increase tempo,%	0	-80.6	-80.8	-61.3	-97.8	-98.3	-96.7	-96.2
Fuel wood, TJ	46115	48150	53071	57229	64170	65539	65290	66603
Specific weight total consumption, %	76.4	81.6	82.9	84.6	88.2	84.7	83.7	86.1

Years	1995	2000	2001	2002	2003	2004	2005	2006
Base increase tempo,%	0	4.4	15.1	24.1	39.2	42.1	41.6	44.4
Renewable resource, TJ	0	0	0	55	159	295	419	729
Specific weight total consumption, %	0	0	0	0.1	0.2	0.4	0.5	0.9
Chain increase tempo,%	0	0	0	0	189.1	85.5	42.0	74.0
Hydro-energy, TJ	10573	10163	10210	8906	8330	11369	12139	9878
Specific weight total consumption, %	17.5	17.2	16.0	13.2	11.5	14.7	15.6	12.8
Base increase tempo,%	0	-3.9	-3.4	-15.8	-21.2	7.5	14.8	-6.6
Total sum, TJ	60373	59027	63989	67617	72739	77334	77969	77351
Base increase tempo,%	0	-2.2	6.0	12.0	20.5	28.1	29.1	28.1

Source: author `s table following data from Central Statistics Board

In table 5 we can see that Latvia has got primary energy resources – firewood acquired from the forests – the highest density in 2006 – 86.1%. The second biggest primary energy resource is hydro-energy with density of 12.8%. Density of renewable energy resources (bio-ethanol, bio-diesel, gas of waste disposal polygons, waste water sludge gas and straw) in 2006 was 0.9% and the highest chain increase tempo in 2003 was 189.1% . Peat moss extraction notices is diminishing for 96.2% against base year.

All together in Latvia primary energy resource increase tempo in 2006 – 28.1%, and the highest chain increase tempo was in 2001 – 8.4%.

Table 6

Energy Resource Final Consumption in Latvia Split in Energy Types 1995 – 2006

Years	1995	2000	2001	2002	2003	2004	2005	2006
Oil products, TJ	50309	47387	50811	51832	55473	57759	59461	66093
Specific weight total consumption, %	30.8	33.7	33.1	33.1	33.8	34.2	34.1	36.2
Base increase tempo,%	0	-5.8	1.0	3.0	10.3	14.8	18.2	31.4
Coal, TJ	4810	2248	3102	2533	2334	2255	2884	3199
Specific weight total consumption, %	2.9	1.6	2.0	1.6	1.4	1.3	1.7	1.8
Base increase tempo,%	0	-53.3	-35.5	-47.3	-51.5	-53.1	-40.0	-33.5
Natural gas, TJ	17045	15294	18129	20798	21228	22885	23628	23887
Specific weight total consumption, %	10.4	10.9	11.8	13.3	12.9	13.5	13.5	13.1
Base increase tempo,%	0	-10.3	6.4	22.0	24.5	34.3	38.6	40.1
Fuel wood, TJ	36890	34499	38307	37316	39071	41356	42250	42234
Specific weight total consumption, %	22.6	24.5	25.0	23.8	23.8	24.5	24.2	23.2
Base increase tempo,%	0	-6.5	3.8	1.2	5.9	12.1	14.5	14.5
Electricity, TJ	16074	16117	16499	17575	18724	19454	20624	22061
Specific weight total consumption, %	9.8	11.5	10.7	11.2	11.4	11.5	11.8	12.1
Base increase tempo,%	0	0.3	2.6	9.3	16.5	21.0	28.3	37.2
Heat energy, TJ	37897	24707	26370	26316	26845	24581	25020	24386
Specific weight total consumption, %	23.2	17.6	17.2	16.8	16.3	14.6	14.3	13.4
Base increase tempo,%	0	-34.8	-31.4	-31.6	-29.2	-35.1	-34.0	-35.7

Years	1995	2000	2001	2002	2003	2004	2005	2006
Renewable resource, TJ	0	0	0	0	80	129	183	202
Specific weight total consumption, %	0	0	0	0	0	0.1	0.1	0.1
Others, TJ	535	331	305	268	449	502	371	292
Specific weight total consumption, %	0.3	0.2	0.2	0.2	0.3	0.3	0.2	0.2
Sum total, TJ	163560	140583	153523	156638	164204	168921	174421	182354
Base increase tempo,%	0	-14.0	-6.1	-4.2	0.4	3.3	6.6	11.5

Source: author `s table following data base of Central Statistics Board

In table 6 we can see that in Latvia energy resource final consumption oil products got the highest density in 2006 – 36.2%. During eleven years oil product consumption has increased by 31.4%. The second position following consumption density was taken by wood with 23.2% in 2006. Coal consumption density – 1.8% has a tendency to grow. Density of final renewable energy resources in final consumption was 0.1% in 2006.

Conclusions

1. Primary energy consumption in the world has been gradually growing during latest eleven years. The fastest increase is with renewable energy – for 51.1% and coal consumption – 41.6%. The least increase is in hydro-electric energy consumption – 16.3% and nuclear electric energy – 17.0%.
2. Crude oil production in the world is growing and base increase tempo in 2006 was 20.2%. The biggest oil production states are Saudi Arabia, Russia and the USA.
3. The highest density of oil consumption in different energy resources: in 2006 – 36.1%. The biggest oil consumer countries in the world are the USA, China and Japan.
4. The biggest reserves in the world are in Saudi Arabia with density of 21.9% and Iran with density of 11.4%. Oil reserves are left over for 40 years more and the future belongs to renewable energy.
5. In Latvia firewood is the biggest primary energy production resource with density of 86.1%. The second biggest primary energy resource is hydro-energy with density of 12.8%.
6. In Latvia's final energy resource consumption in different types of energies oil products got the highest density in 2006 – 36.2%. The second position is taken by firewood with density of 23.2%.

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RESULTS OF THE SECOND STAGE OF LAND REFORM IN THE LATVIAN REGION OF LATGALE

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Abstract

The paper includes economic research results on the second stage of land reform over the 10-year period (1996 – 2006) in the districts of Latgale region. The results explicitly stress the region's variability, therefore, the results are different, but common trends can be also observed. The number of land users has decreased, whereas that of land owners and the area of privatised land have increased. The total area of used and owned land has increased by 33.4% and exceeded a million hectares.

Key words: land reform, Latgale region, property, agriculture, land.

Introduction

In the scientific literature, popular periodicals and other sources one may come across general descriptions, evaluations, considerations or assertions on the land reform and agrarian reform in Latvia (Stradiņš, 2002; Boruks, 1997; Bresis, 2007; Kaktiņš, 1991; Goba, 2002; Špoģis, 2002; Beļavnieks, 2001, 2003). However, one may not find any publications on the results of a special, targeted research investigating processes of the current – fourth – land reform and its results in the regions of Latvia. The first special publication on the processes and results of this reform's first stage in Latgale Planning Region appeared only in April, 2008 (Šķesters and Špoģis, 2008). It provides the analysis and scientific evaluation of the processes and results of the forth land reform's first stage, including the characterization and evaluation of the pre-reform situation, as well as the evaluation of the processes and results of this reform's starting period.

Latgale is a special part of the country both socially and economically. Historically a special small-scale farm structure had formed in rural areas of this region, but as the forth land reform began, the situation was different. Among the local inhabitants, only a small fraction of former landowners had remained. Therefore, many legatees, who in terms of their education and activities had completely withdrawn away from rural areas and agriculture of Latgale, had to engage in the land reform processes. An especially large part was also those Latgalian families who in the course of the reform obtained only a small plot of land without production resources.

The evaluation of the situation convincingly presented a necessity to carry out a scientific research on the processes and results of the second stage of the land reform in Latgale Planning Region. The importance of the topic is reinforced by the fact that, as the second stage – privatization – process of the land reform continued, in the last 5-6 years Latgale experienced a rapid formation and development of the secondary land market, lease relations and the beginning of the polarization process regarding property. By buying and officially registering lands "without owners" (legatees' lands), two groups of owners and land managers emerged: small-scale semi-subsistence farms and big agricultural companies and enterprises were characteristic of Latgale.

Latgale Region has been chosen as the object of the research because of its current situation. For many years it has been investigated why it is the poorest region of Latvia. Analysing the land resources and the results of its reform, on the basis of these materials it will be possible to carry out the further research on the results of the land reform, since it has also indirectly influenced other processes in the region.

Hypothesis: The fourth land reform carried out in Latvia was directed towards the restitution of the structure of small-scale subsistence farms in Latgale.

The aim of the research is to analyse the processes of the second stage of the fourth land reform currently carried out in Latgale Region for a period of 10 years, and to evaluate the results.

The enabling objectives to reach the aim of the research:

- to analyze the quantitative changes in agricultural land use and the structural process of the agricultural-purpose land area;

- to examine the quantitative progression and structure of the composition of agricultural land (K-01) properties;
- to examine the use of the agricultural-purpose land and the dynamics and tendencies of the number and structure of land properties.

Materials and Methods

The object of the research are the districts of Latgale Planning Region, the subject – agricultural-purpose lands, and the subject matter of the research – practical socio-economic results of the land reform. Statistical data of the State Land Service (SLS) and Central Statistical Bureau (CSB) are used for the research.

To process the data materials and to perform the quantitative evaluation of the processes, the dynamic time-array analysis method is applied, carrying out calculations of chain changes and their groups, as well as calculations of base changes. The graphical method is applied to display the results.

Results and Discussion

The process of current land reform, which took place along with the general economic reform, reprivatisation and privatisation of agricultural companies, was legally divided into two periods (stages):

1. in the starting period of the reform, from 1990 to 1995, the claimed land was assigned for use;
2. in the 10 years' period of the reform, from 1996 to 2006, the ownership rights were being registered.

The present paper comprises the findings of the research only in respect of the reform's second stage results.

Table 1

Quantitative Changes in the Number of Agricultural Land Users in Latgale Districts from 1996 to 2006

Districts	Number of land users			Total used area, ha			Average area per user, ha		
	1996	2001	2006	1996	2001	2006	1996	2001	2006
Rezekne	16,868	12,862	9,821	123,783	99,684	67,089	7.34	7.75	6.83
Ludza	11,966	5,563	4,912	110,153	69,227	34,308	9.21	12.44	6.98
Daugavpils	18,561	11,690	9,456	96,594	80,381	69,437	5.20	6.88	7.34
Kraslava	11,527	6,973	5,286	105,112	76,898	54,717	9.12	11.03	10.35
Preili	9,343	5,260	3,788	101,925	57,466	38,471	10.91	10.93	10.16
Balvi	7,679	3,044	3,783	86,506	54,738	42,498	11.27	17.98	11.23
Total in Latgale	75,944	45,392	37,046	624,073	438,394	306,520	8.21	9.65	8.27

Source: SLS land balances' data and the author's calculations.

The number of agricultural land users in the analysed 10 years' period has logically decreased in all Latgale's districts as during this period the second stage of the land reform is already taking place – registration of land ownership rights.

However, if evaluating the attitude of land users, one may observe a very different behaviour. During the first half of the analysed period – from 1996 to 2001 – the number of land users in Balvi District had decreased by 60%, in Ludza District – by 54%, but in Rezekne District – only by 24%.

During the second period – from 2001 to 2006 – the situations in the districts were also different, but on the whole during the 10 years' period the number of users in Preili District and Ludza District had decreased by 60 – 59%, but in Rezekne District – only by 42%.

The land areas registered as a property have increased mostly in Eastern Latgale districts, but Preili District in Southern Latgale has been especially successful. A comparatively neglectful attitude towards the registration of land ownership rights can be observed in Daugavpils District.

Table 2

Agricultural-Purpose Land (K-01) by Type of Use in Latgale Districts in 1996 and 2006 during the 10-Year Period, ha

Districts	Agricultural land		Forests, shrubs and swamps		Under water
	1996	2006	1996	2006	2006
Rezekne	84,843	47,660	26,976	14,772	679
Ludza	72,203	23,016	30,147	8,032	661
Daugavpils	72,219	50,679	17,991	14,784	958
Kraslava	64,861	34,477	27,365	16,350	1,418
Preili	66,456	25,691	27,281	10,263	675
Balvi	50,810	28,614	28,845	11,969	657
Total in Latgale	274,312	124,981	113,249	45,036	2,672

Source: SLS land balances' data and the author's calculations.

Agricultural-purpose lands in private property and efforts for registering ownership rights in Latgale's districts are very different. In Ludza District, during the 10 years land properties have been registered for two thirds of the agricultural land, but in Daugavpils District this work has been carried out only for 29% of the agricultural land areas.

As the processes of ownership rights registration develop, the proportion of the agricultural land has increased, which can be inferred from the results of the Table 2 data analysis. The proportion of forest, bush and swamp areas in Kraslava District and Balvi District exceeds 29%, but in Daugavpils District, Ludza District and Rezekne District the proportion of such areas constitutes only 22 – 23%. Kraslava District is the richest in lakes, followed by Daugavpils District.

The situation is opposite in respect of the changes in the number of land properties and the land areas which have become a property, as displayed in Table 3.

Table 3

Quantitative Changes in Agricultural Land (K-01) Properties in Latgale Districts from 1996 to 2006

Indices	Number of land properties			Total owned area, ha			Average area per owner, ha		
	1996	2001	2006	1996	2001	2006	1996	2001	2006
Rezekne District	1,927	7,737	11,372	19,860	92,511	138,499	10.3	12.0	12.2
Chain increase rate, %	-	302	47	-	366	50	-	16.5	1.7
Ludza District	2,591	5,252	7,002	30,924	83,328	127,094	11.9	15.9	18.2
Chain increase rate, %	-	103	33	-	170	53	-	33.6	14.5
Daugavpils District	2,805	8,054	10,396	27,253	80,245	109,777	9.7	10.0	10.6
Chain increase rate, %	-	187	29	-	194	37	-	2.9	5.6
Kraslava District	1,814	6,667	8,731	22,200	90,206	123,950	12.2	13.5	14.2
Chain increase rate, %	-	268	31	-	306	37	-	10.6	4.9
Preiļi District	2,567	6,675	8,476	32,861	94,892	119,663	12.8	14.2	14.1
Chain increase rate,%	-	160	27	-	189	26	-	11.1	-0.7
Balvi District	1,863	7,155	8,290	27,770	101,408	121,900	14.9	14.2	14.7
Chain increase rate, %	-	284	16	-	265	20	-	-4.9	3.7

Indices	Number of land properties			Total owned area, ha			Average area per owner, ha		
	1996	2001	2006	1996	2001	2006	1996	2001	2006
Total in Latgale	13,567	41,540	54,267	160,868	542,590	740,883	11.9	13.1	13.7
Base increase in lustrums, ha	-	27,973	40,700	-	381,722	580,015	-	1.2	1.8
Base increase rate, %	100	306	400	100	337	460	100	110	115
Chain increase rate, %	100	306	31	100	337	136	100	110	105

Source: SLS land balances' data and the author's calculations.

Evaluating the data of Table 3, the following conclusions can be drawn.

- The number of land properties has increased especially rapidly during the first half of the analysed period in Rezekne District, Kraslava District and Balvi District.
- The development of processes has been even more rapid with the growth of the areas of these agricultural land properties: they have increased seven times in Rezekne District, six times – in Kraslava District, but in other districts – four times.
- During the second lustrum of the analysed period, from 2001 to 2006, the activities of Latgale's municipalities and farmers have radically changed – in Balvi District the number of owners has increased only by 16% in five years, which is three times slower than in Rezekne District.
- The privatised agricultural land areas have increased by 50% from 2001 to 2006, but in Balvi District and Preili District – only by 20 – 26%.
- On the whole, the privatisation activities in Latgale during the second lustrum (from 2001 to 2006) have radically fallen. While during the first five years the ownership rights were registered for 25 thousand users, during the rest five years – half as much. It can be explained by the variety of privatisation methods. During the first lustrum a rapid reprivatisation process – regaining of the nationalised land properties (denationalization) – could take place, in which the owners take part, but later the registration of legatees' rights started, which could take more time, involve larger expenses and less interest on the part of the legatees themselves.

The efforts of the potential owners of Latgale's land in other aspects are displayed in Table 4.

Table 4

Agricultural-Purpose Land (K-01) by Type of Use in the Owners' Areas in Latgale Districts from 1996 to 2006

Districts	Agricultural land, ha			Forests, shrubs, swamps, ha			Land under water, ha		
	1996	2001	2006	1996	2001	2006	1996	2001	2006
Rezekne	11,946	54,492	82,295	63,427	35,458	48,402	146	1,198	2,516
Ludza	19,257	49,995	78,602	10,012	29,018	42,025	386	1,551	2,485
Daugavpils	18,362	51,403	68,845	6,971	23,975	34,640	168	950	1,629
Kraslava	12,102	47,153	64,866	8,602	36,814	51,467	588	1,782	3,234
Preili	20,857	58,767	73,316	10,184	30,880	39,302	560	1,864	2,439
Balvi	15,203	50,755	61,771	11,255	45,776	54,408	577	1,405	1,939
Total in Latgale	97,727	312,565	429,695	110,451	201,921	270,244	1837	8,750	14,242

Source: SLS land balances' data and the author's calculations.

The data of Table 4 clearly demonstrate that

- the AUL proportion in the privatised total area slightly decreases in all districts of the region, which indicates the efforts of land legatees or owners to obtain larger forest areas, as well as water areas – lakes in their property;
- the decrease in the agricultural land proportion may also be caused by the fact that the ownership rights were first – at the beginning of the analysed period – attempted to be reg-

istered for better cultivated land areas, but later one had to privatise also the shrub and swamp areas.

The detailed analysis of the land reform processes revealed interesting regularities and established a basis for important conclusions in relation to both the land reform's first stage – use registration, and the second stage – registering land ownership rights.

Now it is possible to elicit an integrated total result of both processes. Data and calculations are laid out in Table 5 for this purpose.

Table 5

Agricultural-Purpose Land Use and the Total Number and Proportion of Land Properties in Latgale Region from 1996 to 2006

Indices	Number of users/owners			Total area, ha		
	1996	2001	2006	1996	2001	2006
Land use	75,944	45,392	37,046	624,073	438,394	306,520
Land ownership	13,567	41,540	54,267	160,870	542,590	740,883
Land use and ownership in total	89,511	86,932	91,313	784,943	980,984	1,047,403
Percentage of changes	100	97	102	100	125	133
Proportion of land ownership, %	15	48	59	21	55	71

Source: SLS land balances' data and the author's calculations.

The number of agricultural-purpose land users decreased more than twice in 10 years, the number of owners increased almost four times, and the total number of both of them increased.

The quantitative ratio of these processes has radically changed: while at the beginning of the analysed period – in 1996 – the property share constituted only 15%, in 10 years it already exceeded 59%. Even more dynamic changes have taken place in relation to the used and owned areas:

- the total area of used land has decreased twice, but the total area of owned land has increased five times;
- the total area of used and owned land has increased by 33.4% and exceeded 1 million hectares;
- the proportion of the total area of owned land increased from 20% in 1996 almost four times and to more than 70% in 2006.

To draw conclusions, not only empirical research results are important, but also their comparative analysis. The assessments made by scientists who were directly and actively engaged in the process of land reform are especially important.

Dr.habil.agr. A. Boruks, when assessing the consequences caused by the Land Privatization Law, wrote: "It promoted the fragmentation of land holdings, the creation of unviable farms and was in contradiction to the principles of rational use of land" (2001).

The research results on the reform consequences in Latgale, presented in the paper, conforms to the assessment by A. Boruks – a great part of unclaimed land is concentrated in the east of the Republic of Latvia where there were relatively few land claimants.

Doctor in economics R. Zīle (1997), after compiling data on the consequences, conceptual and methodological solutions of privatization in Latvia, assesses the situation as follows: "an increase in social tension has to be negatively viewed as it was not sufficiently assessed (predicted) in the privatization conception".

R. Zīle (1997) analyzed the concepts and consequences of agricultural reforms in other East and Central European countries as well and discovered large differences there, too, the economic impact of which is large and progressive.

As to the assessments of agricultural reform, the research results gained by the author conform to a conclusion made by doctor in economics A. Miglavs (1997) that "the large number of small farms, which emerged as a result of agricultural reform, determines a need for developing agricultural cooperation in some future reform in order to use the most productive resources and technologies in a more efficient way".

In searching for problem solutions to the consequences of agricultural reform, the Latvian Ministry of Agriculture formed a group of scientists and practical specialists which consists of 21 doctors of sciences. These specialists elaborated a development program for agriculture and its industries in Latvia (1998). According to the situation description, "the potential of agricultural land

resources has sharply decreased over the recent 8 years".

Such general assessments, to a great extent, conform to the new and specific research results on Latgale region presented by the author.

Conclusions

1. The research of the second phase of land reform and structural changes in areas of used and owned agricultural land over a ten year period in Latgale was conducted according to a unique program and its results are innovative.
2. The second stage of the land reform involved two processes: the number of land users in the first stage of the reform decreased, but the number of land owners increased.
3. In ten years the number of agricultural land users had decreased by 50% – 60%, but the total area of used land – twice as much.
4. The proportion of agricultural land in the private sector increased and in 2006 reached 69% on the whole in the region. The proportion of forest, shrub and swamp areas respectively decreased.
5. The number of agricultural land properties in Latgale districts has increased 3 – 6 times, but in total in the region – four times. The total area of owned land has increased even more rapidly – 4 – 7 times, but the average area has increased from 11.9 ha in 1996 to 13.6 ha in 2006.
6. The AUL proportion has decreased in the area of owned agricultural-purpose land, but the areas of forests, shrubs and swamps have increased 4 – 6 times, which may indicate the owners' efforts to obtain larger or newer forest areas.
7. The number of agricultural-purpose land users in the 10 years of the land reform's second stage has decreased twice, but the number of land owners has increased four times, as a result of which the integrated total result of both processes has increased. The proportion of the number of land owners increased from 15% in 1996 to 59% in 2006, but the proportion of owned land area – from 20% to 71%, and in absolute numbers the area has increased by a third exceeding 1 million hectares.

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OFFER AND OPPORTUNITIES OF LOGISTICS EDUCATION IN LATVIA

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Abstract

The goal of the research was to evaluate the opportunities in preparation of logistics specialists offered by Latvian universities and to formulate problem solutions. To achieve the goal, study programmes and course syllabuses offered by Latvian universities and colleges were analysed from the logistics perspective. Opportunities to acquire logistics knowledge offered in Latvia by distance, in further education and life-long learning programmes were reviewed. In the end, it was concluded that the development of logistics education in Latvia does not correspond to the speed of the development of logistics industry. Currently Latvia offers 4 Logistics study programmes, but only one study programme offers education corresponding to the professional standard – Manager of Logistics Department – as approved by the MoES. Latvia University of Agriculture currently has no logistics study programmes but different logistics subjects are included in the study programmes of 4 Faculties, therefore there are vast opportunities and it is necessary to develop the offer of logistics education, first by giving students the opportunity to choose specialisation in logistics in the Faculties in the study areas of which logistics is especially important and necessary – Faculty of Economics, Technical Faculty, Faculty of Forestry, Faculty of Food Technology, and Faculty of Agriculture.

Key words: logistics education, offer, opportunities.

Introduction

The advantageous geographical location of Latvia, location on the trade road between West and East, the ice-free harbour and the European Union (henceforward – EU) external border with Russia determine the special place and role of logistics in Latvia. After joining the EU, Latvia is facing new opportunities that have to be used, as well as new problems which need to be solved. The increasing competition in several branches of national economy encourages Latvian enterprises to seek for new, economically effective working methods.

One of the main tools for increasing the competitiveness in such a situation is optimization of enterprise logistics systems. As a result, relevant changes are being observed in the market of logistics services:

1) the demand for high quality services at acceptable price is increasing faster and faster;
2) the part of market participants that form and manage their own competitive logistics systems is increasing;
3) the use of "mixed" logistics functions is decreasing (an enterprise produces a part of a definite function, for example, of international transportation, but a part is bought from logistics service provider).

I can agree with specialists (Virbule, 2006) who have already defined the most essential differences between technical supply and logistics. In its essence, philosophy of planning stocks, reserves, supply and other organization and management components has gradually and drastically changed in the world. Several years ago the main aim of supply departments was to ensure that production did not lack raw materials or goods for shops. Whereas now, the main aim of logistics systems is to deliver only as much as necessary. With the development of international cooperation, problems of just-in-time supply have become more urgent.

In transportation – the main function of logistics systems – a number of factors have become topical, among which the following factors can be regarded as the main ones:

- the constantly increasing costs demand more profound and wider knowledge of economists;
- overstock of service capacity is influenced by radical modernization of transportation management processes (speeding of transportation cycle, liquidation of customs frontier, and development of ferry transport, etc.);
- market globalization escalates discrepancies between big supplier interests and professional possibilities of market participants.

Those factors have also contributed to the demand for a wide range of professional and qualified logistics specialists. Unfortunately Latvia lacks high-qualified logistics specialists. The following could be considered the main reasons for this situation:

- Latvia's inability to join the rapid development processes of the business logistics as a separate function of processes and systems management in the world;
- the alienation of Latvian academic education system from the real needs of logistics systems and business;
- the lack of qualified academic staff, experts and consultants in logistics and the negative attitude of some academic staff towards topicality of logistics science;
- necessity for higher qualification and wider knowledge of logistics specialists;
- the long period of accreditation process prolongs the introduction of new and progressive programs in the education system.

In 1996-2006, the percentage of employees working in logistics (transport, storage, and telecommunication) on average was 9% (the increase of 1.8 thousand people per year with a growth rate of 2% per year) (Employed in the ..., 2008). A number of employees that now work in logistics branch do not have special logistics education – they urgently need further special education.

However, the operative information turnover suggests that the branch experiences a crucial need for highly qualified employees. Skills and knowledge that labour market requires from logistics specialists depend on the specific character of each industry and enterprise (Daugherty, 2004).

Statistical data show that more than 2,000 companies operate in logistics services industry in Latvia, and they all need logistics specialists. Also supermarkets have their own logistics centres which need logistics specialists who would plan fast and qualitative cargo transportation at optimal costs. It means organization of transport network, drawing up of routes, and solving problems connected with warehouses, customs, etc.

Each cargo is specific and requires suitable transport, taking into account packaging of the transportable goods and the desirable kind of transportation. Therefore employees in logistics branch should have knowledge in transport technologies, in cargo specifics, documentation and handling, and in IT (Sarana et al., 2006; Perry, 2006).

Lack of special knowledge and competence can be the reason for the considerably low development level of Latvian logistics services market compared to the developed countries (Millere, 2005). In Latvia, there is a tendency to concentrate primarily on the optimization of transportation functions, but the significance of stocks and reserves management has not been properly estimated yet.

Regarding professional qualification of logistics specialists, N. Krumins (2004) has concluded that there is a difference between academic education in business logistics and practical business needs. To his mind, one of the most important factors not only in Latvia but also in other EU countries is lack of competent academic staff who could transform the interesting and engrossing, but at the same time, bare and mathematical theory into practical tools for daily use. In addition, A. Lietina (2007) points out that logistics specialists are paid higher than professors, which is the reason why the first are not interested in working at university.

A. Šlesers (2008) has looked at logistics problems from another aspect. Based on the data of January 2008, he has concluded that transportation processes in Latvia comply with the transportation policy of Europe: the volume of trucked cargo by Latvian railway company Latvian Railway subsidiary company *LDz Cargo* increased by 31.7% in January 2008 if compared with January 2007 and has reached 5.043 million tons. A total of 5.626 million tons cargo were reloaded in Latvian ports in January this year, which is for 26.5% more than in the first month of 2007.

The analysis of the situation allows stating the several groups of arguments that formed main motives for choosing the research topic.

The increasing topicality of logistics education and science forms one of the groups:

- the increasing necessity for qualified planning of processes and systems of primary, secondary and tertiary areas, the need and greater complexity of regulating and correcting the perfect control of processes and systems flows;
- professional management of the flows of information, knowledge and other intellectual resources;
- cost efficiency of material resources and production flows;
- modernization of the choice, planning and management of energy kinds, sources and volumes;
- the need for more qualified forecasting and planning of human resource flows;
- the increase of the capacity of the knowledge required for the effective management of all these flows and the visibility of its deficit.

All these arguments of the first group form the hypothesis or a part of it that the topicality of logistics knowledge and education is reflected in the study programmes offered in educational institutions. The second group of arguments is made by the development of the use or application of logistics science and its methods: its application is being updated in both production and materials international transcontinental mega flows and the common market of the European Union, in which Latvia participates. The third group of arguments is made by the geographical situation of Latvia, which allows it to perform the function and opportunities of materials flows through the West-East and North-South corridor. The fourth argument is related to the above – development of big logistics centres in Pieriga region, and they also need logistics specialists. The fifth argument is updating of management processes and technology by using global positioning options and systems, which requires special, adequate knowledge from the operators.

The next step – analysis of the topic approved the assumption that over the last years no purposeful studies about education opportunities and problems in logistics have been carried out as no study results have been published. Some considerations or recommendations can be found in periodicals.

Thus, it can be considered that a study of the opportunities of logistics education is not only topical, but also new and possibly original.

Research **hypothesis**: deep dissonance and divergence between the practical application of the cognitions of logistics science and the education opportunities or capacity of logistics specialists have developed.

To verify the above hypothesis, the following research **goal** was set: to evaluate the opportunities in preparing logistics specialists (study programmes) offered by universities and to offer solutions to the problem.

The following **objectives** were set to achieve the goal:

1) to analyse and evaluate the study programmes and course outlines offered by the Latvia University of Agriculture (LLU) from the perspective of logistics science;
2) to study logistics study programmes offered by other universities and colleges of Latvia;
3) to review the opportunities for acquiring logistics knowledge offered by distance education, further education and life-long learning programmes in Latvia.

Materials and Methods

The research covers the study programmes and course outlines available through the web sites of universities and colleges, accreditation information by the Ministry of Education and Science (henceforward – MoES), information published on consultation and training organizations, scientific and academic literature, special publications in periodicals, a.o.

The following methods were used in research:

- methods of analysis and synthesis, as well as the monographic method were used in studying the published materials, theories and standards;
- to find out the essence of logistics education, the inductive method with deduction elements was used;
- to make conclusions and forecasts, the logical construction and interpretation methods were used.

Results and Discussion

1. Logistics Study Programmes Offered by Latvian Universities and Colleges

To find out future opportunities, the author has collected data on logistics programmes in Latvian universities (Data of Higher…, 2008) and concluded that three universities in Latvia now offer 4 Logistics Study Programmes.

MoES of the Republic of Latvia approved the professional standard on November 9, 2004 – Manager of Logistics Department. The description of the profession provides that the manager of logistics department manages supply of raw materials, spare parts and materials, realization of the production output or purchased goods; in a trade company, ensures customer service quality at the certain place and time, determines the storage policy in the company, performs general control over the work quality of suppliers and develops cooperation policy with suppliers and clients. It is important for the logistics specialist to be communicable and a good diplomat, with logical and mathematical thinking because this industry involves serious processes where one cannot rely on feelings.

Education corresponding to this professional standard is currently offered by only one university – Riga Technical University: the Professional Bachelor's Study Programme "Business Logistics" which enrolled its first 20 students in September 2006.

One of the main logistics functions is transport and, as the offered range of university study

programmes indicates, in total 7 programmes offer higher education in different study programmes in transportation area.

One of such programmes – International Carrier Management offered by Liepaja College of Maritime Activity – provides a qualification that corresponds to the professional standard "Logistics specialist", which was approved on November 9, 2004.

Transport and Telecommunication institute (TTI) currently offers the widest range of logistics study programmes – 5 out of the total of 11. In addition, TTI is the only university founded by a legal entity for which the Latvia Council of Science has approved the Doctorate Council, on the basis of TTI, for awarding a Ph.D. in engineering, and it offers the only doctoral study programme in logistics "Telematics and Logistics" (Kabaškins, 2003).

Whereas Riga Air Navigation Institute offers the only Master's study programme connected with logistics – International Carrier Management.

The fact that 9 out of 11 logistics and transportation organization programmes are professional study programmes is natural and only emphasises that this science is topical and applicable and necessary in real life.

When analysing the licensing dates of Logistics study programmes, it can be concluded that all these are new study programmes – they have been offered for not more than 5 years.

Only two universities – RTU and Ventspils University College – offer specialisation in logistics through 4 study programmes. This is the optimum choice of universities if the university is not able to offer a full logistics study programme in the specific study programme branch yet, because Latvia lacks not only logistics specialists but also academic staff that could teach these subjects qualitatively.

2. Opportunities to Receive Logistics Knowledge in the Faculties of LLU

Logistics is of utmost importance in industrial manufacturing and business, but it has not been studied systematically and introduced in the primary sector – agriculture and forestry. However, its development in agricultural and partner enterprises, their groups and regions would create new opportunities for the risk management due to the risks of competition and other social and economic factors, as well as for more effective management of specific risks.

Rather many logistics systems already operate in the enterprises of primary and secondary, as well as tertiary sectors of other industries. Part of them, probably even the largest part, are not registered as companies within the Enterprise Register of the Republic of Latvia or the Commercial Register but they operate as parts or departments of enterprises, as departments of several related enterprises (or enterprise groups) or as business units of enterprise group structures.

Thus, when evaluating the necessity of logistics subject at the Latvia University of Agriculture, it can be concluded that it is very topical and that this course would be the most necessary for several faculties.

One of them is the Faculty of Economics that teaches managers of companies and their departments, public officials, etc., because every manager within a company should be competent in logistics issues (storage management and handling, transport, warehouse management, etc.) even if the manager's direct responsibilities are not related with it. The manager, planner or other administration specialists have to be even more competent if the company deals with offering logistics services, which is one of the most progressive industries in Latvia. One can surely forecast that it will only continue developing. It is acknowledged that when developing logistics systems skilfully, it is possible to reduce production and transportation costs, to increase the quality of output and to enhance its competitiveness in the market.

The second is the Faculty of Food Technology because transporting food and food stock management is especially sensitive and connected with high risk. In most cases these are fast moving goods with a rather short life period that require significantly stricter control, preciseness and adequately high level of knowledge.

The next is the Faculty of Forestry, the graduates of which deal with the growing need for effective management of the flows of round timber and forest exploitation remnants. It is also useful to introduce and use logistics methods and principles in forest growing and utilization. In fact, it can be said that every forestry employee has to know logistics.

The competence of the specialists prepared by the many-profile Technical Faculty is various – car park, containers, warehouse technological equipment, their specifications and utilization, choice and economy of fuel, etc.

Then the Faculty of Agriculture, the goal of the study programmes of which is to prepare specialists with career opportunities in top managerial positions in crop farming, horticultural, cattle-breeding and livestock product farms, firms and organizations. For such specialists logistics knowledge would be especially important, taking into consideration the fact that logistics systems as risk management methods and tools are especially crucial and

effective in quality risk management in dairy farming. These opportunities have already been rather widely and fruitfully used by business self-government organizations – co-op companies. In meat production industry, logistics systems formed on the principles or related company integration work effectively. In horticultural industry in risk management, peculiar logistics systems founded on contractual principles also work effectively.

In the Faculty of Information Technology, the need for such a course is determined by the fact that nowadays different achievements and programmes of information technology are applied to logistics systems management and Latvia feels the lack of such technology and programme management specialists especially sharp. Currently the market faces the situation that several merchants and service providers of such technology and programmes come to Latvia from abroad – Poland, Russia, Finland, a.o., thus these products and services are more expensive and are not fully adapted to Latvian market, the service is rather slow, language barriers are also possible both when consulting specialists and when using their offered products.

The Faculty of Agricultural Engineering prepares specialists in civil engineering, designing, building technology and management. In designing building constructions two factors are important. They create the necessity to offer acquiring logistics knowledge. First, logistics industry requires several functional buildings: warehouses, terminals, etc., and it would be necessary to teach the young specialists in basic planning principles of such buildings. Second, when managing construction works, it is necessary to choose the materials, supply them. In addition, material delivery on time and in the required volume is especially important in this industry because lack of some material causes idle time and losses. Besides, there are construction works that require certain weather conditions and if the supply is delayed or of insufficient volume, construction works can be performed with worse quality or can last longer.

The former activities of the Faculties lead to the following conclusions:

- Faculties of Latvia University of Agriculture have realized the importance of logistics science, therefore logistics courses have been introduced in 8 study programmes of LLU Faculties as mandatory courses and students of all Faculties can choose "Basic Logistics" and "Logistics in Marketing" as electives;
- 2 Faculties offer logistics courses with specialisation in the Faculty area – Faculty of Food Technology offers "Logistics of Food Products" and "Logistics in Hospitality", and Faculty of Forestry offers "Logistics in Forest Exploitation" which is also the widest study programme related to logistics at LLU. The other Faculties offer general and comprehensive logistics courses;
- unfortunately, logistics is not yet offered in the Faculty of Agriculture, the graduates of which are in real need of it. This course would be progressive and student competitiveness in the labour market would be increasing for the Faculty of Information Technology and the Faculty of Agricultural Engineering, in which it is not yet offered either.

3. Study Programmes of Riga and Regional Universities and Colleges that Offer Logistics Subjects

In several Latvian universities logistics subjects are included only as supplementary subjects. Having studied and analysed the information about the contents of study programmes, I concluded that in all biggest Latvian universities logistics subjects are offered in different study programmes, mostly in economics and management study programmes.

At the University of Latvia such subjects are offered in 3 Faculties: Faculty of Economics and Management, Faculty of Law, and Faculty of Physics and Mathematics. Logistics as an elective subject is offered in 13 study programmes. Offering logistics as a course in the Faculty of Economics and Management is self-evident. However, the conception chosen by the University of Latvia to offer the course "Logistics" to the students of the Faculty of Physics and Mathematics should be approved because, as it can be seen, this Faculty prepares programmers and mathematicians that can use their acquired knowledge in several directions – first, by performing independent professional activity and, when offering services to clients, by organising stock management themselves for their own needs; second, by creating new or managing and improving the existing programmes and information technology necessary for logistics systems. For optometrists this subject might be attractive from the following aspect – several optometrists perform their professional activity in private practices that are combined with shops for glasses. Thus they need to manage stocks and it is not cost-efficient to pay salary to people performing this function in small enterprises, therefore optometrists have to know this area themselves. Law students of the Faculty of Law might need logistics knowledge when designing different contracts of transportation, purchase and other agreements for both Latvian and international companies, consulting them in signing such deals.

At Riga Technical University, logistics subject is offered in 2 programmes of 2 Faculties: in the Faculty of Engineering-Economics, and in the Faculty of Transport and Engineering. Both study programmes are more of technical character and in both of them Logistics course is mandatory in difference from the University of Latvia.

At Riga Stradins University, International Transport Logistics is included as a mandatory course in the study programme "Management of Small and Medium-size Business".

In several private non-university type colleges and the ones established by legal entities in Riga (BA School of Business and Finance, School of Business Administration "Turiba", Riga Teacher Training and Education Management Academy, Baltic International Academy, Information Systems Management Institute, Culture and Economics University College), Logistics is offered as a mandatory course in economics and management study programmes. The exception is Riga Aviation Institute, where the course "Logistics" is included as a mandatory course in Master's Study Programme "Engineering - Aviation Transport". But in Rezekne and Vidzeme regional universities, Logistics course is mandatory in Business Management Study Programmes. Whereas in Juridical College and Riga Business School, Logistics course is an elective subject.

4. Opportunities to Study Logistics by Distance, in Further Education and Life-long Learning Systems

European Logistics Association (henceforward – ELA) has been working in Europe for several years already. Its main goal is to support the development of logistics industry in its Member States, to enhance solving of different issues related to industry specifics, to encourage observance of unified principles by developing logistics norms and quality standards.

For developing logistics education, ELA has defined European Logistics Education Standards. To ensure the implementation of these standards, European Certification Board of Logistics (ECBL) was established. Its main responsibility is to monitor and coordinate training, evaluation and certification processes in all Member States, in this way guaranteeing the legitimacy of the awarded certificate of the logistics specialist in every European country which is a member of ELA (ELA – Certification for…, 2006; Master Programme in …, 2005).

Currently in Latvia, Logistics Partners, Ltd. have worked out the only in Latvia complete training course for logistics specialists, based on the ECBL provided qualification requirements, as well as including specific aspects and conditions of Latvia. However, as the membership fee in ELA is very big and equal to all countries, Logistics Partners, Ltd. is not registered as an ELA member, but it operates as a subsidiary of Finland, which is an ELA member, and upon graduation, the new logistics specialists receive an ELA certified certificate of Finland.

The training programme worked out by Logistics Partners, Ltd. also anticipates very close involvement of the company represented by the logistics specialist's candidate (more specifically the candidate's direct supervisor) in the training process, so that the qualification received by the candidate would be most widely applicable to the specific company, as well as all practical tasks and projects are made on the basis of the specific company, using its real data and corresponding additional information.

Further education programme courses in logistics are also offered by RTU and TTI, as well as by several consultation and training firms of Latvia.

However, in total, the offer of Latvian further education in logistics is very narrow and most courses are specific, for receiving a specific certificate, not for preparing qualified logistics specialists. In addition, the training programme offered by Logistics Partners, Ltd. is the only one that offers internationally recognised certificate of a logistics specialist. All the other training organizations offer course graduates their own organization's certificate.

International carriers managers' certificate of professional competence (CPC) can be obtained by the graduates of International / Local cargo and passenger transportation and it is a sufficient proof of professional competence as provided by Directive 96/26/EC of April 28, 1996 "On Cargo and Passenger Carriers' Admittance to Profession and on Mutual Acknowledgement of Diplomas, Certificates and Other Documents Certifying Professional Qualification" in order to give these carriers wider rights to get involved in inland and international carriage. A qualified administrator with a certificate of professional competence (CPC) in road transport management currently is one of the main requirements for a company to get a licence that allows performing inland and international carriage. However, it is not enough with such education for a graduate to become a logistics specialist in a company.

Conclusions

1. The development of logistics education in Latvia does not correspond to the speed of its industry development.
2. Currently Latvia has 4 Logistics study programmes, 3 of which are accredited: one of them is a doctoral programme, 2 – professional Bachelor's study programmes.
3. Only RTU Professional Bachelor's Study Programme "Business Logistics" offers education corresponding to the professional standard – Manager of Logistics Department – approved by the MoES. Graduates of other study programmes receive a degree in engineering and management.
4. Nine out of 11 logistics and transport organisation programmes are professional study programmes. It only emphasises the fact that this science is topical and applicable and necessary for use in real life.
5. Latvian universities now offer 7 higher education study programmes in transportation and 4 of them are accredited.
6. Raising logistics competence in Latvia is absolutely necessary in all business areas and at all levels, especially in the primary sector of agriculture.
7. Latvia University of Agriculture currently does not offer any logistics study programmes but different logistics subjects are included in the study programmes of 4 Faculties.
8. Latvia University of Agriculture has vast opportunities and it is necessary to develop the offer of logistics education, first, by giving students the opportunity to choose specialisation in logistics in the Faculties, in the study area of which logistics is especially topical and necessary – Faculty of Economics, Technical Faculty, Faculty of Forestry, Faculty of Food Technology, and Faculty of Agriculture.

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A FORMATION AND ANALYSIS OF THE SCENARIOS IN THE VOCATIONAL EDUCATION RESEARCH PROCESS

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Abstract

In the vocational education research, different methods including a formation and analysis of the development scenarios can be used. In the research of vocational education method of scenarios analysis is hardly ever used. In the article the chance to use the method of scenarios analysis in the research of vocational education in Latvia is evaluated. There is the AHP (Analytic Hierarchy Process) method for analysis of scenarios of the Latvia vocational education development used in the article.There are given.methodological recommendations for the realisation of the formation and analysis of development scenarios.

Key words: vocational education, development scenarios, analysis methods

Introduction

Processes in the socially – economical sphere in Latvia become more dynamic and complicated; nevertheless, the system of formal education in its terms remains conservative. It aims to at stability and thoroughness. In the vocational education, there will always be the time difference between the moment when the demand of economy is formed and the moment when after the formation and realisation of the educational program in the labour market educated specialists appear. While researching the development of the vocational education, it is useful to form both development scenarios and models of system. In the research of CEDEFOP (Leney et al., 2004) it is stated that the formation and analysis of scenarios is frequently used in economics, but there are only few publications about the use of this method in the research and planning of the development of education.

The basic problem of the research: institutionalized research of the development of the vocational education in Latvia is not persistently functioning. There are separate researches that analyse the present state and address the past, but there are no researches of prognosticating origin. How will the system of the vocational education in definite period of time develop in future? The formation and analysis of the development of the vocational education scenario is one of the methods that could help to provide more qualitative planning work for the development of the vocational education as well as could help to recognise potential risks and problems in time.

The object of the present research: the vocational education in Latvia.

The subject: the research in vocational education.

The aim: to evaluate the possibility to use the scenario analysis method in the research of the development of the vocational education in Latvia.

The tasks:

1. To appraise the theoretical and methodological aspects of the Scenario analysis method;
2. To formulate and evaluate four scenarios of the vocational education development in Latvia;
3. To give some methodological proposals for realising vocational education scenario analysis.

Methods

Study of academicliterature and normative documents concerning the vocational education, regional economy and research methods in education. Statistical data analysis. Analytic Hierarchy Process.

Results and Discussion

In Thinking approach – statement that 'We are in systems and systems are around us' (Broks, 2000) is on the basis of modelation. Systemic thinking means to perceive and study system holistically: evaluating both causes and effects of interaction of its separate components and factors of macro setting and interaction of micro setting and macro

setting. In systemic thinking it is considered that each interaction between separate elements of the system always will lead to consequences that will influence function of the system in general. The objects of analysis are the given interaction and the potential changes. The approach of systemic thinking is developed further in Systemic Dynamical Approach. (originally: Forrester, 1961, see: *http://www.valuebasedmanagement. net/ methods_forrester_system_dynamics.html)*. Systemic Dynamical Approach differs from systemic thinking only with the graphical models which are made by computer as an analysis. The aim of systemic dynamical approach is not a definite model of the system but rather the solution of some particular problem. There are cases that in the solving process of problem it is necessary to return to the beginning phase of modelling and to define problem once again because it can turn out that firstly prognostic problem is a part or consequence of some larger problem.

The beginner of the scenarios method is USA futurologist K. Hahn (see: Sellin, 2004). Methodology of scenarios forming firstly was developed in 20th century beginning of seventies in the sphere of business (Wack, 1984; Porter, 1985; Shell, 2000, Leney et al., 2004). The method of scenarios forming is useful when it is necessary to better understand the nature and influence of motive factors of system development in some precisely marked time period in future. Nevertheless, as B. Sellin mentions (Sellin, 2004) the forming of scenario in the research of development of the vocational education does not mean to forecast future but to pay attention to the main factors that affect the development. Scenarios are defined as follows:

- Description of the probable following actions in logical and concrete order considering time factor and coherence that could lead the mentioned actions to materialization. (Бешелев, Гурвич, 1973)
- Description of the development of predictable future of separate object considering alternative critical conditions (Hanssmann, 1983)
- Internally consistent aspects of the predictable future (Porter, 1985)
- The order of hypothetical action constructed purposely to concentrate attention to causative processes and decision making (Kahn, Wiener, see: Zanoli et al., 2000)

The formation of scenarios usually includes the analysis of present situation, the choosing of several determative factors, their analysis and prediction of variability for some definite period of time. In the strategic planning of the formation and analysis of scenarios, it is advisable to use, for example, forecasting, benchmarking, Delphi method, SVID analyse, STEEP analyse, etc.

Van der Heijden points out the necessity to choose method in order of period of time in future. From his point of view, it is derived that the defining and analysis of scenarios is useful in medium-term strategic planning.

The process of forming scenarios usually consists of the following stages:

- choice of experts
- the evaluation of the macro setting of the system (in the form of interviews or discussion)
- the grouping and clasterization of the viewpoints of experts
- the modelling of scenarios draft based on experts' viewpoints and priorities
- further development of the draft scenarios to definite scenarios
- defining the indicative factors for the evaluation of scenarios
- evaluation of scenarios

In the figure 1, one can see the author's Zanoli, Gambeli and Vairo (Zanoli, Gambeli, Vairo, 2000) adapted logical scheme of the formation of developmental scenarios which includes three main modules: analysis of present situation, the formation of description (scenarios) of developmental route and defining future situation and evaluation of the scenarios.

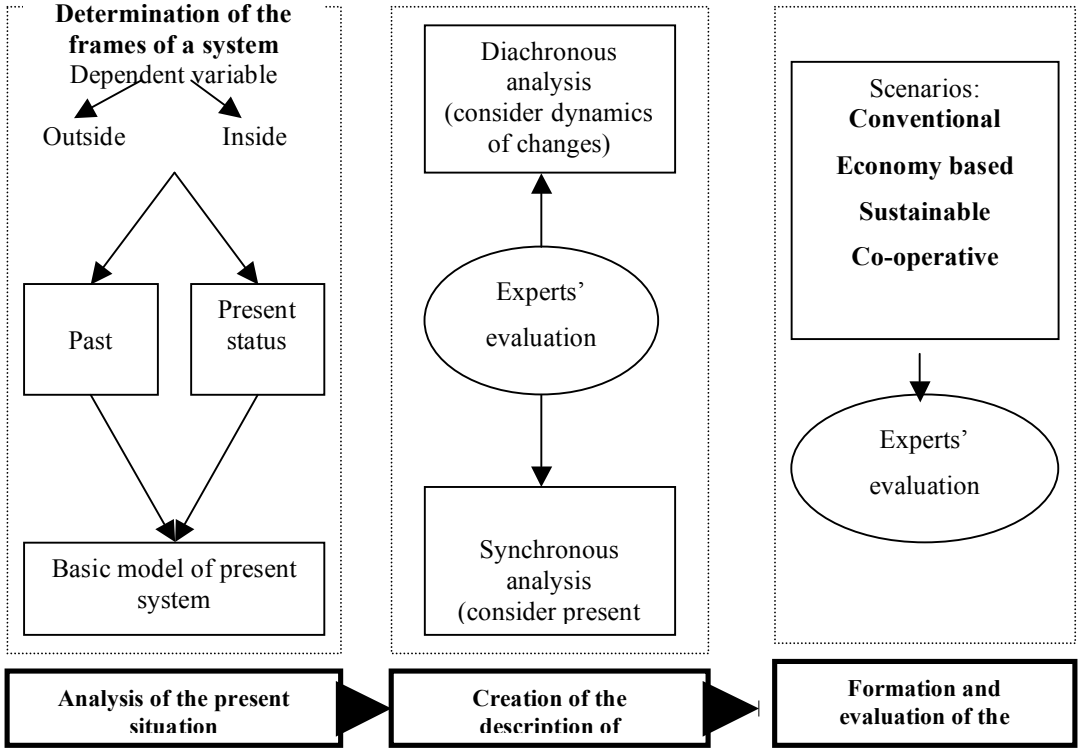

Figure 1 **A formation and analysis of scenarios of the development of the vocational education** *(Adapted to Zanoli, Gambeli, Vairo, 2000)*

In this article the author's explorative route is different according to the model of Zanoli, Gambeli and Vairo taken as the basis, the analysis of the present situation and also the formation of scenarios was done by the author, whereas experts were asked to evaluate criteria and scenarios. In the time of analysis none of the presented scenarios was rejected but they were ranged; in the result, the global priority respectively to the most acceptable scenarios was chosen. For evaluation of macro setting STEEP method was used (see table 1).

Table 1

The Evaluation of Macro Setting of the System of the Vocational Education in Latvia Using STEEP Method

Social factors	
Demographical situation	The decrease of the population in separate regions all over the country.
Migration processes	Inner migration in the country. Outer immigration and emigration.
Technological factors	
New technologies	Both in traditional and in novel developed spheres the newest technologies are used
New electronical systems	Modern electronical systems involve the necessity of new knowledge for the personnel
Information and communication technologies	It is possible to have more effective communication between the subjects involved in vocational education. The speed of gaining information increases.
Economical factors	
State's economical development	The finances of the state and local government for the modernization of material basis of vocational education increases. Increase of salaries and social guarantees gives way to increasing motivation of teachers/lecturers' work.

Social factors	
Possibility to use EU supportive funds	The possibilities to use funds expand. In projects attached funding supports both the development of material base for learning, practice and mobility of students and mobility and training of teachers/lecturers.
School cooperation with companies	The interest of companies to cooperate with vocational schools increases. That provides direct interchange of information about the changes in necessary competences for workers.
Setting factors	
Requirements of environmental protection	The requirements of natural resources and environmental protection become stricter. They are included in the content of educational programmes.
Political factors	
Legislation	Legislative acts and other laws and regulations that directly or medially can influence function of the system of vocational education.
EU common trade market	Free workforce migration and possibility to get vocational education in any of EU acceding countries create new demands for communicative competences.
Employment policy of the country	The possibilities to predict the development of trade market and to evaluate the changes of workforce demand.

At the beginning of the research a hypothesis that one of the most important factors of negative influence of the development of vocational education can be insufficiently effective cooperation between the system of vocational education and all interested social partners was directed.

In the table 2 four scenarios of development of vocational education in Latvia are defined and characterised: Conventional, Economy- based, Sustainable and Co-operative scenarios.

Table 2

The Scenarios of Predictable Development of Vocational Education in Latvia

Conventional Scenarios Conventional scenarios	Radical changes are not predictable. The present system of vocational education is not changed substantially. Cooperation between the ministries in charge mostly is formal. Numberr of vocational schools continues decreasing in several districts. In the preparation of standards of professions initiative of educational institutions dominates. The necessity of the formation of vocational education programmes is not based on systematic research of demands in labour market. The development of material basis is only in the limits of state and local government finances. The growth of salary for pedagogical staff is in the conceptual framing of the salary for workers in all state. The use of EU funds is in the initiative of governing body of each educational institution.
Economy-based Scenarios	The future of vocational schools is fixed by the economically beneficial criteria. The preference is given to such educational institution in which providing appropriate quality of vocational education the expenses are the lowest for one student. On the basis of economical calculations the number of vocational educational institutions continues reducing. Perspective schools overall continue working concentrating mostly in Riga and bigger cities. Economical profitability and state interests dominate over regional interests. In the cooperation of responsible ministries, the position of the Ministry of Economics dominates Not more than 5 vocational secondary schools/colleges and LLU offer agriculture programmes. The state actively supports involvement of private funds in the financing of vocational education.

Economy-based Scenarios	The state fund donations mostly increase due to political resolutions about support of the development of some definite sphere as well as due to the closed vocational schools. The main task of primary vocational education programme is to form concrete basic competences. Preparing specialists for precise profession and also for new spheres of manufacturing (profession) is carried out in relatively short – termed modules when educational institutions cooperate with manufacturing companies. The formation of new profession standards and educational programme is due to the employers' initiative. Cooperation between educational institution and companies is realistic only if the company considers it to be economically profitable.
Sustainable scenarios	The state supports and stimulates balanced development of all regions. That makes economical basis for existence of vocational school in a particular region. Deciding on some concrete school's destiny interests of the local government and region are considered both from current and perspective aspect. Economical profit is not the main factor. The main task of primary vocational education programme is to form particular basic competences. Functioning of vocational schools becomes more varied. Donations of state/ local government for support of schools and development of methodological base are equally increased for all vocational schools. State supports the growth of salary for pedagogical staff and real functioning of system of further education of vocational school teachers.
Co-operative scenarios	State supports and stimulates different forms of cooperation between vocational education and all social partners. The function of vocational schools and also formation and development of study programmes is looked at from the point of view of interests both of sphere, regional, and state. State stimulates the flow of private funds in vocational education. Close cooperation between responsible ministries is realised both in the prediction of the demand of the trade market and in providing of support of career development in vocational schools. Companies are interested in investing in the development of schools and in providing practice places in the company because they get possibility to plan their guarantee of human resources. In the formation of profession standards employers' and professional association initiative dominates. The main task of the primary vocational education programme is to form basic competences. Vocational training is carried out in relatively short – termed modules when educational institutions cooperate with manufacturing companies. The formation of vocational education programmes is based on systematic research and prediction of demands in trade market. The cooperation between vocational education institutions and local government, and local companies become more active within the framework of EU projects.

There where defined 11 criteria for the evaluation of scenarios: Reduction of social tension, Students' interests, Parents' interests, District interests, Regional interests, State interests, Quality of education, Principles of life-long education, Private finances, Use of EU funds and Cooperation with employers.

In the analysis of the scenarios of the development of vocational education was used method of Analytic Hierarchy Process (AHP). The author of present method is mathematician T.Saaty (USA). AHP is systematic procedure for hierarchic arrangement of elements of any problem. The problem is gradually divided in smaller segments that means the decomposition of problem is done. Experts compare these parts in pairs evaluating the level of intensity of interaction of problem elements in hierarchy. Experts' deductions are announced in numbers. The hierarchy of the elements of problem form: aim, groups of criteria (1st interlevel), criteria (2nd interlevel) and enumeration of alternatives (3rd interlevel). As in this research the number of criteria is comparably small; the grouping of criteria was not done. All the elements of AHP system are grouped in 2nd figure.

For the evaluation of the scenarios 8 experts who

represent both secondary and higher vocational education inter alia agricultural education, small, medium and large manufacturers, as well as representatives from Ministry of Education and Science and Ministry of Welfare where interviewed. The information about experts' professional status and their represented institutions are shown in 3rd table.

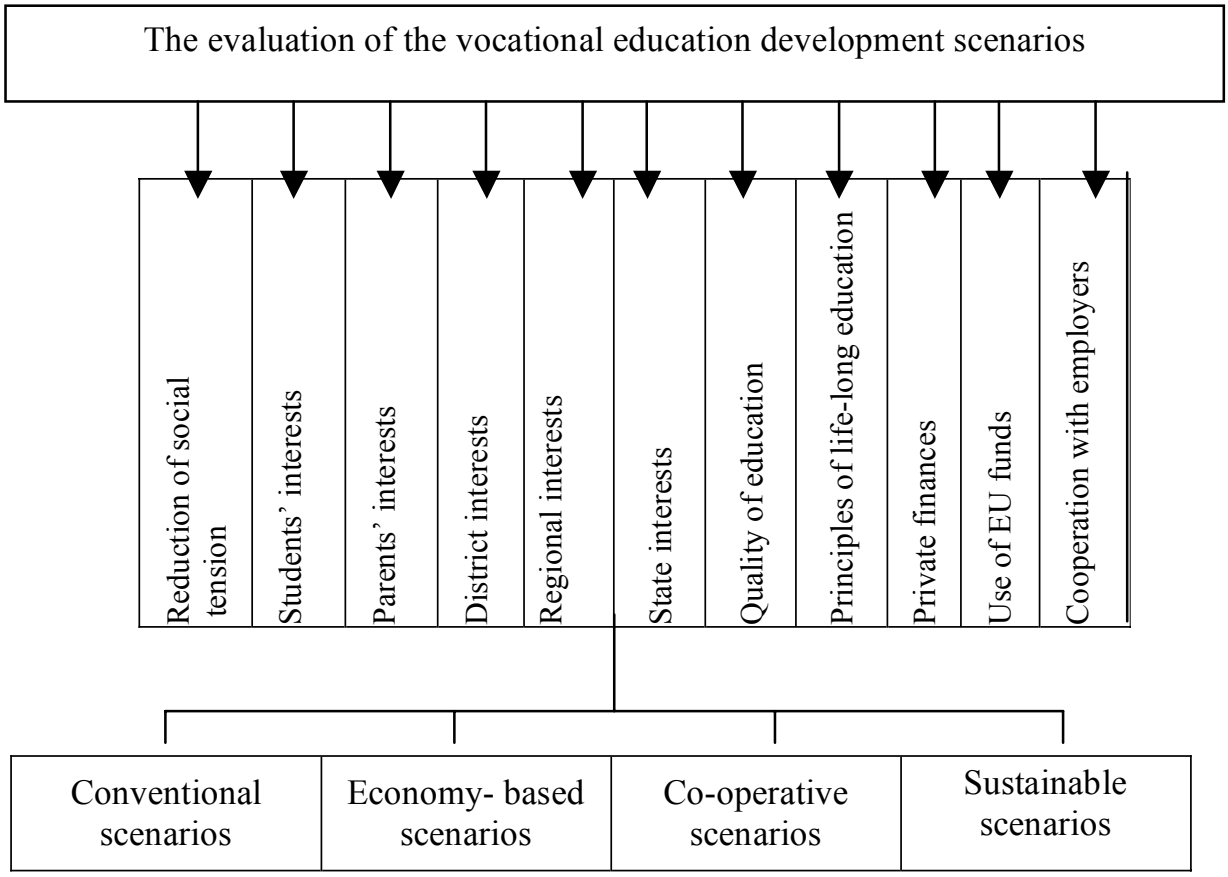

Figure 2 **A hierarchy of evaluation of the vocational education development scenarios** *(adapted to T.Saaty)*

Primarily all experts compared evaluation criteria of the vocational education development scenarios; thus, theoretically ranging them. Each expert results were treated separately and after that combined in the summary of evaluation.

Table 3

The Professional Status of Experts of Evaluation of the Vocational Education Development Scenarios and Represented Institutions

No	**Position**	**Institution**
1.	Director	Priekuli State Vocational School
2.	Director	VAR-C Ldt, metal-working factory (50 employees)
3.	Director	Priekuli Machinery Station Ldt, (7 employees)
4.	Vice-director of the Department	Ministry of Welfare. Labour Department
5.	Director of the Department	Department of Career Development at the Ministry of Education and Science
6.	Director	Riga vocational school Nr 13
7.	Docent	Latvia University of Agriculture
8.	Director of the Department of Vocational Training	Domenikss Ldt, automotive trade and service (260 employees)

Data calculations were done by computer programme MS Excel. The results of data calculations are summarized in the 3rd figure as each factor's minimum, maximum and medium vector co-ordinate of priority.

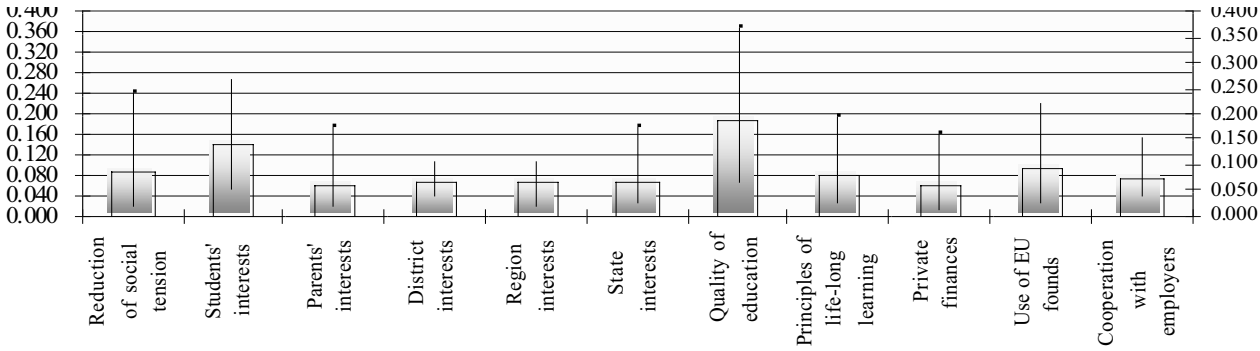

Figure 3 **A graph of the summary of the evaluation of criteria**

The picture shows that experts gave the highest rank for 'Quality of education'. However, experts' answers amplitude of absolute value can be seen as well. Next is 'Students' interests' that is indicative in respect of human centred attitude and democratic fundamentals and also makes to pay more attention to students' supporting questions of career development in the vocational education institutions. The criteria: 'Reduction of social tension' that shows that there is not only educative role but also social role of vocational school in Latvian society, 'Use of EU funds' and 'Principles of life-long education' have received relatively higher evaluation by experts. The other criteria have got mutually similar, lower evaluation. In the following analysis experts compared mutually the scenarios of development of vocational education considering each criterion separately. Some expert results of calculation are summarized in the 4th table and the outcome is summarized in the 4th figure. The picture shows that the amplitude of dispersion is relatively big that means experts' opinions differ giving the highest and lowest evaluation. However, the summary of evaluation clearly forms precise hierarchy of the development scenarios.

Table 4

Results of Calculation of the Evaluation of Vocational Education Development Scenarios Seperatly for Each Expert

Alternative	Experts								
	1	2	3	4	5	6	7	8	Aver.
Conventional	0.093	0.092	0.070	0.056	0.098	0.286	0.137	0.069	0.112
Economy based	0.105	0.119	0.337	0.068	0.258	0.069	0.086	0.114	0.144
Sustainable	0.525	0.338	0.305	0.269	0.199	0.179	0.388	0.403	0.326
Co-operative	0.277	0.451	0.287	0.607	0.446	0.465	0.390	0.414	0.417

The Co-operative scenarios have received the highest evaluation by experts. Once more it is necessary to stress that in this scenario co-operative factor dominates ower enlargement of finances for vocational schools. The results of experts' evaluation with certainty confirm the speculation highlighted in the beginning that the present cooperation between the system of vocational education and all social partners was not enough fruitful and parties were not enough interested in it.

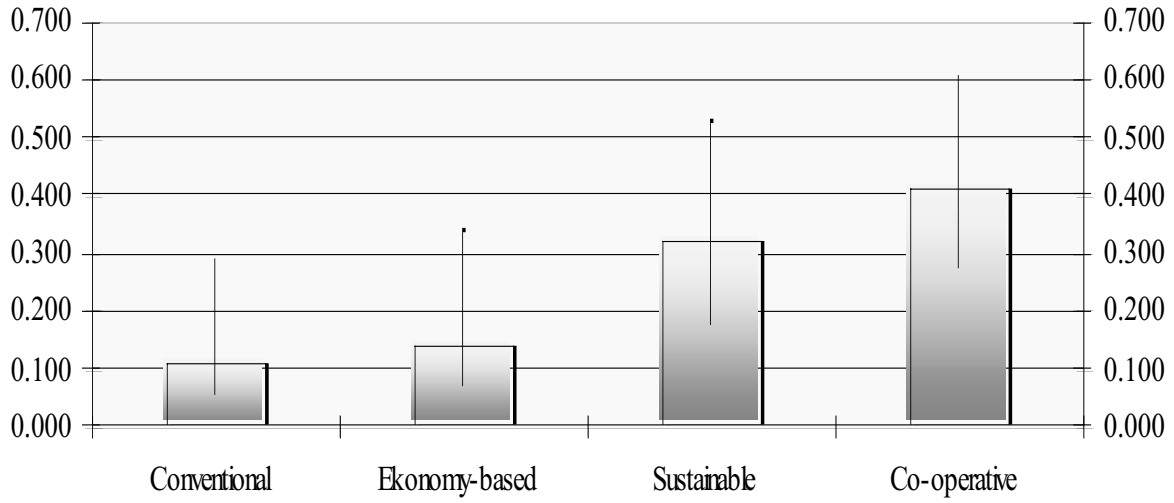

Figure 4 **A Summary of the Evaluation of Development Scenarios in Vocational Education**

Comparatively high rating the experts have given to 'Sustainable' scenarios but the lowest evaluation has got 'Conventional' scenarios which in the description were defined as scenarios that continue present progress in the development of vocational education. That convincingly approves the author's hypotesis that with the present situation are not satisfied neither employers, nor representatives of vocational education, nor representatives of the government.

Some Methodological Recommendations

1. In the formation of scenarios two approaches can be used:
   a) Scenarios are made by one or more experts but analysis is done by other group of experts
   b) Scenarios are made and analysis is done by one group of experts

2. The purposefulness of the formation and analysis of scenarios and the quality of results can be influenced by criteria from which the expert team and the leader are selected – it is necessary to choose them very wisely.

3. The number of experts could differ in each case but 'if the experts are few, it will increase experts united mistake of action' (Бешелев, Гурвич, 1973), but if there are too many experts that will be longer and more complicated, and more expensive in general.
4. The invited experts should be interested in the formation and evaluation of development scenarios of vocational education.
5. In expertsteam should be not only representatives from the micro setting of the system, but also representatives from macro settings of the system (responsible ministries, local government, employers and the Council of National Triangular Cooperation of Vocational Education).
6. If in the process of formation and evaluation of scenarios the probability of substantial change the present or formation of a new system is predicted, or if the tasks of the formation of the scenarios include the request for new, novatorical or untraditional solutions, then at least 2 as far as 50% of experts should not be connected with vocational education neither in present, nor in past. Thus, the principle that experts discussion would be '... free from experience and function' (Lumann, Habermas, Klafke; see: Martial, 1996) could be held. In this case those participants of discussion who are not connected with the field of investigation most probably will be idea men but those experts who are connected with the field of investigation – positive critics. About influence of 'in-box thinking' in the formation of scenarios (in the evaluation of the scenarios it could be insignificant) involved experts', is already warned in for example in CEDEFOP research (Leney et al., 2004).
7. In the formation of scenarios one should avoid: perceiving them as prognoses, differentiate and define them in too simplified way, formation of them in too narrow view, perceiving scenarios as informal, institutional tool.

Conclusions

1. The method of formation the scenarios is useful when it is necessary to better understand the character of impulsive factors of the development of vocational ducation system and the influence in definite period of time in future.
2. The formation of scenarios in the research of the development of vocational education does not mean the future prediction but paying attention to more important, development influencing factors.
3. Before the formation of scenarios, it is necessary to define the factors of macro settings and evaluate their influence.
4. The results of experts' evaluation approve the projective speculation that the present cooperation between the system of vocational education and all social partners was not enough fruitful and parties were not enough interested in it.
5. With the present situation in the vocational education neither the employers, nor vocational schools, nor the representatives from government are satisfied.

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THE PROFESSIONAL READINESS TO PURSUE PEDAGOGICAL WORK DURING THE TEACHING PRACTICE IN THE SCHOOL EDUCATIONAL ENVIRONMENT

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Abstract

The article deals with the issue of the impact of teaching practice on training of the future educators. At the Institute of Education and Home Management of the Latvia University of Agriculture, approaches of human pedagogy and education lie at the basis of the conceptual grounds of the school practice. The phases of the school practice are characterized and the readiness obtained by the students within the training are discussed. In every phase of the school practice, students gradually adapt themselves to the school, pedagogic and educational environments. Results of student survey on the development of readiness to pedagogic work in school educational environment and the developing role of competency are presented .

Key words: readiness to professional activities, readiness to pedagogical work, learning environment, pedagogic environment, educational environment.

Introduction

Readiness of students for pedagogic professional activities are created and developed both during theoretical training in the educational environment of higher educational establishment and in the school educational environment during the school practice. During the school practice, students start to accumulate their experience of pedagogical work. The topicality of research is related to the problem of the training of future educators, because the teachers' role in the education of next generation is again studied in the 21st century.

The aim of the research: to evaluate students' views on the formation of readiness in the school educational environment during the school practice.

To implement the aim of the research, following methods were selected:

- The theoretical analysis and synthesis by creating methodological grounds of the research.
- Survey on the formation of readiness of the students to the pedagogic work in the school educational environment.
- Reflection of personal experience length of the author's pedagogical service is 30 years.

In order to elicit the opinion of the fulltime and parttime students on the formation of readiness for the professional activities in the school learning, pedagogical and educational environments, we invited respondents to evaluate every of the proposed indices between 0 and 10 points. In the research, 30 respondents participated (4th -year and 5th - year parttime students).

Results and discussion

Creation of the readiness for professional work is both the aim and the result in the process of preparing the new specialists. Readiness of the personality for activities is determined by the need for activities, psychological processes, position, experience, and personal properties.

The Russian educationist Kapterev P. (Нестерова, 2006) pointed out that the teacher's personality ranks in the teaching situation in the first place as these or those personal properties of the teacher will rise or decrease the educational effect of teaching. Already in the start of the 20th century, the author elicited the objective and subjective factors required for the pedagogical work. Personal properties of the teacher are divided into **the special and personal moral and free will properties. The objective personal property is characterized by:** knowing his/her own subject; scientific readiness for the given occupation, related subjects, education in its widest sense; knowing the methodological and general didactic principles; knowing the child's character.

The subjective personal property is characterized by: the art of teaching; the teacher's peda-

gogical talent and creativeness.

In turn, the moral and free will properties of the personality are as follows: objectiveness, attentiveness, sensitivity (particularly, to the children whose results of attainment are not so good), scrupulosity, persistence, self-criticism, and true love of the children.

Kuzmina N. (Кузьмина,1985) in the structure of subjective factors includes: type of orientation, level of skills; competency which includes the special pedagogical competency; social psychological competency; differential psychological competency; and auto-psychological competency.

As the most significant from subjective factors, the author considers to be the personal orientation which enables to attain the peak of the professional pedagogic work. To the author's opinion, the main strategy of the work is determined by three types of orientation:

- the truly pedagogic; the formally pedagogic; the false pedagogic.

Only the first type of orientation enhances attainment of high results in the pedagogic work as its leading motive is interest in the content of the pedagogic work. The Russian scientist Markova A. (Маркова, 1993) divides the subjective properties of the teacher into two blocks:

1) ***the objective characteristics:*** professional knowledge, professional skills, psychological and pedagogic knowledge;
2) ***the subjective characteristics:*** psychological positions, motivation, 'I conception', orientation, personal properties.

The most important **professional properties** are as follows: erudition, setting targets, practical and diagnostic thinking; intuition; improvisation; keenness; optimism; readiness of mind; forecasting capability; and reflection.

The psychological portrait of any subject teacher consists of the following structural components: individual properties of the personality (temperament, inclinations, etc.), personal properties, i.e., his peculiarities as a personality, communicative (interactive) properties; status and position, i.e., condition, roles, relations in the collective body; actions (the professional and subject); outer behavioral indices.

In the structural-hierarchal model of the teacher's personality developed by Mitina L. (Митина, 1994), most essential properties of the teacher are considered to be the projective-epistemological and reflective-perceptive pedagogic skills which are considered as a peculiar combination of personal properties and features.

The author adds an essential significance to the following professional properties: setting pedagogical aims; pedagogic thinking; pedagogical orientation; pedagogical reflection; and pedagogical tact.

Every of these properties is a combination of several properties.

The practical readiness of the student - the future teacher irrespective the organizational model is based on **the following principles**: principle of unity of theory and practice; principle of the professional skills sequence and principle of the system; principle of the functional link with future professional activities; principle of visualization; principle of the gradual increase of independence and responsibility in professional activities; the developing principle of practical teaching of students.

The system of functional assignments of **the student preparation**: development of a stable positive attitude to the future profession; development of respect towards children; desire to master professional skills and to professionally perfect oneself; development of psychological readiness for independent professional activities; development of skills for organizing extra-curricular activities; development of methodical skills in the education sphere at school; development of teaching skills in teaching your own subject to the pupils; development of methodological skills in the teaching sphere; development of interaction skills with the parents of the pupils; and development of school management skills (Блинов, 2004) .

At the Institute of Education and Home Management of the Latvia University of Agriculture, the findings of human pedagogy and ecological approaches lie at the basis of the conceptual grounds of the school practice (Amonashvili (Амонашвили, 2003, 2007), Brofenbrenner (1996), Katane (2006), Peks (2006), Petrovsky (Петровский, 1992)) stressing the fact that regularities of the dyadic interaction are observed. In the research of the above mentioned authors, **three phases of the dyadic interaction** are observed: observation, joint action, and independent action. During school practice, students undergo all three phases passing from one role to another, they improve their professional and personal competencies.

The first phase of the practice (the lesson visit practice). The 2nd-year students are only observers. The main assignment of the lesson visit practice is to see the operation of the studied theoretic findings in the teaching process at school and to know how to evaluate it. In the start of the practice, under the guidance of specialists, the students observe and analyze the lesson which they attend. The leaders of the school practice share their experience with the students in their open lessons and optional lessons

at schools. They jointly analyze and evaluate these lessons indicating the most essential which the students should know and take into account. In the second part of the practice, the students start to act as assistant teachers in the preparation process of lessons and methodical materials.

The second phase of the practice. The 3rd - year students act as assistants of the specialists (the teachers-leaders of the school practice), in joint actions taking over the best practice and dividing the responsibility of quality of the pedagogical work and learning to critically think, to evaluate the pedagogical process and themselves in it. Prior to starting the assistant job, the students visit lessons where they familiarize with the style of work of experienced teachers, their teaching methodology as well as observe the pupils in classes where they will have to work in the near future assisting their leaders of the school practice. In this phase of the school practice it is topical for the students to see, know, analyze and evaluate the obtained theoretical knowledge in a real education process: the taught laws, basic principles, theoretical thoughts of the teaching methods used by the educators-practical workers in their definite subject, paying adequate attention to the management issues of the teaching process as well.

When the student has proved his skills to see the theory and to evaluate it in the pedagogical activities of other educators, he starts to work as the assistant teacher maintaining partnership with the leader of the practice in the base school. The student actively gets involved in the planning (the visit lessons) of the teaching process, in the practical implementation and joint evaluation.

The third phase of the practice. The 4th - year students prove their competencies obtained in the independent pedagogical activities, evaluate the school as a multilevel and multifunctional educational environment and himself in it on the whole; the role of the leader of the practice is to be an advisor/consultant. The students have an opportunity to independently plan, organize, conduct and evaluate the self-conducted teaching process in the subjects of his occupation. The leader of the practice has the role of an observer and consultant. The student has to analyze the teaching process in compliance with the state standards, the formal plans of the school, and the sample plans of the state approved lessons. At the same time, the student can creatively construct his own structure of the lesson by selecting the logics and structure in explaining the new material, reviewing, strengthening, checking/control, trying to find possibilities to vary the demonstrations applying methodology adequate to the aims and didactic tasks of the lesson, information technologies. The circle of competencies and the spectrum of functions for the students increase in every phase of the school practice in correspondence with the integration level.

The school environment can be viewed as a hierarchic, mutually subordinated environmental structure. In accordance with I. Katane (2006) finding, the ecological approach ensures a whole outlook to the school as an educational environment from the structural, functional and evolutionary aspects. The school environment includes: a) the teaching environment; b) the pedagogic environment; c) the educational environment. During the practice, the students gradually acquire every of the given levels.

The pedagogical work is a complicated system which includes several actions.

1. The teacher's activities. 2. The action of summing up the experience. 3. The action to create the teaching aids and subjects. 4. The programming action (creation of programs of study).

The pedagogical work has its own definite structure, the specificity of which the future teacher is acquiring (Table 1).

Table 1

The structure of the pedagogic work (Baltušīte, according to Nesterova, 2006)

Phases and components	Pedagogical activities	Professionally important skills
The preparation phase	■ Statement of pedagogical aims ■ Diagnosing peculiarities of the pupils and the level of training	**1. High scientific and professional knowledge.**
1. A constructive activity	■ Choice of the teaching contents ■ Choice of the teaching methods ■ Designing your own activities and activities of the pupils	**2. The psychological, pedagogical and methodical knowledge.** **3. Knowledge of the practical educational methods.**

Phases and components	**Pedagogical activities**	**Professionally important skills**
The implementation phase of the pedagogical process II. Organizational activities	■ Creation of labor conditions in lessons (discipline, creative and active atmosphere) ■ Promotion of the pupils' activities ■ Preparation of your own activities for effective explanation of the material ■ Organizing your own behavior in real conditions ■ Organizing the pupils' activities ■ Organizing control of the pedagogical impact and the results of the correction	**4. Observation skills, understanding the psychological condition of the human, the spirit of the collective body.** **5. Rapid reaction in the given situation, behavioral flexibility.** **6. Ability to explain the material so as it is understood, logic, sequential and emotional.** 7. The speech culture, quick wit. 8.The expression capability. **9. A good division of attention, the conceptual memory, flexible creative thinking.** 10. Endurance, self-control. 11.Ability to command your own body, voice, facial expression, gestures. 12. Organizational skills. 13.Ability to receive the feedback for the acquired material.
III. Communicative operational activities	■ Creation of the right relations with pupils ■ Implementation of the educational work	**14. Communication needs.** **15.The pedagogical tact.** **16. The pedagogical improvisation skill to use different means of the psychological lever.** **17. The democratic communication and management style.**
The evaluation phase of the obtained results IV. The epistemological activity	■ Evaluation of the teaching and educational results ■ Eliciting results of deviations from the set targets ■ Analysis of reasons for these deviations ■ Designing elimination of the reasons ■ The creative seeking of new teaching and education methods	18. Critical evaluation of your own strong and weak points and operational activities. 19. Self-education skills, learning new educational and training methods. **20. A creative approach to the pedagogical work.**

By **Bold** the skills are elicited which are needed in every of the given phases.

The category 'readiness for the professional activities' in teaching of the educators is very complicated and many-sided (Katane, Baltušīte, 2007). It includes several conceptual meanings of readiness for the professional activities. During the school practice the future teachers should develop various types of readiness, related to the professional activities. In Table 2 the author has systemized the types of readiness the future teachers have to develop during the school practice according to the aim of each practice.

Table 2

Development of readiness for the pedagogical work during the practice

Readiness	Lesson visit practice	Practice 1	Practice 2
Readiness to observe	X	X	X
Readiness to analyze	X	X	X
Readiness to integrate in the school teaching environment	X	X	X
Readiness to evaluate and to take over the best pedagogical experience of other teachers	X	X	X
Readiness to sum up and to advertise the pedagogical experience of other teachers	X	X	X
Readiness to accept the pupil as he stands	X	X	X
Readiness to apply information technologies in lessons	X	X	X
Readiness to start the methodic activities of the subject teacher	-	X	X
Readiness to plan your own pedagogic work	-	X	X
Readiness to organize your own pedagogic work	-	X	X
Readiness to forecast results of your own operational activities	-	X	X
Readiness for cooperation and joint actions with pupils	-	X	X
Readiness for operational activities of the form master	-	X	X
Readiness for cooperation and joint activities with other teachers	-	X	X
Readiness to evaluate your own pedagogic work by means of reflection	-	X	X
Readiness to get involved in the provision of the educational offer of the school interests	-	X	X
Readiness for creative activities of the educator	-	X	X
Readiness to get involved in the work of the school team	-	X	X
Readiness to assume responsibility of your own pedagogical work	-	X	X
Readiness to integrate in the school pedagogic environment	-	X	X
Readiness to implement the theoretical thoughts into practice	-	X	X
Readiness for cooperation and joint actions with parents of the pupils	-	-	X
Readiness to sum up and advertise your own pedagogical experience.	-	-	X
Readiness to move forward the aims of the lesson and to attain them	-	-	X
Readiness to integrate in the school educational environment	-	-	X
Readiness for self-education	-	-	X

By "X" the skills are elicited which are formed and developed in every of the given practice phases.

On the basis of readiness criteria, the respondents evaluated the formation of readiness for the professional work in the school learning, pedagogical and educational environments in the study years 2005/2006 and 2007/2008. The dynamics of the process was evaluated according to the median indices (Table 3).

Table 3

Formation of readiness (the median indices)

	2005/2006 Lesson visit practice	2006/2007 Practice 1	2007/2008 Practice 2
Learning environment	6	7	8
Pedagogical environment	6	7	8
Educational environment	6	8	8

The median indices show that Practice 1 and Practice 2 facilitate the formation of readiness for the professional activities. These changes take place at all levels of school environment. Thus, during the practice, formation of readiness for the professional work takes place by deeper acquiring its different levels.

At the next stage of survey we found out to what extent the learning, pedagogical and educational environments develop and support competency, open and involving environment from the study year 2005/2006 till 2007/2008.

The dynamics of the process was evaluated according to the median indices (Table 4).

Table 4

Evaluation of the school environment (the median indices)

	Learning environment	Pedagogical environment	Educational environment
Developing competency	8	8	8
Supporting, open and involving	8	8	9

The median difference shows that essential changes occur in the educational environment. Compared to the learning and pedagogical environments, the educational environment is evaluated higher by the respondents as being supportive and open, because in the third phase of practice the students get more involved in the school educational environment. However, the question remains to be open on the support and openness of the school environment, if the school does not need the future teacher, and how significant is the role of the supervisor of the practice in this process. Having evaluated the school environment from the view of developing competencies, the median indices appear to be equal. However, as it is proved by practice, qualitative changes occur with the indices which are related to the different levels of acquiring readiness (Table 2). It is showed also by the results obtained during the previous research (Katane, Baltušīte, 2007). Within the next research it is planned to find out the role of the supervisor of practice in the school environment and to compare the obtained data with the results obtained at other state higher educational establishments.

Conclusions

- The readiness criteria had been developed, which are acquired by the future teachers during the school practice when they pass from one phase of practice to another.
- Passing from one phase of practice to the next, the amount of readiness to be acquired widens, but qualitative changes occur in the readiness of the prior phase. It is proved by research results obtained in the year 2007.
- The students emphasize the significance of the educational environment as being supportive, open and involving. It is particularly seen during Practice 2, when the students get more involved in the school educational environment, which facilitates both the formation of competences and support. However, it is necessary to explore further the factors affecting the support and openness of the school environment.

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THE PHYSICAL ACTIVITIES AND HEALTHY EATING HABITS OF THE POST-GRADUATE STUDENTS OF LATVIA UNIVERSITY OF AGRICULTURE

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Abstract

This study was conducted to investigate the lifestyle of post-graduate students. The purpose of the present study was to find out opinion of the post-graduate students how significant are physical activities and healthy eating in their life. The study was initiated due to the growing knowledge of the importance of healthy food.

The study was carried out by using empirical methods and the opinion of post-graduate students living in Latvia analysed. The authors have used questionnaire method and in February 2008 received answers from 86 respondents who are the post-graduate students of Latvia University of Agriculture (LLU).

Studies showed that the biggest part of research subjects appreciates the importance of physical activities and healthy eating, and treats it as a positive part of the post-graduate studies process.

Key words: post-graduate student, physical activities, healthy eating.

Introduction

In the period of dynamic changes and technological development in Latvia, we considerably lose the balance between mental and physical work. There is a tendency to increase hours of mental work, but the load of physical work is reduced. We feel tired after the intensive mental work. The tiredness is caused by unbalanced mental and physical proportion.

Even the outstanding such as as Claude Adrien Helvetius, Immanuel Kant, Jean-Jacques Rousseau et al. emphasized the idea that physical activities influence our mental abilities and suggested exercising to increase these abilities. (Jansone, 2000)

The basic principle of the development of harmonious personality stresses the necessity to focus on physical activities and healthy lifestyle in the society.

Physical activity is defined as „any body movement by skeletal muscles that results in energy expenditure". Physical activities in daily life can be categorized into occupational, sports, conditioning, household, or other activities. Leisure time physical activity represents a broad category of activities performed outside work. (Caspersen,et al., 1985). Engaging in physical activity is more than just a matter of personal choice. (Sallis, et al., 2006). Physical activity for improved health and well-being has been an important theme throughout.

We can keep optimal health through physical activity and food variety. It helps to remind us of the important links between being active, our food intake and our health. In other words to be healthy we need to eat well and be active every day.

The Healthy Eating Pyramid uses the idea of food groups and organises those according to the energy and the nutrients that they supply. It shows the proportions of one group of foods to our total food intake.

With the variety of food pyramids available, we may wonder which one to follow. It may help us if we know that the basic principles of food pyramids are largely the same and generally emphasize the following:

- Eat more fruits, vegetables and whole grains;
- Reduce intake of saturated fat, trans fat and cholesterol;
- Limit sweets and salt;
- Drink alcoholic beverages in moderation, if at all;
- Control portion sizes and the total number of calories you consume;
- Include physical activity in your daily routine (Kerr, 2008).

Food pyramids place foods in categories — such as dairy products or meat and beans — to help to guide your food choices. As Figure 1. shows, no

single food provides all of the nutrients that your body needs, so eating a variety of foods within each group ensures that you get the necessary nutrients and other substances that promote good health.

The connection between food and disease is known to doctors already from Hippocrates time. The ancient Greek physician Hippocrates of Cos said „Nutrients should be our remedy, and our remedy should be nutrients."

Our health and feeling depends on food that supplies our body with energy we need and biologically active nutrients. We can get acquainted with broad investigations in the field of food quality; however, we are not sure that food we daily consume is of good quality and harmless to our health.

The tendency to purchase biological farming products or eco-products as well as the number of citizens that support healthy lifestyle taking care of overall body condition and health gradually increases.

The purpose of the present study was to find out the opinion of the post-graduate students to what extent their physical activities and healthy eating habits are significant for them.

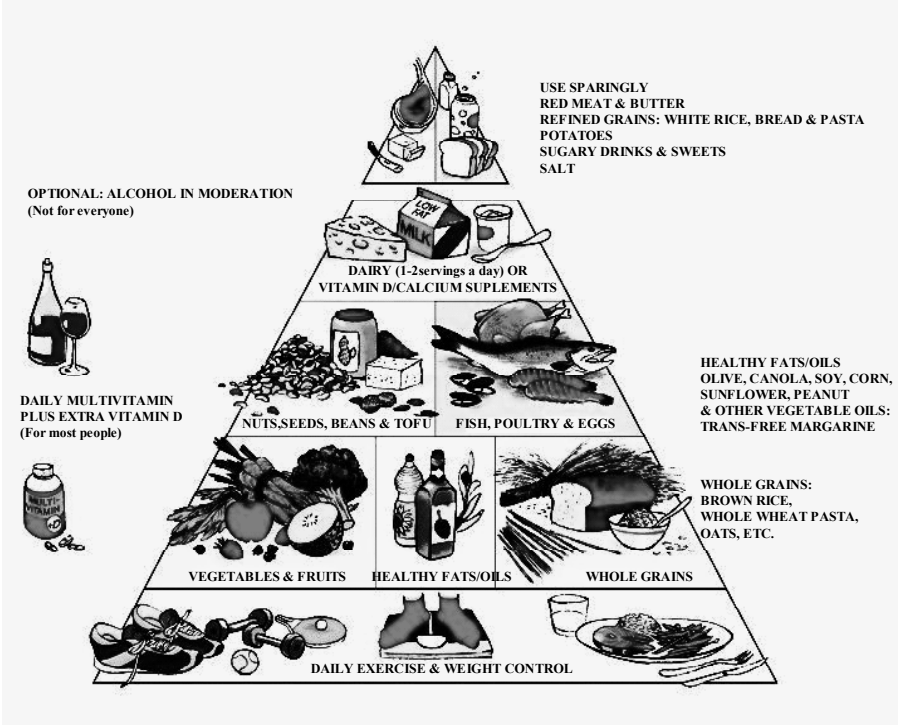

Figure 1.The healthy eating Pyramid (source: http://thenutritionsource.org).

Studying process, especially post-graduate studies, is very demanding and brings a great deal of mental strain. It is vital not to lose interest in physically active and healthy lifestyle, particularly, while studying for doctor's degree. The studying process creates an enormous load to the central nervous system (CNS). Professor N.Amosov emphasizes the crucial role of physical activities in development of all CNS functions, the agility and balance of nerve process due to which the mental abilities increase (Амосов, 1987).

The student needs change over time, and it is in line with their social, mental, physical development (Heidi and Hutton, 2007).

Materials and Methods

The studies were carried out by using empirical methods and the opinion of post-graduate students living in Latvia analysed. The authors have used electronic version of structural questionnaire method and sent it to all 200 post-graduate students of Latvia University of Agriculture (LLU) in February 2008. A total of 86 post-graduate students participated voluntarily. The studies were carried out by Department of Sports in cooperation with Department of Post-graduate studies of LLU.

Studies were based on analysis of answers of 20 male and 66 female post-graduate students to 15 questions of the questionnaire.

Respondents participated in this study were with

mean age in their thirties (females 34, males 28.6), ranging aged from 23 to 53 years.

The respondents of those studies represent opinion of post-graduate students of ten different sciences: agriculture (6), agricultural engineering (8), agrarian and regional economics (27), food sciences (8), forest sciences (10), wood processing (4), veterinary medicine (10), water management (1) and educational sciences (12).

After reviewing the literature, the questionnaire was designed by the authors. The questionnaire contained questions about the benefits of physical activity and details of their own practice of physical exercise (frequency, duration). Other questions included knowledge about healthy food and personal practise of eating habits. The questionnaire was a part of a comprehensive questionnaire on lifestyle.

For the evaluation, the methods of statistical grouping, comparison and logical analysis, graphical viewing and summing were used.

Results and Discussion

The respondents were asked to point out the opinion on the question „Are you a follower of the active way of life?".

The results were consistently positive across post-graduate students (74%), just a few of them mentioned reasons, why they are not followers of the active way of life: „I would like to, but laziness is in my way" or „Mostly I am sitting in front of the computer, but I walk a lot during the day" (Table 1.). The answers indicate that students know and realize the importance and necessity of physical activities in every day life.

Table 1

Numbers and % of Post-graduate Students who are Followers of the Active Way of Life

Statement	Males		Females	
	No.	%	No.	%
Yes	16	80	44	67
Sometimes	2	10	22	33
No	2	10	-	-

The research results of the scientists of physiology, psychology and sports pedagogy show that physically active students to serious mental loads adapt with minimal strain of regulatory mechanism. Physically active students demonstrate higher steadiness to disruptive factors than less physically active students do (Кретова, 1990).

The respondents were asked a question „Do you participate in physical activities?", and Table 2 shows the results.

The majority thinks that they are participating in physical activities. But few answers illustrate the problems: „Unfortunately, I cannot manage my time and devote it for physical activities".

Table 2

Numbers and % of Post-graduate Students who participate in Physical Activities

Statement	Males		Females	
	No.	%	No.	%
Yes	14	70	50	76
Sometimes	2	10	16	24
No	4	20	-	-

According to American scientist Bredemeiier opinion, all sports provide an opportunity to pursue excellence, both of physical performance and character. Virtually all sport teams can be turned into miniature caring communities where growth is stimulated through mutual encouragement, challenge, and support (Bredemeier, Shields, 2006).

The respondents were also asked to point out, what kind of physical activities they participate in. Descriptive statistics are shown in Figure 2. The post-graduate students mentioned very specific types of activities in Notes part of the question („walking, instead of taking transport", „physical work during summers", „daily walking to 5th floor", „my job is physical work all around 9 months per year", mountain skiing, snowboard, orienteering, skijoring, cycling, fitness club, body bike, shooting and et al..

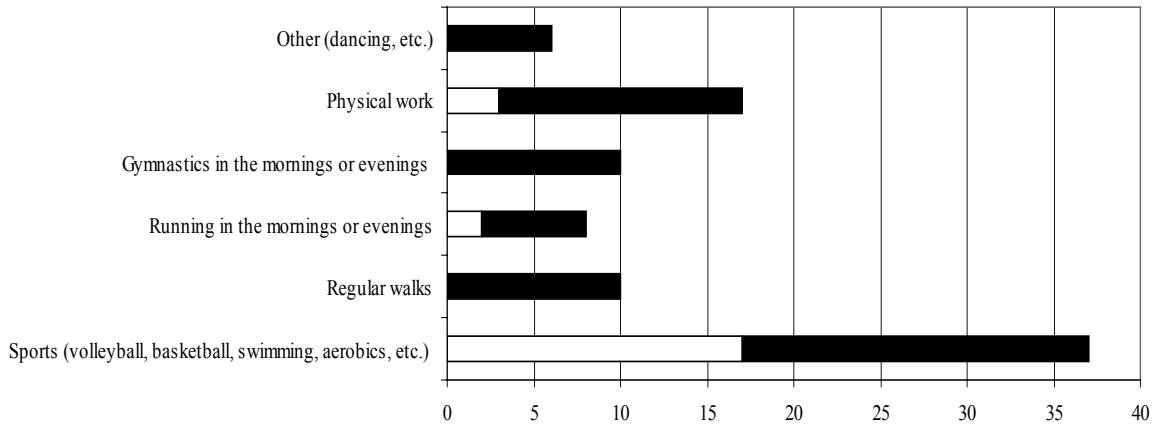

Figure 2. Self-reported practice of different types of physical activities by male and female students.
□ - male, ■ - female

People quite often misleadingly consider that it is enough if you do physical work every day; it successfully substitutes physical activities. Unfortunately, in day by day physical work one engages only certain muscular groups. Although a person feels muscular pain, it does not indicate that we do healthy physical activity; it just shows fatigue caused by muscular and joints overload. At the same time many other muscular groups and joints are not occupied at all.

To avoid unhealthy overload of certain joints or muscular groups, one should stick to the following main principles:

- Taking care of right posture;
- Not carrying load in one hand for long periods;
- Straight back sitting to avoid muscular strain and back deformation;
- Wearing comfortable footwear (Kancāns, 1989).

The authors of the research share the conclusions made by the sports scholar I. Liepiņš in his research – the students are aware of the importance and necessity of physical health although not all of them try to improve their physical health; therefore, first, it is important to acquire knowledge about healthy lifestyle and importance of physical activities. If a person has willpower to exercise and knowledge that physical exercises improve his/her health, he/she definitely will find time and possibility to do it. It is obvious that physical health and status depend on one's willingness to improve it. One should not forget that taking care of one's health is a lifelong process as well as it is true about self-development process (Liepiņš, 1993; Markevics, 2004).

Regular physical exercises in any kind of sports are linked to target-oriented physical activities. They facilitate physical development in early adolescence as well as help to maintain physical health and shape in middle age. It is also important to realize when time comes to switch from training to health building on activities (Kravalis and Grants, 2003).

Table 3 presents the answers to the question „Do you have regular physical activities?" An analysis of data collected from answers allows concluding that 51% of post-graduate students of LLU participate in those studies and have regular physical activities.

Table 3

Numbers and % of Post-graduate Students who have Regular Physical Activities

Statement	Males		Females	
	No.	%	No.	%
Yes	10	50	34	52
Sometimes	6	30	14	21
No	4	20	18	27

Some of respondents admitted that „15 minutes of daily exercising", „more yes than no – I mentioned daily walks to public transport and other places", „periodically regular, according to opportunities, if I have time, definitely take advantage of physical activities" or „regularity depends on amount of work (included studies) and free finances for training fees".

As the respondent mentioned above, again answer was „yes, but before it I have to struggle with my laziness". It is very natural for a human being.

The respondents in the questionnaire were asked to indicate „how often they have their physical activities" (Table 4).

There were additional comments: „walking every day" or „daily activities during summers, few times in winter time".

More than 33% of the respondents participate in various physical activities three times a week. We could conclude that students have the sufficient amount of trainings for physical potential.

Table 4

Frequency of Different Types of Physical Activities by Male and Female Students

Frequency	Males		Females	
	No.	%	No.	%
Once a day	-	-	8	13
Once a week	6	30	14	21
Twice a week	8	40	14	21
Three times a week	6	30	24	36
Other (seldom)	-	-	6	9

Recreationally active individuals were those who performed aerobic and/or resistance training exercises for 30-60 min on 2-3 days/week, but who did not participate in collegiate or professional sport (Markevics, 2004).

The post-graduate students were also asked to characterize their physical condition (Figure 3.).

Some respondents said that „it is better for a person not to be an athlete", „average, but feel good", „I do not have any complaints, but physical shape should be improved". During the studies students sometimes are under high stress: „I feel stressed weight on my mind, and finally I do not like to have any physical activities".

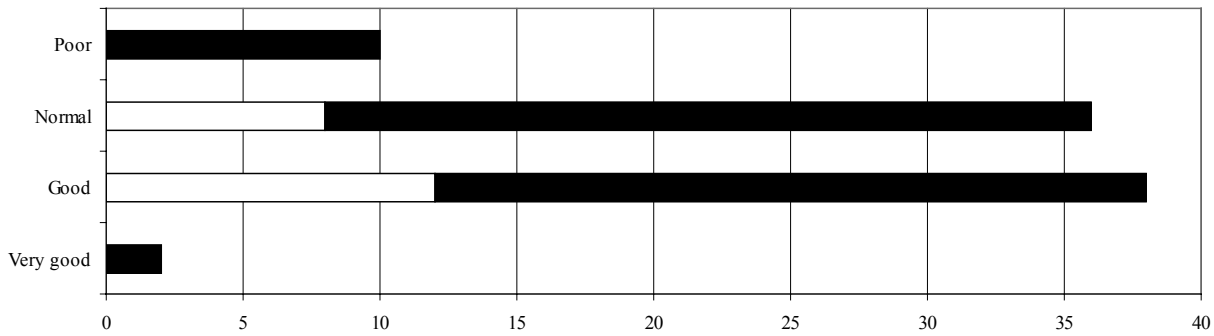

Figure 3. How do post-graduate students characterize their physical condition? : ☐ - males, ■ - females

The results of studies show that majority of respondents evaluate their physical condition as normal or good. It is a positive self-appraisal, of course.

The second part of the questionnaire was based on healthy food problem. First of all, students discussed the issue about eating habits and gave the answer to the question „Do you have qualitative and healthy food?" (Table 5.).

The survey results show that post-graduates (59%) are aware of the necessity to use healthy food and only few (6%) of them does not pay any attention to that.

Very positive answers state: „I prepare healthy food of high quality as often as I can" or „My husband is a sportsman, so everyone in our family should eat healthy food".

Respondents point out that „I know healthy food

and healthy eating principles, but it is quite hard to follow them" and „due to busy lifestyle there is no time to think about it.

Table 5

The Opinion of Post-graduate Students about Their Eating Habits

Statement	Males		Females	
	No.	%	No.	%
Always	2	10	18	27
Sometimes	4	20	8	12
Used to think about it	12	60	38	58
Do not pay attention	2	10	2	3

Food habits and meal patterns obviously differ between the sexes: women having a better choice of foods, but men having more regular food habits (Hoglund et al., 1998).

According to Kravalis and Grants, scientists claim that healthy food means balanced food – the amount of food consumed in 24 hours corresponds to the round-the-clock energy consumed. It is a vital problem for students since being busy all day round, they quite often prefer fast food to healthy food. Long term consumption of fast food facilitates the cumulation of overweight that results in harm of health (Kravalis and Grants,2003).

Authors with great interest looked forward to answers to the question „What kind of food do you prefer (%)?"

As illustrated in Figure 4, the choice of food is balanced enough and corresponds to the principles of healthy food.

However, post-graduate students decided that „It is hard to point out percentage; it changes each week". Authors appreciated the answer and found it out to be very professional „I try to choose balanced food: I pay attention to the variety of product groups (meat, vegetables, fruit) and various preparation technologies (raw, boiled, stewed, steamed)", „Speaking in general, I try to use various products in meals, and I try to reduce the consumption of fatty products. I strive to increase consumption of products that contain protein" or "I use vitamins and mineral substances in addition."

The seafood are very healthy, but, unfortunately, few respondents do not have them at all. Juice was not mentioned in the questionnaire, but a number of respondents drink home-made juice (carrots, orange) or drink water. Very few respondents have an allergy to dairy products and fruits. Unfortunately, the economic situation in our country limits having products of high quality or eco-products.

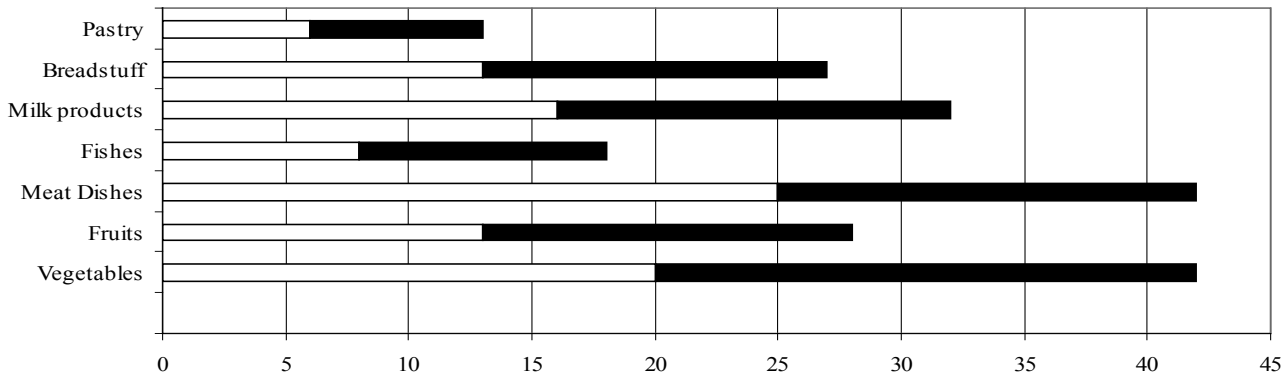

Figure 4. Food preferences of post-graduate students in per cent: □ - males, ■ - females

The author could conclude and totally agree with the statement that nutrition knowledge level of girls was higher than that of boys (Hee-Wan and Sang-Sun, 2006).

The respondents were also asked to point out the pace where they have their meals. As shown in Table 6, the majority of post-graduate students (75%) have their daily meals both at home and public catering.

It is very common to take with you home-made or ready-made sandwiches at the working place. Unfortunately, at the university we do not have common area to relax and have the meals. A very useful advice is „I change catering places to diversify food in order to absorb necessary vitamins and mineral substances."

Table 6

Placement of Meals

Placement	Males		Females	
	No.	%	No.	%
At home	2	10	12	18
Public catering	-	-	-	-
Both (at home and public catering)	16	80	46	70
Others	2	10	8	12

The post-graduate students were also asked to define frequency of meals.

The authors found out a very interesting opinion „irregularly, because then I should not bother about probable problems if I have to interrupt regularity. The experience shows that if one interrupts eating on a regular basis even for two days, the stomach problems might arise."

It should be admitted that having meals three times a day (59%) is not a bad indicator although it would be better to have meals at least four times a day (19%) but taking smaller portions. It is scientifically proven that if you eat small portions of balanced and healthy food, your organism completely uses ingested calories and does not form fat reserves (Table 7).

Table 7

Regime of Meals of Students

Eating frequency	Males		Females	
	No.	%	No.	%
Once a day	-	-	-	-
Twice a day	2	10	12	18
Three times a day	12	60	38	58
Four times a day	4	20	12	18
Five times a day and more	-	-	-	-
Others (irregularly, when I wish, somehow)	2	10	4	6

Is it possible to improve average level of study achievements and cognitive abilities if one consumes healthy and balanced food? The answer is "yes" because healthy food is related to intellectual achievements indeed (Geidge and Berliner, 1999).

Finally, the respondents could evaluate to what extent physical activities and healthy eating habits influence post-graduate studies process." The post-graduate students were very active to give answers to this question.

Generally, the answers were positive (62), which means that physical activities and healthy food definitely facilitate post-graduate studies. There were a lot of interesting comments: „I consider that any physical activities improve mental abilities and work capacity", „I haven't thought about it before (food – physical activities – post-graduate studies), but healthy food and physical activities anyway is a positive attitude towards life" or „I haven't thought about correlation of this type, but I am sure that

active and healthy lifestyle assures better work capacity in general."

There was a piece of advice given to the university administration: „as concerning physical activities – I assume that the largest part of post-graduate students would be delighted to have some support from the university administration to have discount in Jelgava Fitness centres."

According to our experience from other lifestyle studies, post-graduate students try to answer questionnaires honestly, and authors appreciate it greatly.

Conclusions

1. Research shows that the biggest part (73%) of respondents follow active way of life and participate in physical activities.
2. Studies indicate that more than 60% respondents regularly (2- 3 times a week) participate in physical activities (sports, physical work).
3. There are similar findings showing that the biggest part (70%) of respondents have qualitative and healthy food and strictly take their meals on regular bases.
4. Research also indicates that products pyramid of daily meals is comparative, properly balanced and according to healthy eating basic principles.
5. In summary, studies showed that the biggest part (75%) of research subjects appreciates the importance of physical activities and healthy eating, and treats it as a positive part of the post-graduate studies process.

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FOREST VALUES PERCIEVED BY THE PUBLIC IN FOREST SECTOR

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Abstract

Forest is the ecosystem which consists of different related components and fulfils important environmental, economic, and social functions. Each of these components is of particular value in public perception. In the beginning of September, 2007 social research was carried out in Latvia in order to understand the meaning and importance of forest value on the questionnaire base. This survey focuses on how people whose every day life is related to forest sector, perceive forest values. The forest values were divided into thirteen factors. To determine the most important forest value, the participants' answers significance was evaluated basing upon the concordance coefficient and using descriptive statistic methods. The research revealed that despite the multifunctional use of forest the basic value is granted to timber and forest land. As well as respondents had not shown significant difference expressing their opinions when they were divided into different groups (forest owners, forest sector employees and other). Results of the survey have shown that the public in Latvia are not able to value and calculate forest environmental and social functions.

Key words: forest owners' survey, timber value, forest land value, non - wood forest products value.

Introduction

Forest values are perceived differently by the public because the forest value is not just for timber but represent the priceless weight for the following non - wood forest products (Niskanen, 1996; Saastamoinen, 1997):

- material values which are related to forest and should be separated from it (hunting trophies, wild plants, and berries),
- recreation, environment stabilized and ecological values (carbon sequestration, oxygen produce, and water resource quality regulation).

According to several scientists (Freer-Smith, 2007; Zalitis, 2006) forest value should be evaluated taking into consideration environmental (ecological), economic, and social values (Fig. 1). The economic value means where a particular forest-origin product is bought or sold for a certain price in order to get profit.

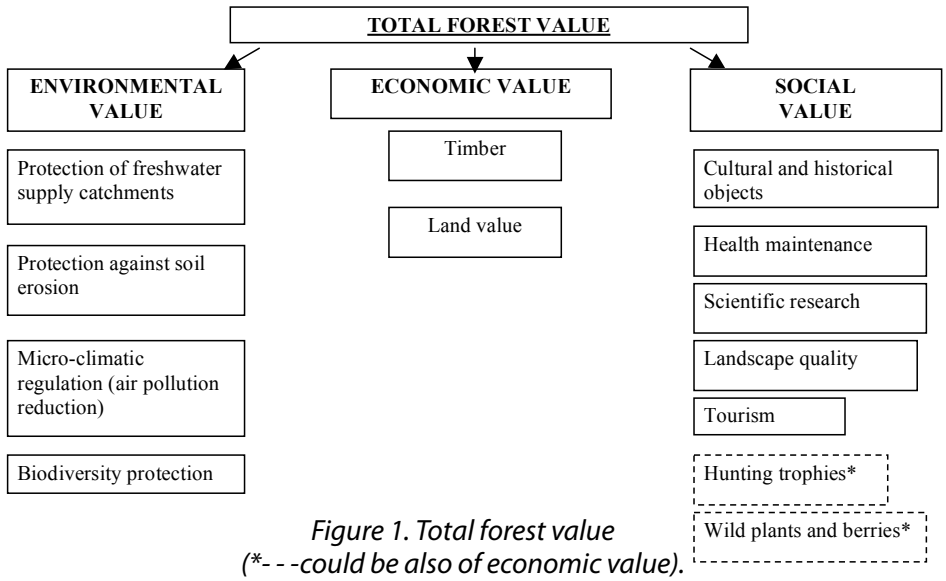

Figure 1. Total forest value
(- - -could be also of economic value).*

Social value is connected with public benefits such as hunting, picking mushrooms and berries, seeds and plants gathering, as well as cultural and historical environment, health maintenance and recreation value. Forest has significant ecological value, because it helps to maintain nature diversity. Forest creates the necessary life conditions for many other plant groups and gives shelter and protection for animals as well for plants which can not grow in the fields. Forest is of extremely great importance in a climate regulation providing oxygen and carbon balance, air cleaning from dust and other hazardous additives. It also has influence on the hydrologic conditions of different water basins because forest reduce above-water flow down a part of them turn aside in the groundwater, thereby protecting soil against water erosion and improving quality of water (Bisenieks, 2003).

A part of forest values (prevailing economic) can be easily translated in terms of money, but for sure it is impossible to transfer other non- wood forest products, for example, human health maintenance in terms of money. Problem appears when defining non- wood forest products value as well as when determining total forest value (Lette and Boo, 2002).

However, public experience and opinion show the general trends and guidelines in the perception of forest value as well as in determination of the value. In order to clarify this issue, a survey was done involving respondents connected with forest and forest sector. The present research is aimed at defining the importance of forest values according to public perception existing in the forest sector. The survey expected return was foreseen that it could be possible to highlight the most important aspects in determining the forest value in order to develop a new improved forest value estimation concept.

Materials and Methods

The social research methodology based on an eight question survey was used for making analysis of the situation. Primary data were collected in the beginning of September, 2007 in Latvia. The research participants were fifty random chosen people from the forest sector, 10 out of which were forest owners, 26 working for the forest sector companies and holding certain offices, and 14 of them represented students of the Latvia University of Agriculture, as well as the teaching staff of the forest faculty and others who operate in forest sector. All participants had experience in the forest sector. 22% of the respondents had 1 year experience, 76% more than 2 years, out of which 28% have more than 10 years experience. It allowed to judge that answers are sufficiently proficient. The purpose of this questionnaire was to verify the attitude and understanding of forest value by the people involved in forest sector, therefore the questions were formulated in the way to get the sample group view about forest value, which parameters from forest values are most significant, which values could be expressed in terms of money, are respondents know how to calculate forest value, the economic, social and environmental percentage in total forest value, it is necessary to develop the new forest valuation concept.

The participants' answers significance was valued based upon the concordance coefficient W (Kendall, 1955, Djakova and Krug, 1966) in compliance with the following formula (1):

$$W = \frac{\sum_{i=1}^{n}\left(\sum_{j=1}^{m} y_{i(j)} - \frac{1}{2}m(n+1)\right)^2}{\frac{m}{12}\left(m(n^3-n) - \sum_{j=1}^{m}\sum_{r=1}^{k}(t_{r(j)}^3 - t_{r(j)})\right)} \quad (1)$$

where: $\mathbf{y_{i(j)}}$ - rank of object i accordingly to estimation of respondents in j questionnaire

i - number of criteria (**i**=1...n, where **n** – total number of criteria; n=13);

j - number of questionnaire (**j**=1...m, where **m** – total number of questionnaires);

k - number of rank conformities in questionnaire;

$\mathbf{t_{r(j)}}$ – number of rank conformities repetition in j- questionnaire.

The significance of concordance coefficient was valued using Pearson's criterion $\chi^2_{\upsilon,\alpha}$ in compliance with the following formula (2):

$$\chi^2 = \frac{\sum_{i=1}^{n}(\sum_{j=1}^{m} y_{i(j)} - \frac{1}{2}m(n+1))}{\frac{1}{12}(mn(n+1) - \frac{1}{n-1}\sum_{j=1}^{m}\sum_{r=1}^{k}(t^3_{r(j)} - t_{r(j)}))} \quad (2)$$

After collecting the data, it was counted and summarized in EXCEL table. The most significant information was systemized and mathematically analyzed using descriptive statistic to calculate the average for results.

Results and Discussion

The first question in the questionnaire was open-search question and was asked to formulate a forest value. Three of respondents or 6% mentioned that forest value is just a timber value, 10 of respondents or 20% mentioned that forest value is just a timber and forest land value, 5 of respondents or 10% answered that a forest value is for timber and non timber products, 7 respondents or 14% said that social, economic and environmental values are included in the forest value, 10 respondents or 20% gave an answer that without a timber and land value such the values should be taken into account as non timber products, all alive in the forest, environmental and social values, 3 respondents or 6% mentioned that everything what is located in the forest to be comprised in the forest value. The rest or 22% gave various answers, as an example, that forest value is just for environmental qualities, for ecosystem, long term management, sustainable forest management or forest quality, age, location, forest present value and forest long-term capital value. One respondent did not give any answer. Based on these findings it might be concluded that forest value is appraised not just according to timber amount in the forest, but many other forest values are listed too. However 80% from respondents counted timber value in total forest value, but 44% from respondents highlighted a forest land value separately in total forest value.

In the second question participants should arrange priority of each of the criteria; the most significant criteria should be marked with 1, but less significant with 13. Own label was assigned to each criterion:

x_1	- protection of freshwater supply catchments
x_2	- protection against soil erosion
x_3	- timber
x_4	- biodiversity protection
x_5	- landscape quality
x_6	- scientific researches
x_7	- tourism
x_8	- hunting trophies
x_9	- wild berries, mushrooms, plants and other materials
x_{10}	- cultural and historical objects
x_{11}	- forest land value
x_{12}	- health maintenance
x_{13}	- micro-climatic regulation (air pollution reduction)

Each factor (in our case determinative forest value criteria) defined summary rank weight (Fig. 2). The less is summary rank the most important is criteria. The greatest significance according to respondents was given to two criteria's timber (x_3) and forest land value (x_{11}) in assessment of the forest value. Such selection could be justified with such assumption that the timber and forest land are tangible and visible assets wherewith economic deals take place in everyday life, because they are usually purchased and sold for money.

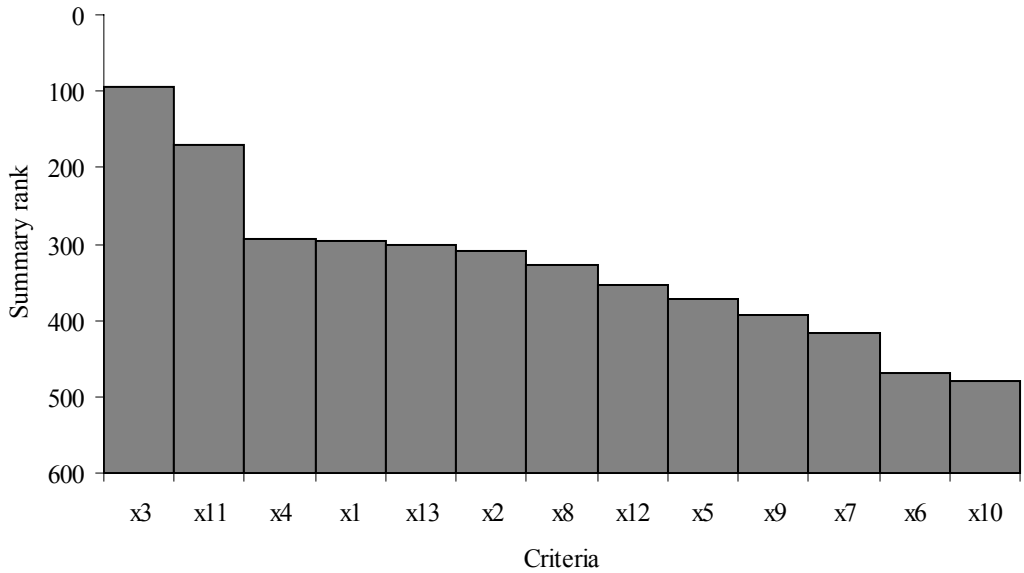

Figure 2. Factors significance according to summary rank.

Therefore the public paid great importance and value to those two criteria, while poor importance to the cultural and historical objects (x_{10}) and scientific research (x_6) in the forest value assessment, because these factors are no popularized and their value is not explained to the public. For that reason the public with difficulties could perceive and recognize these factors which seem intangible and not carrying out special benefits. Almost at the same level were four factors x_2, x_{13}, x_1 and x_4, which shows that environmental issues occupy the next important place after the economic values.

Hunting trophies (x_8) criteria were in the middle, which could be explained with rich hunting traditions in Latvia as well as often the forest sector forming people are hunters, therefore these criteria were respectively valuated. Health maintenance (x_{12}) gained not a high result which points out that the public do not think sufficiently about themselves. Tourism (x_7) and wild berries, mushrooms, plants and other materials gathering (x_9) and land visual quality (x_5), which play social role were ranked to be almost one of the last criteria. If the answers were grouped according to different respondent groups then results had no significant difference, which shows the respondent groups' coherence in their answers.

The participants' appraisal survey was valued based upon the concordance coefficient. The value of the concordance coefficient (W) varies within the range $0 \leq W \leq 1$. If all the respondents rated the objects same W=1, but if there is no relation between the ranks W= 0, wherewith W is higher as more respondents' answers are coherent. The value $W \geq 0.348$ is considered sufficient for the concordance rate and it may be regarded that the concord between the respondents is high in this research. If concordance coefficient is satisfactory it does not mean that results are objective, because such results could be gained accidentally. Therefore the significance of concordance coefficient was defined according Pearson's criterion $\chi^2_{\upsilon,\alpha}$, where α – materiality level; υ – number of freedom degrees (υ = m-1). In our case υ = 46 and materiality level α – 0.01. After calculations Pearson's criterion value was 196.2. The calculated Pearson's criterion χ^2 value was compared with $\chi^2_{\upsilon,\alpha}$ critical value according special tables from biometric literature (Liepa, 1974). If $\chi^2 > \chi^2_{\upsilon,\alpha}$ then at materiality level α it could be affirmed that the respondents' answers are not accidental. In this research the result for $\chi^2_{\upsilon,\alpha}$ is 196.2 >76.15 at materiality level α=0.01 according to the given tables, so the results may be considered objective.

It was required to assess forest value position significance of 5 point scale system (5-very important; 1-not needed) in the third question. From these responses appeared that the timber (x_3) and forest land value (x_{11}) as most important values. Findings have shown the lowest values are for historical objects (x_{10}), tourism (x_7) and scientific research (x_6). As seen from Figure 3, the health maintenance and micro-climatic regulation had obtained rather large

significance. Figure 3 represents that the sample group valuated very much alike other criteria x_1, x_2, x_4, x_5, x_9 and x_8. Based on this data it could be concluded that all criteria which make a forest value are rather significant because in general no one of the criteria was valued less than 3. The answers were almost similar when dividing them into different respondent groups (forest owners, forest sector employees and other).

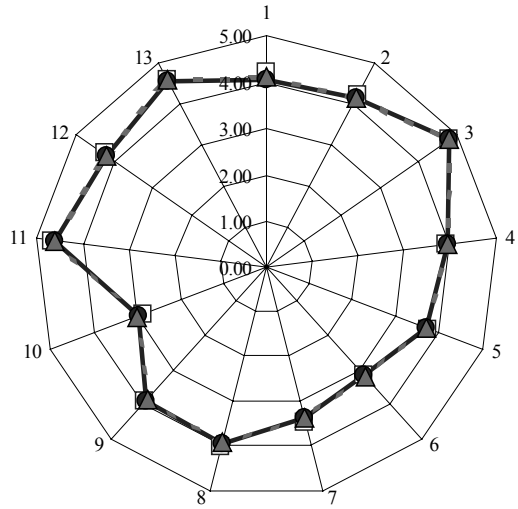

Figure 3. The valuation of criteria in different respondents' groups,
(□- other, ●- forest owners, ▲ - workers).

As an answer to a question which values from the total forest value is possible to calculate in terms of money and which is not, all respondents responded that it could be feasible for timber (x_3). However almost 96% expressed that it is possible to estimate the value of forest land (x_{11}), as seen from Figure 4. More then a half of participants considered it would be possible to estimate hunting trophies (x_8) and wild berries, mushrooms, plants (x_9) and other materials collected from the forest. Exactly a half of respondents thought that they could calculate tourism (x_7). According to respondents' judgment other values may not be estimated at all or just approximately. Figure 4 shows that the relevant sample group thought it is not possible to calculate the forest value for human health maintenance (x_{12}).

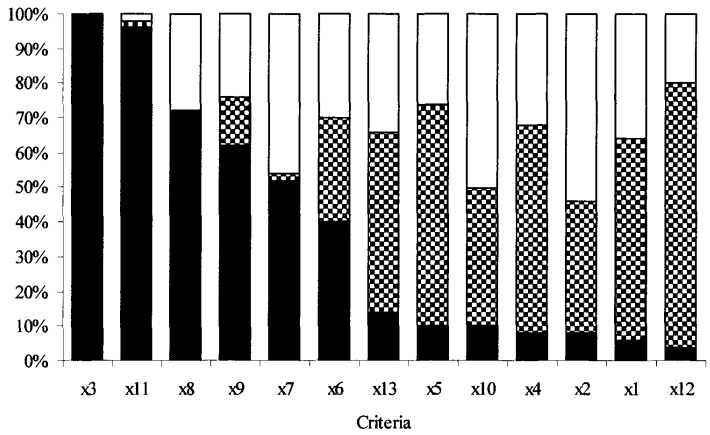

Figure 4. Distribution of forest values calculation possibilities in terms of money in percentage,
(□- approximately, ▩- no, ■ - yes).

Forest plays an important economic, social and environmental role, therefore one of the questions asked to respondents to estimate the significance thereof in percentage in each of these

aspects. According to respondents' judgement the most significant was economic value and then environmental and social values occupy just almost the same position. There is the following proportion 50: 28: 23. 6 respondents or 12 % pointed out that economic, social, and environmental values are equally important. The concrete value of those three was valued more then 33% as follows- 38 respondents out of all believed that it is the economic value, 10 out of all - environmental value, 7 out of the sample group - social value. The point of view for different respondent groups was equal in estimating the importance thereof for each aspect.

As an answer is forest value clearly defined in Latvia the major part or 41 of participants responded that the forest value is insufficient formulated in Latvia, while 9 respondents considered that the forest value is completely clear defined. Thereby the majority or 46 considered the need of developing new forest value determination conception; just 4 respondents believed it is not needed. However, more then a half of participants knew how to estimate the forest value. Such results were obvious because all the participants represent the forest sector and they should know how to estimate the forest value.

Conclusions

As a result of the research information was obtained and described about the forest values and factors which determine its significance. Different level of importance has been obtained for these criteria or factors that affect the forest value. Based on these findings it is concluded the forest value is not clearly defined in Latvia. In general the public perceive different the forest values. If respondents are divided into different groups (forest owners, forest sector employees and other) the answers are almost similar and it would be impossible to recognize any significant difference. It might be possible to justify if people had similar thinking in the forest sector.

Based on the analysis of the forest value findings there were drawn the following conclusions:

1. Results seem to demonstrate that the most important role is given to the economic aspect taking into account the total forest value. The emphasis is laid onto the timber and forest land as the main value. The least importance is given to the cultural and historical objects, scientific research and tourism possibilities in total forest value. It is required to promote the estimation of other forest values making further scientific research besides the development of the methods of timber and forest land calculation.
2. No one of the criteria was valuated less than 3 times in assessing the forest value position significance according to 5 point scale system (5 - very important;1 - not needed) from the values defined in general, which shows that all the forest value making criteria are rather important.
3. The objective and coherence of the results determine the concordance coefficient, which at materiality level $\alpha=0.01$ was higher than given in tables.
4. According to respondents' thoughts it is not possible to calculate social and environmental values. It could be done just approximately. All participants pointed out that timber value could be estimated but 96% of respondents that the land value could be transferred into the terms of money.
5. The respondents pay more importance to the environmental values then to the social values in total forest value.

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THE CONTINUOUS FIELD VIEW OF REPRESENTING GEOGRAPHY: OPPORTUNITIES FOR FOREST INVENTORY

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Abstract

This paper discusses the continuous field view of representing geography and its role in forest inventory. Describing all forest attributes at any location or point and storing this information in digital databases, as an alternative to store forest compartments as vector polygons and associated attributes, is considered to be important for development of remote sensing and GIS applications for forest inventories. Main results achieved following this approach during the last decade in Lithuanian university of agriculture are described. Special research polygon near Kaunas was developed. Four auxiliary data sources (Spot Xi, Landsat TM, digital aerial photos and stand-wise inventory material), three estimators (two-phase sampling with stratification, the k-nearest neighbors and regression) as well as different methods for auxiliary data integration were examined to get point-wise forest characteristics. The lowest root mean square errors at a level of virtual sample point using optimal implementation tactics are – for mean diameter 24 %, height 18%, age 28%, basal area 37%, volume per 1 ha 40% and percentage of coniferous trees 29% of the mean value of corresponding forest characteristic. Integrating additional auxiliary information – characteristics of forest compartments, estimated during the conventional stand-wise inventory – and satellite images improved the overall estimation accuracy. Pre-stratification of sample plots using the attributes of compartments improved the estimation accuracy for certain stand groups. A new approach of segmentation, aimed to construct conventional forest compartments – estimation of point-wise forest characteristics for every pixel of satellite imagery and using them instead of original image values – was suggested and investigated.

Key words: forest inventory, geographic information systems, remote sensing, segmentation

Introduction

What is "a forest"? E.g. Russian forestry scientist G.Morozov defines forest as an aggregate of trees, which grow near-by, affect each other and surrounding space and, therefore, are changing their outside and inner structure (Морозов,1930). This is purely naturalistic approach. Legally, as a forest one may consider at least 0.1 ha area grown-up with trees the height of which may reach 5 m and more under natural conditions, as well as thinned out or even having lost the vegetation naturally or because of human activities (Forest act of Republic of Lithuania, 1994). Both definitions directly influence the data model to be used to describe the forest in a digital data base.

There are two fundamental ways of representing geography in digital computer environments: discrete objects and continuous fields (Longley et al., 2005). Discrete object view assumes the world to be empty, except where it is occupied by objects having well defined boundaries, linear or point-wise locations. Locations may overlap, we may count them. Biological organisms or man-made objects fit this model well, e.g. trees, roads, buildings, etc. The continuous field view assumes the real world as a series of continuous maps or layers, each of them representing the variability of a certain attribute over the Earth's surface. There are no gaps in such layer – each location has one or another value of an attribute, e.g. "forest" OR "non-forest".

Modern science and technology theoretically allows describe the forest using the model of discrete objects. Every single tree, its location and descriptive characteristics may be measured and stored in a digital database. However, the continuous field approach prevails in operational forestry up-to-date. Stand-wise forest inventories define the boundaries of forest compartments and assign uniform characteristics for all locations inside the polygon already for several centuries. The value of such attribute changes abruptly on the boundary

of compartment, which is dependant on many factors among them human activities are the key ones. The main concepts of forest compartment and stand-wise forest inventories have been developed long before introduction of mathematical statistics, computers or remote sensing. This type of continuous field view to represent forest is beyond the scope of this paper. Our approach is to describe all forest attributes at any location or point and store this information in digital databases. We call this model to store forest related information as model of point-wise (or local) forest characteristics – for every point inside the forest unique value may be recorded for any attribute (outside the forest the value will be equal to zero).

The approach as such is not new. It has been used for several decades by many countries which try to combine their National forest inventories by sampling methods with remotely sensed information (e.g. Tomppo, 1993; Nilsson, 1997; Tomppo et al., 1999; Gjersten et al., 2000, Franco-Lopez et al., 2001 and many other authors). It is used to aggregate detailed stand-wise forest information to be represented at a more coarse scales (e.g. Kurlavicius et al., 2004) or when the information at more detailed level is not available (Paivinen et al., 2001). Our approach is to combine all the advantages of these studies with current forest inventory solutions used in Lithuania.

Information on the forest is organized using grid of systematically distributed virtual samples or points, which correspond to the pixels in a raster data model. Such points may be distributed rather sparsely, e.g. 250x250 m, as used for controlling of forest area in Lithuanian National forest inventory by sampling methods (Kasperavičius et al., 2000) or may form very dense networks, e.g. 25x25 m, 1x1 m and so on. Each point may represent any forest attribute at that location. Such point-wise information may be used the aims of conventional stand-wise forest inventories. Points are easily grouped based on values of certain characteristics (e.g. all set of characteristics that are used to single-out forest compartments) to form some spatially continuous aerial units (conventional compartments, polygons where certain assortment is available for logging, etc.). As such aerial units may change in their size, shape and purpose, we call them as virtual compartments or dynamic compartments. The idea of dynamic forestry unit that is developed following the principles described above has been discussed somehow by Swedish scientists (Holmgren and Thuresson, 1997; Gunnarsson et al., 1999), however it has not received very much attention in the forest inventory literature.

There are several ways to provide virtual samples with forest characteristics: (i) to measure in the field (Gunnarsson et al., 1999), however this rather expensive, (ii) to measure at some subset in the field and spread-out for other locations using geostatistical methods, e.g. kriging interpolation (Gunnarsson et al., 1999), but some spatial autocorrelation should be present in the phenomenon under investigation, (iii) to measure e.g. on aerial images using some stereo photogrammetric equipment, (iv) to use any auxiliary information that correlates with forest characteristics – satellite and aerial images, historical forest inventory information, GIS databases, etc. The most attractive seems to be the last approach. Numerous parametric and nonparametric estimations, GIS analysis are used combine the auxiliary information, available both for all virtual and field samples with the actual forest characteristics, measured just for field samples: regression (e.g. Hagner, 1990; Nilsson, 1997; Mozgeris and Augustaitis, 1999), static and dynamic stratification (e.g. Poso et al, 1987; Mozgeris, 1996), k-nearest neighbor estimation (e.g. Tomppo, 1993; Gjersten et al., 2000; Tokola et al., 1996), GIS-driven pseudo-raster transformations (Kurlavicius et al., 2004).

The aim of this paper is briefly to summarize the main results achieved during the last decade by group of Lithuanian scientists from Lithuanian university of agriculture and Lithuanian forest inventory and management institute in the field of modernization of forest inventory techniques. Main direction of our research has been the use of remotely sensed information and GIS data to provide forest characteristics for any point within the forest.

Material and Methods

Seven blocks of Dubrava forest (total area around 250 ha) near to Kaunas were chosen as the test sites (Fig. 1). A well developed network of field observations is available in the area and is maintained continuously. Most of Lithuanian forest conditions are available within this forest as well.

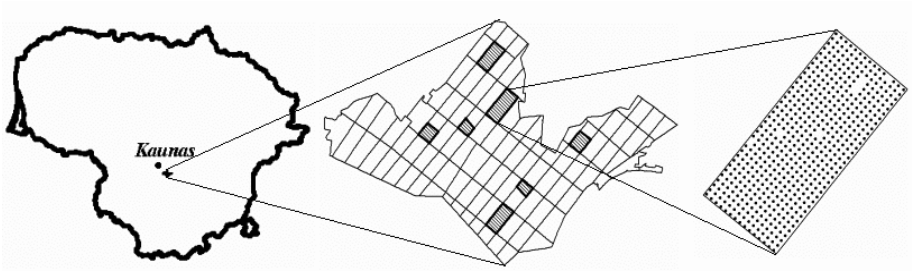

Fig. 1. Location of test sites.

A systematic grid of points (35x35 m) for field measurement was generated and marked in the appointed blocks. Coordinates of each plot were GPS measured using Trimble Pro XRS receiver. An independent measurements indicate that the root mean square error of georeferencing the points in the field does not exceed 2 m. All forest stand and tree parameters were measured on 1945 angle count plots following the methodology of Lithuanian National forest inventory (Kuliesis and Kasperavicius, 1999). The following characteristics were calculated for each story and stand in total: shares of tree species, mean ages, diameters and heights, basal areas, volumes per ha, diameter and height indexes.

The following remotely sensed images and GIS layers are made available for the study:

1. Spot-4 HRV2, Xi scene, observation data 01.08.1999. Pixel size 20x20 m.
2. Landsat-5 TM scene from 25.08.1987. Pixels have been resampled to the size 20x20 m. Diferent Landast TM scenes from Lithuanian Image2000 database, used to develop CORINE land cover database.
3. Panchromatic aerial photographs from summer of 1998. The scale of photography was 1:30000, photos were printed at scales ranging up to 1:10000. Negatives were scaned and orthorectified. Pixel size of photoimages – 0.4 m in the field. CIR orthophotos from 2001, pixel size 0.15, 0.30 and 0.50 m.
4. Soil maps from 1959. These maps were prepared as the result of detailed soil investigations within the Dubrava forest.
5. Standwise inventory (1988, 2002) material – maps, tabular stand descriptions.
6. Boundaries of all silvicultural activities, carried out since 1988 in the map form, as well as their descriptions. Some boundaries of clear-cut areas were checked using GPS.

All maps were digitized and transferred to GIS database.

Conventional GIS and remote sensing packages (Arc/Info, ArcView and ERDAS Imagine, PCI Geomatics) were used to perform GIS processing tasks, working with satellite and aerial images. Non-standard software used for the research is SMI system developed at Helsinki University, SkoGIS software, developed at the Remote Sensing laboratory at Swedish university of Agricultural Science in Umea, Arboreal software by Arbonaut Oy, Finland, as well as own tools.

There are several directions of the research, which differ in the methods used. First of all, different methods were tested on the point-wise accuracies that may be achieved at the level of virtual sample on the base of limited field sample and various sources of auxiliary information. Four auxiliary data sources (Spot Xi, Landsat TM, digital aerial photos and new stand-level inventory material), three estimators (two-phase sampling with stratification, the k-nearest neighbors and regression) as well as different methods for auxiliary data integration were examined. Field sample was divided into two parts, one of which was used for the estimation and another – for the validation. Bias, root mean square error in estimation of main forest characteristics was used to judge the methods tested.

Several tools were used to segment the images into some units, potentially corresponding forest compartments. Two approaches were used to assess the segmentation results – calculation the relative effectiveness off block division into the segments-compartments and evaluating of classification error matrices. The relative effectiveness off block division into the segments for each key forest parameter (*E*) is found as a ratio:

$$E = 1 - \frac{\sum_{j=1}^{k} \sigma_{xj}^2 * n_j}{\sigma_x^2 * n} \qquad (1)$$

where σ_{xj}^2 - variance of the mean parameter x within segment-compartment j,

n_j – number of plots within segment-compartment j, $\sum_{j=1}^{k} n_j = n$,

n – total number of plots within forest block,

σ_x^2 - variance of the mean parameter x within forest block.

Effectiveness of singling-out individual segment-compartment (E_j) is calculated:

$$E_j = \frac{\sigma_{xj}^2}{\sigma_x^2}. \qquad (2)$$

Development and evaluating of classification error matrices is described e.g. in Lillesand and Kiefer, 1994.

Later, the k-nearest neighbor (*k-NN*) method was chosen as the best fitting our objectives. The same inputs where manipulated to select optimal tactics for the use of *k-NN* method, relying on certain conditions as well as to test whether the specific auxiliary information for Lithuania – digital data of conventional stand-wise inventory, available in digital form for all forests of the country – does improve the accuracy of results. Bias and root mean square errors were used to validate the tests. Relative error values are used quite often two compare the achievements of two approaches.

Results and Discussion

Testing different sources of remotely sensed auxiliary information and estimation methods we came to a conclusion that the quality of auxiliary data is of main importance for the estimation accuracy, while the implementation tactics plays only the secondary role. The best achieved point-wise accuracies are summarized in Table 1.

All estimators yielded in similar accuracies. The smallest root mean square errors are achieved by weighting alternative estimates, but the improvement does not exceed 10 of the best one. Weighting means that we may estimate the value for validation points using different methods and achieve different accuracies. After that independent estimates may be combined together:

$$\hat{y} = \sum w_k \hat{y}_{ki}, \qquad (3),$$

where $\hat{y}$ - final estimate at a point i;

w_k - relative weight of an estimate using method k;

$\hat{y}_{ki}$ - estimate at a point i achieved using method k.

Table 1.

Point-wise estimation accuracy

Variable	Diameter	Basal area	Height	Age	Volume per 1ha	Percentage of coniferous
Spot Xi as the auxiliary data source only						
Bias	0.39	-1.23	-0.06	0.69	-2.02	2.22
Root mean square error	8.53	9.29	5.59	26.00	128.01	25.22
Relative RMSE* (100% - object average)	33	43	25	42	50	36
Remote sensed images (Spot Xi, Landsat TM and aerial photos) as the auxiliary data sources						
Bias	0.36	-1.23	0.39	2.81	8.07	0.50
Root mean square error	8.30	9.29	5.49	24.29	126.02	23.94
Relative RMSE (100% - object average)	32	43	25	39	49	35

Variable	Dia-meter	Basal area	Height	Age	Volume per 1ha	Percentage of coniferous
All available auxiliary information						
Bias	-0.10	-0.26	-0.30	0.42	-3.26	0.74
Root mean square error	6.24	7.93	4.02	17.50	103.14	20.12
Relative RMSE (100% - object average)	24	37	18	28	40	29

* *Note: RMSE is exhssed as the percentage of the average value of selected parameter*

Squared correlation coefficients between the estimated and true values on validation points were found to be the best weight function.

k-NN estimator is chosen for all subsequent investigations. It yielded in relatively low estimation errors and: (i) is well discussed in scientific literature, (ii) easy to understand and use, (iii) rather universal and works practically with any phenomenon or type of auxiliary information and (iv) there are numerous free software developments to implement it. So, we tested the peculiarities of using *k-NN* estimator with different types of auxiliary information to improve the point-wise estimation accuracies. The most important parameters for use of *k-NN* methods were found to be the following: 10 nearest neighbors (value of *k*), inverse distance weighted scheme for defining the weights of selected neighbors. However the main our finding was that integrating of additional auxiliary information – characteristics of forest compartments, estimated during the conventional stand-wise inventory – with Spot Xi images improves the overall accuracy of estimations – Fig. 2. Digital numbers of Spot Xi image were integrated with the estimates of stand-wise forest inventories (we used data from 2 inventories – year 1988 and 2002. Inventory data from 1988 represents common situation for many other areas in Lithuania, where outdated forest inventory information is available in digital format and can be used together with remotely sensed images without additional costs) via principal component transformation. Pre-stratification of sample plots using the compartment attributes from stand-wise inventory improved estimation accuracy for certain stand groups, too. Under pre-stratification we understand here grouping the points – both used for estimation and validation – into groups according to volume of compartments, they are in.

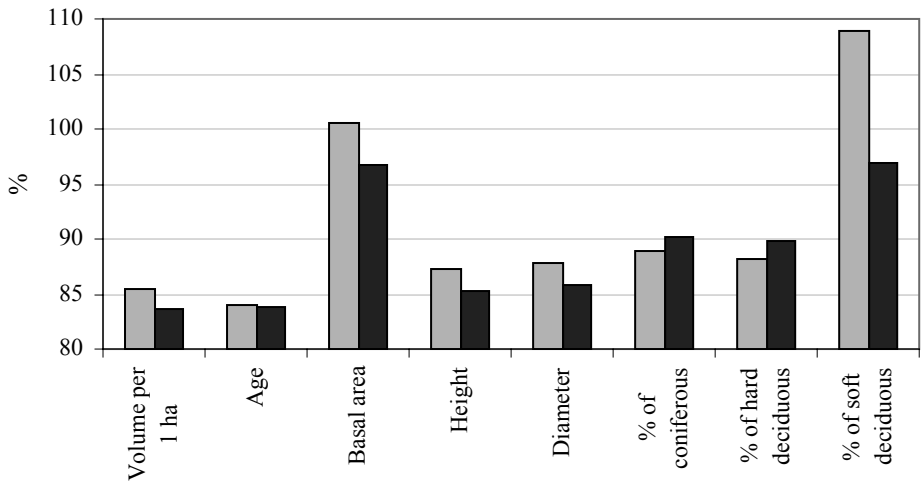

Fig. 2. The influence of integrated use of information from stand-wise inventory and Spot images on the accuracy of forest variable
k-NN estimation. 100% refers to the estimation root mean square error without information from the stand-wise inventory
1988 y., 2002 y.

Several types of images were segmented into segments, potentially corresponding to forest compartments. The segmentation properties are behind the scope of this paper. Approximately up to 60% of tested cases optimal segmentation resulted in the best effectiveness, exceeding even conventional stereoscopic delineation of compartments on aerial photographs followed by field inspection. A new approach in segmentation tactics – estimation of point-wise forest characteristics for every pixel of satellite image and using them instead of original image values – resulted in improved segmentation efficiencies practically regarding all forest characteristics at all bocks of the study site – Fig. 3. Effectiveness of segmentation according the minimizing of variance of forest characteristics is higher on the blocks with relatively more complex forest conditions.

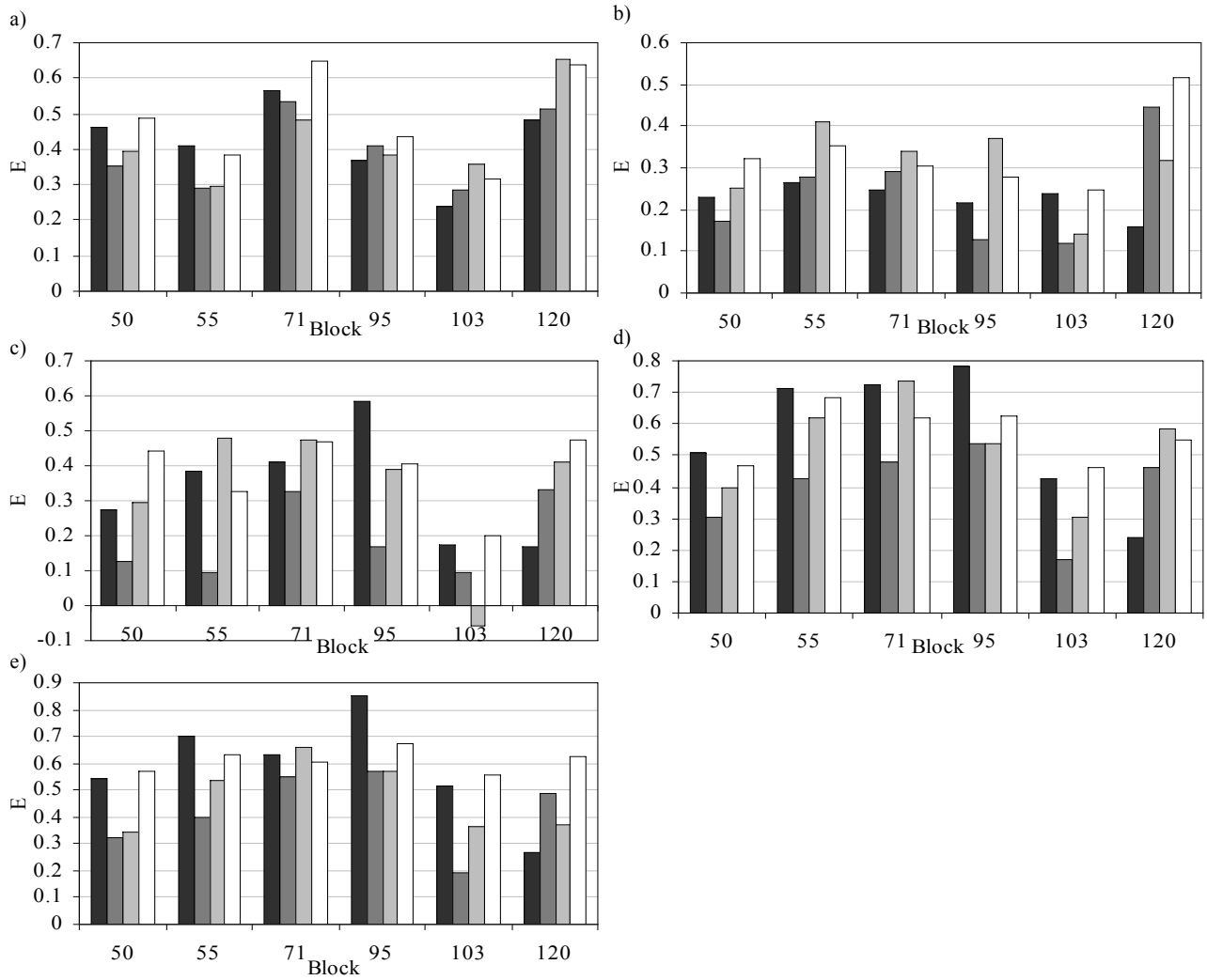

Fig. 3. Effectiveness of segmentation according to the minimization of variance of key forest characteristics: a) percentage of coniferous trees in the stand species composition, b) stocking index, c) Hab index, d) diameter and e) age

Fused Spot Xi and Landsat TM image, Original Spot Xi image, Point-wise forest characteristics, estimated using *k-NN*, Conventional stand-wise inventory

Average overall accuracy of compartments, singled-out by segmenting grids of pixel-wise key forest characteristics, reaches 53, but it is still lower than the one achieved by forest inventory engineers during their training at the same object (evaluating of classification error matrices). Positioning of stand borders via segmentation seems to be somewhat lower than the stand classification and is insufficient to be introduced in to practical stand-wise forest inventory.

Research presented above is currently further continued focusing on the needs of operational stand-wise forest inventory. Subtracting pixel-wise estimates of main forest characteristics from raster grids of the same characteristic generated using GIS boundaries and attributes of compartments is very promising in accurate and fast and easy to implement change detection. *k-NN* estimation is already operationally used in the inventory of mature and over-mature stands, mapping of forest health conditions, etc.

Conclusions

1. The continuous field view of representing geography plays major role in operational forestry up-to-date.
2. Describing all forest attributes at any location or point and storing this information in digital databases is an alternative to storing forest compartments as vector polygons and associated attributes.
3. The lowest root mean square errors at a level of virtual sample point using optimal implementation tactics are – for mean diameter 24%, height 18%, age 28%, basal area 37%, volume per 1 ha 40% and percentage of coniferous trees 29% of the mean value of corresponding forest characteristic.
4. Integrating of additional auxiliary information – characteristics of forest compartments, estimated during the conventional stand-wise inventory – and satellite images improves the overall accuracy of estimations.
5. Pre-stratification of sample plots using the compartment attributes from stand-wise inventory improves the estimation accuracy for certain stand groups.
6. Effectiveness of segmentation, aimed to construct conventional forest compartments, improves when original image values are substituted by point-wise estimates of key forest characteristics.

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THE INFLUENCE OF DIFFERENT INVENTORY TECHNIQUES ON THE GEOMETRICAL ACCURACY OF FOREST GEOGRAPHIC DATA

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Abstract

This paper deals with the evaluation of the geometrical accuracy of Lithuanian forests compartments geographical data that has been developed using different forest inventory techniques. Geo-reference background database GDB10LT was used as the standard for comparisons. 2500 control points on clearly identifiable places – crossroads, dikes' intersections, etc. – were selected randomly. The main finding was that the maximal positional root mean square error of clearly identifiable objects in forestry geographic data was 16.47 m (12.37 m and 10.87 m for X and Y coordinates respectively). However, such rather big errors refer to the techniques of GIS database development using paper topographic maps as a background for forest maps and manual digitizing. Enhancement of techniques for GIS database development was found to lead to significant increase in geometrical accuracy of the information.

Key words: forest inventory, geographic data, accuracy, geo-reference background.

Introduction

The first cycle of the stand-wise forest inventory using GIS was finished in 2006 in Lithuania. The technologies used for forest inventories were redesigned essentially during the last decade (Fig. 1) – e.g. the GIS database for the first GIS-inventoried Biržai forest enterprise in year 1995 was developed using manual digitizing from the paper topographic map with stand boundaries, transferred onto the maps from aerial photographs using photo-mechanical projectors. Since 1996, orthophotographic maps had been used as a map-base, however the manual digitizers were used to capture the geographic forest inventory data. Special color infrared aerial photography based orthophotos are used since 2002. These orthopotos are created specially for forest inventory and management planning purposes.

Lithuanian Forest Inventory and Management Planning institute introduced technologically new solution since 1999 in development of forest inventory GIS databases. This technology is based on the integration of all cartographical material using GIS and on-screen vectorization of orthophoto maps. The main points of this technology are (Kuliešis and Mozgeris,2000; Kuliešis, 2002; Palicinas, 2007):

1. Collection of all available information to be used for possibly objective singling-out of the forest inventory units – forest stands (old forest maps, remote sensing data, general GIS databases and maps, measurements, etc);
2. Automatization and integration of all collected information (scanning and geo-referencing of paper maps);
3. On-screen interpretation of new forest compartment boundaries carried-out by forest inventory engineers. The same person will implement the field work and finalization of the compartment level GIS database later;
4. Development of initial version of forest compartment GIS database and printing-out of sketch maps for field surveys;
5. Conventional field survey;
6. Finalization of forest compartment GIS database, development of cartographic elements, calculation of some specific attributes (area), mapping, etc. using conventional techniques.

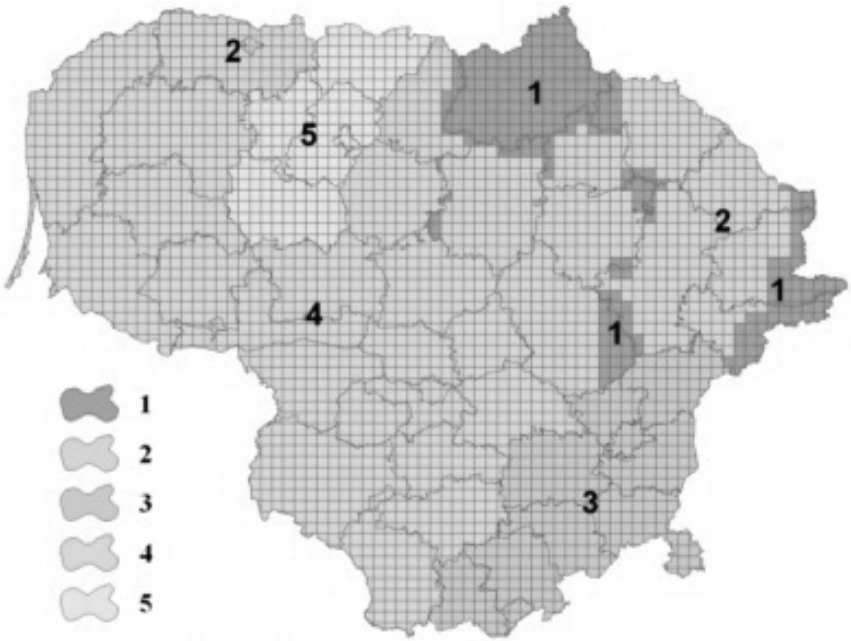

Fig. 1. The development of technologies for creation of forest compartment GIS databases within the frames of Lithuanian stand-wise forest inventories: 1 – manual digitizing of paper topographic maps at a scale 1:10000 with the boundaries of forest compartments transferred from interpreted aerial photos; 2 – manual digitizing of hardcopy outputs of panchromatic orthophotos at a scale of 1:10000 with the boundaries of forest compartments transferred from copies of interpreted orthophotos; 3 – on-screen vectorization of panchromatic orthophotos, assisted with numerous auxiliary information, including maps from previous forest inventories; 4 – on-screen vectorization of color infrared orthophotos, assisted with numerous auxiliary information, including maps from previous forest inventories; 5 - on-screen vectorization of color infrared orthophotos, assisted with numerous auxiliary information, including maps from previous forest inventories and georeference GIS databases

It is expected that this innovation has enabled to obtain more accurate data than using manual digitizing, however, this has never been tested. Even more, there is practically no information on the geometrical accuracy of geographic data, collected during stand-wise forest inventories. There are some publications on the quality of orthophotos used for inventory (e.g. Mozgeris and Dumbrauskas, 2003), but only theoretic accuracy assumptions are done in the technological descriptions of works. The instruction of forest inventory and management planning activities (Miškotvarkos, 2006) provides just the requirements for GIS data basis accuracies that are expected.

This paper introduces the first results of investigation of the geometrical accuracy of GIS database, created within the frames of Lithuanian stand-wise forest inventory. Different technological solutions to construct the database are compared. The main question to be answered is whether the technological innovations have had positive impacts on the quality of product being developed.

Material and methods

Identical object on two GIS databases – forest compartment GIS database at a scale of 1:10000, developed within the frames of stand-wise forest inventories and Lithuanian georeference background data base GDB10LT – are compared in this study. Five different technological solutions in development of the first database (Fig. 1) are compared in context of positional accuracy. Approximately 2500 of control points are located on both databases (Fig. 2). Clearly identifiable objects on both databases, such as road, dike intersections, sharp corners of forest tracts, etc., have been digitized. (Fig 3.)

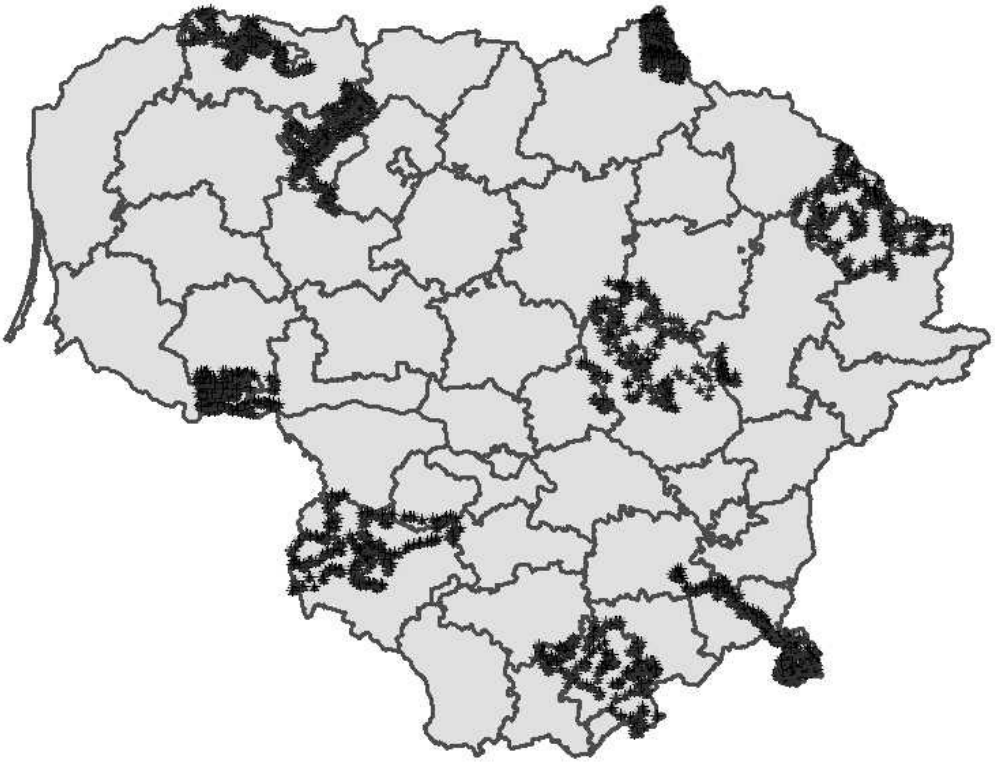

Fig.2 Locations of control points on the Lithuanian forest direktorate: ☼- Forest inventory GIS database; ▲ - GDB10LT database

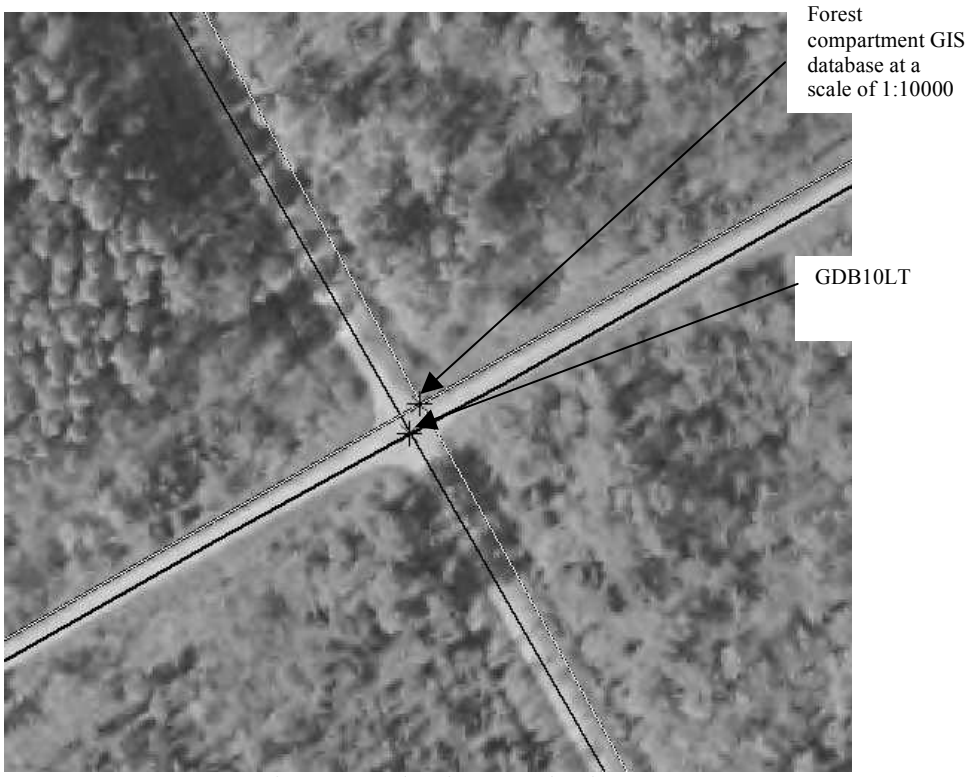

Fig.3 Example of a control point

Cartesian X and Y coordinates (National coordinate system LKS94 is used) of corresponding control points in regards of both databases are defined. Euclidean distances between points are calculated, as well as the distances in X and Y directions. GDB10LT is considered as the standard. Conventional accuracy estimates, such as bias, location root mean square error, including the ones in X and Y directions, standard deviations are calculated. Standard ArcGIS software is used for capturing the control points and calculating the accuracy estimates.

Results and discusion

Results achieved during this study are summarized in Table 1. One could easily observe rather large single errors to be present, reaching even 69 m, which is completely not acceptable for mapping at a scale of 1:10000. However, these deviations refer to the technologies used in the beginning of forestry GIS era. We can see that the largest root mean square errors (12.37 m and 10.87 m, for X and Y coordinates respectively) are found on a version of forest compartment GIS database, developed using manual digitizing of topographic maps, too. The overall root mean square error here is 16.47 and the bias – 13.2 m. The geometric accuracy of forest compartment GIS database seems to improve steadily with the introduction of more advanced techniques. By the way, introduction of color infrared orthophotos instead of panchromatic ones has resulted in slightly decreased geometrical accuracy of clearly identifiable forest objects. But this is what one could expect – color infrared orthophotos are focused on improvement of forest stand delineation but not the detecting topographic objects, such as rods and dikes. Visibility of topographic objects is obscured by the fact that color infrared aerial photography is acquired in summer season. And, finally, the geometrical accuracy of forest inventory oriented color infrared orthophotos is somewhat less than the one of panchromatic orthophotos (Mozgeris and Dumbrauskas, 2003).

Table 1.

Geometrical accuracy of selected objects on forest compartments GIS database at a scale of 1:10000 (for all variant n=500)

Technological variant of GIS database	Accuracy parameters											
	X coordinate				Y coordinate				Distance between points			
	Min.	Max.	Bias	RMSE**	Min.	Max.	Bias	RMSE	Min.	.Max.	Bias	RMSE
I *	-45.75	68.69	-1.61	12.37	-58.5	54.75	1.64	10.87	0.31	73.18	13.23	16.47
II *	-37.69	62.62	0.39	7.24	-32.00	29.75	0.05	6.92	00.22	66.25	7.43	10.02
III *	-40.51	26.90	0.07	5.25	-24.56	22.72	0.22	4.63	0.00	40.76	4.88	7.00
IV *	-30. 4	30.06	-0.65	6.01	-21.9	50.3	0.30	5.92	00.22	50.89	6.16	8.44
V*	-18.49	24.09	-0.07	2.24	-10.33	10.49	-0.09	1.74	0.00	24.10	1.37	2.83

I var – manual digitizing of paper topographic maps at a scale 1:10000 with the boundaries of forest compartments transferred from interpreted aerial photos; II var* – manual digitizing of hardcopy outputs of panchromatic orthophotos at a scale of 1:10000 with the boundaries of forest compartments transferred from copies of interpreted orthophotos; III var* – on-screen vectorization of panchromatic orthophotos, assisted with numerous auxiliary information, including maps from previous forest inventories; IV var* – on-screen vectorization of color infrared orthophotos, assisted with numerous auxiliary information, including maps from previous forest inventories; V var* - on-screen vectorization of color infrared orthophotos, assisted with numerous auxiliary information, including maps from previous forest inventories and georeference GIS databases*

*RMSE** - root mean square errors*

The results achieved may lead to a conclusion that forest compartments GIS databases, created a decade ago, fail to meet the requirements of mapping at a scale 1:10000. But all technological innovations, which that took place later, have improved the geometrical accuracies well. For sure, we do not take into account other advantages of the new methods, like improved accuracies in stand boundaries, increased productivity, etc.

Conclusions

1. The geometrical accuracy of forest compartment GIS database at a scale 1:10000 developed a decade ago manually digitizing the paper topographic maps fails to meet the requirements for mapping at a 1:10000 scale – the root mean square error of well defined objects is 16.47 m.
2. Technological innovations in development of forest inventory GIS databases have had positive influence on the geometrical accuracy of well defined geographic objects.
3. The introduction of on-screen vectorization techniques has reduced the errors bellow the level required for mapping at a scale of 1:10000.

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FOREST CHANGE DETECTION USING *KNN (K-NEAREST NEIGHBOUR)* -BASED ESTIMATIONS OF POINT-WISE FOREST CHARACTERISTICS

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Abstract

This paper discusses the usability of non-parametric *knn* (*k-nearest neighbour)* method to detect changes in forest areas from satellite images. Spot Xi images acquired 1999, main forest characteristics from field measured sample plots and data of conventional stand-wise forest inventory from the year 1988 were used to estimate the grids of following forest characteristics: mean age of main forest storey, diameter, basal area, height, volume per 1 ha, as well as the percentages of coniferous, soft and hard deciduous tree species. The differences of grids, created using stand-wise forest attributes from the 1988 inventory and estimated using the *k-nearest neighbor* methods were experimented to detect changes in the forest. 68.7-75.5% of areas, classified as the potential felling areas, were detected to be clear cut areas or young stands under 15 years according to the data of stand-wise inventory of year 2003. Different settings for the methods investigated are evaluated, too.

Key words: forest inventory, satellite images, knn (*k-nearest neighbour)* method, point-wise forest characteristics, change detection

Introduction

Lithuania has a long tradition in forest inventories. Current forest inventory practice can be divided into two broad approaches – stand-wise inventory and National forest inventory (NFI) by sampling methods. Even the NFI plays important role in providing forest statistics for various objectives, the main source of forest related information in the country that is used for forestry operations remains the stand-wise inventory. Since 1950 the inventory has been based on a combination of interpretation of aerial photos and conventional fieldwork. The elementary inventory and management planning unit is a forest compartment. It has to be uniform regarding the site types, stand parameters and it's functional characteristics. Conception of forest compartment and stand-wise inventory was settled when there were no such disciplines and technologies as mathematical statistic, computers or remote sensing. Nowadays, there are technical problems to estimate all forest parameters at every point of forest area or even measure tree's crowns and store all this information in digital databases. The idea to organize forest resource information on systematically distributed virtual sample units is studied at Institute of Environment of Lithuanian University of Agriculture already for more than ten years (Mozgeris, 2000, Mozgeris, 2001). The point of this method is to generate large number of first phase sampling units (plots, points) for the area being inventoried. All these units are supplied with some set of values of auxiliary information (the 1st phase). Auxiliary information – is any information correlating with phenomenon being inventoried, for example, satellite images and aerial photographs, general use and forestry GIS databases, etc. Needed forest characteristics are field measured for the second phase units. The number of second phase units is usually small and it depends on resources for field survey. The parameters, which are measured in the forest, are later supplied to the first phase units using different techniques (Mozgeris, 2000). Such method is operational in Finnish National forest inventory (Tomppo, 1993), it has been tested and used in other countries: USA (Franco-Lopez et al., 2001), (McRoberts et all., 2002), Sweden (Nilsson, 1997), Norway (Gjersten et al., 2000), New Zeland

(Tomppo et al., 1999), Germany, China (Tomppo and Halme, 2004). Researches are going on in Latvia (Zarins, 2006), Poland (Tomppo and Stachura,2006). There are different techniques to get the forest parameters for all 1st phase virtual units –two phase sampling method using static and dynamic stratification (Poso et al., 1987), (Mozgeris et al., 2006), kNN (k-nearest neighbour) method and it's modifications (Tomppo, 1993,Gjersten et al., 2000), (Tokola et al., 1996). Information of satellite images may be combined with forest parameters using regression, usually multiple (Hagner, 1990,Nilsson, 1997,Mozgeris and Augustaitis, 1999). This approach has been also studied in Lithuania (Mozgeris, 2000).

The possibilities of k-nearest neighbor (knn) method to detect forest changes are studied in this paper. Traditionally, numerous solutions are used for satellite image based forest change detection (Singh, 1998, Eastman and McKendry, 1991): differencing of images, regression of images, ratio of images, the principal components analysis, comparison of two independent classification results, classification of integrated information from different dates of acquisition. All of them are based on the use several satellite images from different date of acquisition. Our approach is to use single time image to detect the changes.

The point of this method is:

1. Stand-wise forest inventory in Lithuania is still one of the main sources of forest resource information today. This means that all forests of the country are inventoried at least once in 10-15 years – compartments are singled out, their parameters are estimated. All this information is stored in digital databases.
2. The information of inventory changes with time: forest is growing, it may be felled, planted and etc. Forest managers follow all these changes and record in databases. Natural forest increment is modeled using stand grow models.
3. Forest inventory information gets outdated no matter the efforts to manage it and and it's accuracy is getting lower.
4. Continuous surfaces or grids of any forest characteristic can be easily achieved using single time satellite images that usually fail in using for conventional stand-wise inventory and knn methods, utilizing limited field measurements (for instance, observations from National Forest Inventory by sample methods) – radiometry pixel values of satellite images are replaced by mean stand volumes, ages, diameters, heights, etc.
5. Subtracting the parameters established by stand-wise inventory and corresponding grids of knn method based estimates indicates the forest changes and, up to some extent, inaccuracies of stand-wise inventory.

The knn method (Tomppo, 1993) can be briefly introduced as follows: Euclidean distance $d_{i,p}$ is calculated between each 1st phase sampling unit p in n dimensional feature space of auxiliary information and 2nd phase unit i with field measured forest characteristics. n refers here to the total number of layers of auxiliary information – channels of satellite image, parameters from stand-wise inventory, etc. k (1-10 and more) distances $d_{i,p}$ - $d_{(1),p}$ ... $d_{(k),p}$, ($d_{(1),p} \leq ... \leq d_{(k),p}$) are found and the weight is calculated:

$$w_{(i),p} = \frac{1}{d^t_{(i),p}} \sum_{i=1}^{k} \frac{1}{d^t_{(i),p}} \qquad (1)$$

Value $\hat{m}_p$ of forest parameter M on sample unit p of 1st phase equals:

$$\hat{m}_p = \sum_{j=1}^{k} w_{(j),p} \cdot m_{(j),p} \qquad (2)$$

Where $m_{(j),p}$, $j=1,...k$ – values of forest parameter M in k nearest 2nd phase plots to p in n dimentional space.

Material and methods

For our studies we use research area near Kaunas established near a decade ago for forestry remote sensing oriented investigations (Mozgeris, 2000). It includes 7 forest blocks of Dubrava forest (total area 250 ha) covered by systematic network of field plots located on a 35x35 m grid (Fig. 1), totally 1945 plots. All field plots are geo-referenced with 2 m accuracies.

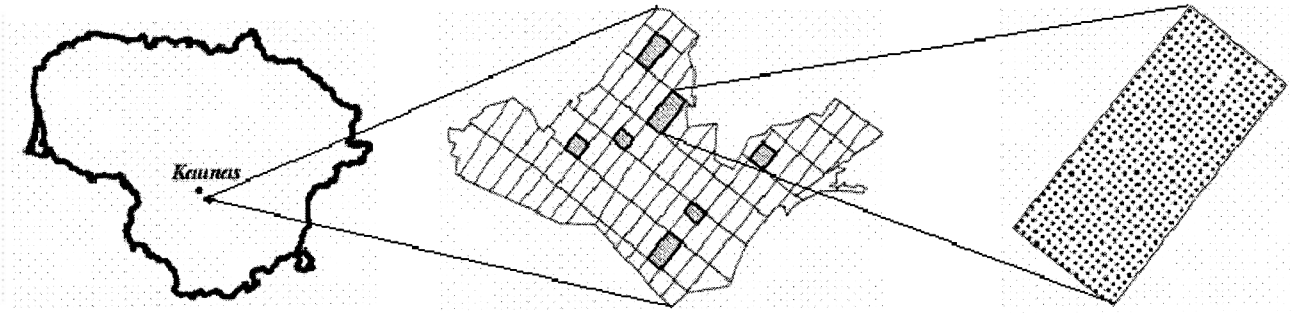

Fig. 1. Location of test sites

All forest stand and tree parameters were measured on all plots following the methodology of Lithuanian National forest inventory (Kuliesis and Kasperavicius, 1999). The following characteristics were calculated for each story and stand in total: percentage of tree species, mean ages, diameters and heights, basal areas, volumes per ha, diameter and height indexes, up to some extent indicating site conditions.

The kNN method was used to calculate grids for the following forest characteristics: stand mean diameter (average value on all field sample plots equals to 26,1 cm), height (22,1 m), basal area (21,6 m), age (62 y), volume per 1 ha (252.9 m^3), percent of coniferous trees (by volume) in stand (69Same in all text%), percent of hard deciduous trees in stand (7%), percent of soft deciduous trees in stand (24%). In all cases, k=10, t=1 and Spot Xi (Spot-4 HRV2, Xi scene, observation data 1999.08.01. Pixel size 20x20 m) channels' digital numbers have been used. Only 1988 field plots were used for the calculation, excluding plots on non-forest areas.. In addition to that, all former standwise inventory (1988, 2003) material – maps, tabular stand descriptions and boundaries of all silvicultural activities, carried out since 1988 in the map form, as well as their descriptions were stored in digital databases. Some boundaries of clear-cut areas were checked using GPS.

The following algorithm was used for change detection:

1. Volume per 1 ha (or other forest parameter, for example, age) from the 1988 y. inventory is converted to raster. Cell size did range 20x20 m, 10x10 m and 5x5 m..
2. Grid of kNN estimated forest characteristic (volume per 1 ha) is subtracted from the grid, generated from stand-wise forest inventory vectors using volume per 1 ha as the value field.
3. Reclassify – IF DIFFERENCE < -127, THEN 1, ELSE 0. 127 is the value of point-wise root mean square error that was achieved in kNN estimation.
4. The result achieved is multiplied by binary mask raster where 1 corresponds the areas of interest - clear cut areas and forest areas, and 0 – all other areas and forest nearer than 10 m from the open areas, roads and waters.
5. Reclassify - IF PRODUCT 1, THEN 1, ELSE No-Data
6. The area of continuous cells with value 1 is estimated using functions REGION GROUP and ZONAL AREA.
7. Reclassify – IF AREA < 800, THEN 0, ELSE 1. It means that all areas smaller than 2 cells are filtered out (clear cut areas can not be less, so we assume that all smaller areas are natural gaps in forest canopy or assessment noise).

All calculation was implemented within ArcGIS software using model builder.

Accuracy of forest change detection was estimated using compartments' boundaries from 2003 y. inventory. Compartments identified as clear-cut areas or forest stands younger than 15 years were selected (all areas with potential clear

cut since 1988). Non-clear cuttings were controlled using GIS layer of silvicultural treatments in 1988-1998. To estimate the accuracy, the following binary grids were overlaid: [Cuttings according kNN data (1) and no cutting according kNN data (2)] X [Cuttings according 2003 y. inventory data (10) and no cuttings according 2003 y. inventory data (20)]. Confusion matrixes were created.

Results and discussion

Fig. 2. illustrates the continuous grids of two major forest characteristics estimated using kNN method from Spot Xi satellite images. We see that characteristics of forest behave like a continuous phenomenon. The estimation root mean square error at a cell level is rather high - 20-45% of mean value of a certain stand parameter. However, the differences of parameters if we compare mature stands and young stands or clear cut areas are much larger.

Only sudden decrease of forest parameter is analyzed in this paper. The reason for such jump usually is related with forest cutting. Cuttings are not differentiated by their type. Simplified confusion matrix is shown in Table 1 (as described in Lilesand and Kiefer, 1994). Here we restrict ourselves by using just the 'user's' and 'producer's ' accuracies.

Jump-like changes in volume per 1 ha and stand age were used as an indicator of the change in forest.

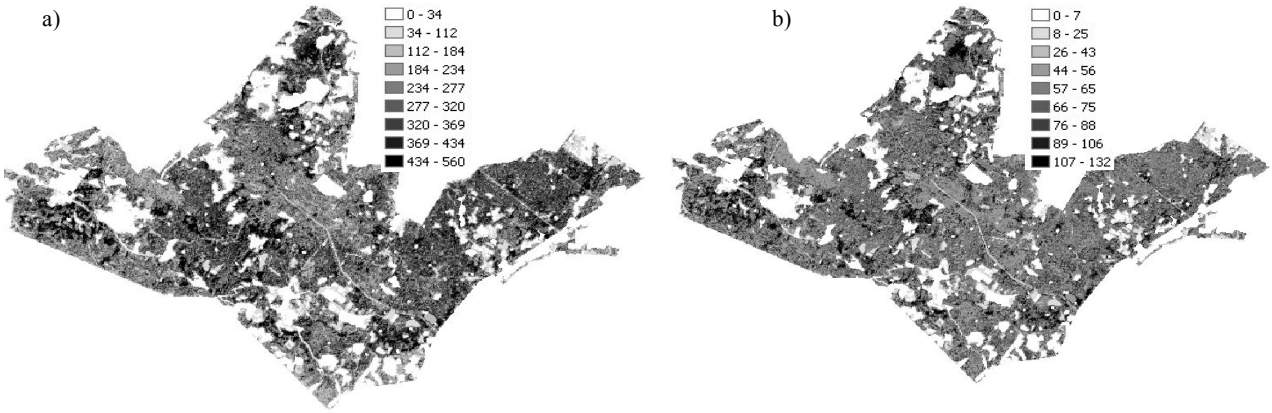

Fig. 2. Selected forest characteristics estimated using knn method and Spot Xi satellite images, cell size 30x30 m; a) volume per 1 ha b) age

68.7-74.8% of areas identified as potential cutting actually were clear-cut areas or stands under 15 years. At the same time 67.1-71.4% of clear-cut areas and stands under 15 years according to 2003 standwise inventory data were detected. 24.5-31.3% of areas classified as potential cuttings actually were neither clear-cut areas nor stands under 15 years. Increasing the resolution of raster grids does not improve the user's accuracy but results in somewhat improved producer's accuracies. E.g. 62.5% classified cutting areas actually were correctly classified for 10x10 m resolution. This estimate has decreased down to 60.7% for 5x5 m resolution. In-depth analysis of wrongly classified cutting areas are most probably non-clear cuttings, which have lost their volume but are not identified as clear cuts or young stands in stand-wise forest inventory data. Unfortunately, there were no detailed records on silvicultural history in stand-wise inventory data from 2003. Therefore we used another GIS database containing the boundaries of all silvicultural treatments in Dubrava forest during the period of 1988-1998. If we remove the stands with non-clear cuttings during the mentioned above period, the 'error' area is reduced by 24-32%. We failed to eliminate the error completely, probably because of the following reasons:

- There are no data in GIS data base about cuttings after 1998 y.
- The accuracy of mapping silvicultural treatments may be not accurate enough. There is a common problem in stand-wise inventories that the bondaries of compartments are not persistent between the inventories.

Table 1.

Accuracy of forest change detection subtracting grids of a certain forest characteristic based on old stand-wise inventory data and kNN estimates (numerator: area, ha, denominator: first number – 'user's accuracy', second number – 'producer's accuracy'

		Stand-wise forest inventory data from 2003		Sum
		Clear-cut area or stand under 15 years	Other	
Volume per 1ha, grid cell size 20x20 m				
Estimated	Potential cutting	441.28 ha (68.7%; 71.4%)	201.00 ha	642.28 ha
	No change	176.72 ha		
Sum		618.00 ha		
Volume per 1ha, grid cell size 10x10 m				
Estimated	Potential cutting	462.32 ha (62.5%; 74.5%)	277.19 ha	739.51 ha
	No change	158.22 ha		
Sum		620.54 ha		
Volume per 1ha, grid cell size 5x5 m				
Estimated	Potential cutting	456.44 ha (60.7%; 73.6%)	294.78 ha	751.22 ha
	No change	163.38 ha		
Sum		619.82 ha		

24.4-32.9% of all areas which were identified as clear-cut areas or stand less than 15 years in 2003, were not detected using the method discussed. The reason could be that we used Spot Xi satellite images from 1999 y. – forest changes could occur after 1999. Detailed study of such stands confirms this assumption – all they are 1-3 y. of age or clear-cut areas. So, all areas which were clear-cut are detected.

Conclusions

1. Single acquisition time satellite images, transformed into cell-wise estimates of major forest characteristics, together with the data from stand-wise forest inventories, can be used to detect clear-cut areas in the forest.
2. Best achieved user's accuracy equals 68.7%, producer accuracy - 74.8%.
3. Introduction of improved knowledge on the study object enables to explain the estimation errors and reduce them.
4. Increasing the resolution of raster grids used for analysis did not improve the user's accuracy but resulted in improved producer's accuracies

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GENOTYPE-ENVIRONMENT INTERACTION IN LATVIAN SCOTS PINE GROWTH AND QUALITY TRAITS AND ITS IMPACT ON PROGENY TESTING

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Abstract

Progeny testing of Scots pine in Latvia is carried out in only few locations, however, material from selections via seed orchards is deployed in various climatic and soil conditions, therefore concerns arise for influence of genotype-environment interaction on levels of genetic gain. Problem is addressed based on 3 open pollinated progeny tests, consisting of 80 open pollinated families, located in 3 distant climatic regions in Latvia. Test age is 27 years, therefore not only growth, but also branch quality traits can be reliably analyzed. Strong genetic correlation (r_b=0.80-0.94) among sites for tree height and diameter was found, but considerably weaker for branch traits like diameter of thickest branch (r_b=0.52-0.67), average branch diameter, and sum of branch diameters (r_b=0.41-0.49). Coefficients of additive genetic variation and coefficients of phenotypic variation among family means, determining potential of improvement via breeding, can be inflated by up to half, based on single site estimates for growth traits and double for quality traits. Backward selection based on results of several trials, in contrast to forward selection or utilization of single experiment results, could lead to improvement of branch traits close to the same as for growth traits (height and diameter). Single site narrow-sense heritability estimates for analyzed growth and quality traits are up to twice as large as across site estimates, indicating possibilities of serious bias in genetic gain estimates based on results from one test site. Testing at 4-5 sites for further breeding work is recommended.

Key words: genetic correlation, heritability, branch traits

Introduction

Forest tree breeding of Scots pine in Latvia started in early 1960^s, and most of activities in this field until 1990^s were attributed to this species that was considered to be most economically important. Plus tree selection activities resulted in ~970 trees selected and 39.2 ha of progeny trials established, mostly (73% of area) located in relatively poor sandy soils (3 site types). Reason for that was very practical – easier establishment and lower costs of management since not that much weed control must be carried out. In contrast, artificial regeneration of Scots pine is carried out in 8 forest site types (out of 23 in classification by Bušs, 1976), both on mineral and peat soils, in wet and dry (naturally or drained) conditions. Obviously it is a concern, if testing in restricted conditions would be reliable (produce genetic gain) in large variety of conditions, where material is diploid. Immediate response to this problem in 1970^s was establishment of seed orchards targeted to produce material for regeneration for especially dry sandy soils (*Cladinoso-callunosa*) and drained peat soils. However, these orchards have never been fully utilized in this way, since keeping track of particular seed and plant lot for relatively small regeneration areas from orchard through cone processing, seedling production and logistics to forest plantation was too complicated from the view point of practical forestry. Practically and economically impossible also seems to be the other response – testing of material in all the variety of forest sites, where results of selection will be realized as forest plantations. Especially considering large number of un-controlled factors affecting tree growth and large annual climatic variation, such, that several authors claim 'neither the sites nor the years of planting are the same' (Matheson, Coterrill, 1990; Pederick, 1990; Turkia, Kellomäki, 1987). Therefore it is important to find out to what extent genotype-environment interaction is influencing estimates of

genetic gain and how reliable are predictions made based on single site (since majority (%) of plus-trees are tested on single site). Since large proportion of Latvian Scots pine trials are now 20-30 years old, it is possible to evaluate more reliably not only growth, but also branch traits that are important for the intended end-product – sawn logs.

Even more important than retrospective evaluation is to work out guidelines for testing of next generation material, crossings for which have been started in the year 2006. It includes not only number of sites needed for reliable testing, but also particular parameters of sites that are or are not recommended for establishment of experiments as well as indicators of reliability of current division of country in breeding zones.

Numerous studies have addressed the issue of genotype-environment interaction working with Scots pine (Lindgren, 1984; Haapanen, 1996; Zhelev et al., 2003) and other *Pinus* species (McKeand et al., 1997; Zas et al., 2004; Wu, Matheson, 2005); however, no such study has previously been carried out in Latvia. In some of studies branch quality is covered, but in those cases branch traits are evaluated in grades. I am not aware of any study previously reporting genotype-environment interaction of quantitatively measured branch traits (of Scots pine).

The aim of the study is to evaluate genotype-environment interaction of growth and branch traits of Latvian Scots pine and draw conclusions for further progeny testing. To accomplish it, the following research tasks have been formulated:

1) evaluate parameters characterizing influence of genotype-environment interaction;
2) evaluate estimates of genetic parameters obtained from single site and across sites;
3) evaluate genetic gains obtained based on single site and across site estimates.

Materials and Methods

Study material consists of 3 Latvian Scots pine progeny trials, located in eastern, central and western part of the country, in total containing 3190 trees (Table 1).

Table 1

Description of Latvian Scots pine progeny tests used in the study

Trial	Age	Site type	Spacing	Number of:					Survival, %
				families	trees per plot		replications		
					planted	survived	planted	survived	
30	27	Vacciniosa	2x1	80	10	2.7	8	6.9	44
31	27	Hylocomiosa	2x1	80	10	2.3	6	4.9	45
32	27	Vacciniosa	2x1	80	8	2.3	8	4.3	48

Note: trial – trial number in Latvian long-time forest experimental database;
age – absolute age in time of measurement;
site type – characterized according to dominant ground vegetation according to Bušs, 1976;
number of trees refers to dominant and co-dominant trees;
no thinning has been done in experimental plots prior to measurement.

Tree height, height up to first living branch, diameter at breast height (1.3 m), and diameter of all branches in the whorl closest to breast height and having no damage have been measured. Branch diameter has been measured 1 cm from the stem, parallel to stem axis. In cases branch has been lost, but scar remaining, diameter of it has been measured in direction parallel to stem axis.

Position in the stand for every tree has been reported. Suppressed trees (Kraft class 3 and 4), comprising on average 24% in older trials, were not included in analysis. Due to small number of trees per family, inclusion 1 or 2 suppressed trees notably reduces average height for family in comparison to other family, where the same suppressed trees have died 1 year ago. It was assumed that if a suppressed tree is dead or alive at the moment of measurement, it is, at least partly, a random process.

Plots were not included in analysis, if at least one tree had died from root rot.

Variance components have been calculated with SAS Proc mixed, based in each experiment separately, using general linear model:

$$y_{irs} = \mu + F_i + B_r + FB(S)_{ir} + FS_{is} + E_{irsk}, \quad (1)$$

where: y_{ir} – trait y measured; μ – overall mean; F_i – the effect of family; B_r – the effect of block; $FB(S)_{ir}$ – interaction among block (within site) and family (plot effect); FS_{is} – interaction between family and site; E_{irk} – the error term. For calculations of single-site estimates site factor is not included.

Open pollinated families were assumed to consist mostly of half-sibs, consequently $4\sigma^2_F$ were considered to be an estimate of the additive genetic variance (σ^2_A).

Narrow sense heritability (h^2_i) and its standard error as well as half-sib family mean heritability (h^2_{fam}) and its standard error were estimated as described by Falconer and Mackay (1996).

Coefficients of additive genetic variation (cv_a) in percentage were estimated as:

$$cv_a = \frac{100 \cdot \sqrt{4 \cdot \sigma_F^2}}{\mu}, \quad (2)$$

where μ – overall mean; σ^2_F.- family variance.

Coefficients of phenotypic variation among family means ($cv_{p\,fam}$) in percentage were estimated as:

$$cv_{pfam} = \frac{100 \cdot \sqrt{\sigma_F^2 + \frac{\sigma_{FB(S)}^2}{bs} + \frac{\sigma_{FS}^2}{s} + \frac{\sigma_E^2}{bns}}}{\mu}, \quad (3)$$

where: σ^2_F. – family variance; $\sigma^2_{FB(S)}$. – family-block (within site) interaction variance; σ^2_{FS}.- family-site interaction variance; σ^2_E. – error variance.

Genetic correlation for traits among test sites (tape-b genetic correlation) was calculated according to formula, denoted as Yamada I, since it has smallest deviation from true genetic correlation (Lu et al., 2001).

Percentage genetic gain from backward selection based on half-sib families (Δg%) was estimated according to Falconer, Mackay (1996) as:

$$\Delta g\% = i \cdot h_{fam}^2 \cdot cv_{pfam} \cdot 2 \quad (4)$$

Coefficient 2 is used since material in experiments are half-sib families.

Results and Discussion

Genetic correlation

Tape b genetic correlation is demonstrating the utility of results obtained in particular site to predict genetic gain of selections, if utilized in another site. Values can exceed 1 due to sampling error (Burdon, 1977; Haapanen, 1996; Stener, Jansson, 2005). Correlations among pairs of sites, demonstrated in Table 2, for height and diameter are high (0.80-0.94), which indicates, that selection in a particular site would lead to minor reduction of gain if material will be utilized in other sites. These estimates are high in comparison to results from Scots pine trials in Scandinavia, however, they fit in a range of variation as published in some cases in Finland (for height at the age of 10 years average r_b=0.61, standard deviation=0.39 – Haapanen, 1996) and in southern Sweden (for height and diameter at the age of 12 and 16 years r_b ranges from 0.38 to 0.97 – Zhelev et al., 2003).

Table 2

Correlations among sites for different growth and quality traits

Trait*		Tape b genetic correlation (r_b) for pairs of trials		
Abbreviation	Description	30-31	30-32	31-32
h	height, m	0.84	0.94	0.89
d	diameter at breast height, cm	0.80	L	0.91
vol	stem volume, m^3	0.65	0.93	0.43
bd1	diameter of 1st, 2nd, and 3rd thickest branch in the whorl, mm	0.60	0.52	0.56
bd2		0.53	0.67	N
bd3		0.67	0.54	N
hgb	height up to first living branch, m	L	L	L
gc	length of living crown, %, $((h-hgb)\cdot h^{-1})\cdot 100$	0.87	0.83	0.74
bn	number of branches in the whorl	L	L	0.84
bdsum	sum of diameters for branches, mm	0.48	0.41	0.45
bdav	average branch diameter, mm, $(bdsum\cdot bn^{-1})$	0.49	0.43	0.47
bdtop	average diameter of 3 thickest branches, mm, $(bd1+bd2+bd3)\cdot bn^{-1}$	0.48	0.44	0.46

*Note: *bd1-3, bn, bdsum, bdav, bdtop – evaluated in a whorl without defects closest to breast height;*
N – r_b can not be estimated because site-family variance component is 0;
L – r_b larger than 1.

Similar estimates for growth traits have been reported also for other species, like Douglas fir – r_b=0.70 on average, ranging from 0.42 to 0.84 (Johnson, 1997); and slightly lower for Norway spruce (in Southern Sweden) – r_b=0.36-0.61 (Karlsson, Högberg, 1998).

Site-family interaction variance component was significant (p<0.001) in all analysis of growth traits and was on average 25% of family variance component for height and diameter. Higher $\sigma^2_{FS}*\sigma^2_F{}^{-1}$ ratio has been reported for growth traits of Norway spruce ($\sigma^2_{FS}*\sigma^2_F{}^{-1}$=0.5 – Karlsson, Högberg, 1998), radiata pine (for stem diameter 1.2 – Pederick, 1990) and hybrid aspen (Yu, Pulkkinen, 2003); in all cases site-family interaction component significant.

Higher values of $\sigma^2_{FS}*\sigma^2_F{}^{-1}$ ratio and consequently lower values of tape b genetic correlation have been observed for branch thickness (r_b=0.52-0.67) and other traits characterizing branches, like bdav, bdtop and bdsum (r_b=0.41-0.49). In contrast, r_b values for number of branches in grades and branch thickness in grades within the same interval as for growth traits have been found by Karlsson and Högberg (1998) for Norway spruce and by Stener and Jansson (2005) for Silver birch. This discrepancy could, at least partly, be explained by differences in heritabilities for particular traits: as pointed out by Johnson (1997), if heritability is low, accuracy of family ranking is also low, therefore high genetic correlation among sites can not be expected. It corresponds well with results of McKend et al. (1997), demonstrating notably lower heritability for diameter than for height in loblolly pine trials, and $\sigma^2_{FS}*\sigma^2_F{}^{-1}$ ratio 1.3 for diameter and 0.59 for height.

Additional complexity of analysis and interpretation of genotype-environment interaction is added by the fact that in tree breeding selection is not done by a single trait rather than by an index, containing several traits. McKend et al. (1997) found that, if index involves two negative correlated traits, $\sigma^2_{FS}*\sigma^2_F{}^{-1}$ ratio of it is higher than for separate traits involved; in contrast, if traits are positively correlated, ratio for index is somewhere among the values of each particular trait involved.

Based on values of genetic correlations, borders of breeding zones can be specified. Zhelev et al. (2003), based on data from 4 Scots pine trials in Southern Sweden and r_b values from 0.38 to 0.97 for growth traits, noted that single breeding zone should be sufficient for the region. Similar conclusion

for Southern Sweden was drawn by Karlsson and Högberg (1998) for Norway spruce (r_b=0.36-0.61), and by Stener and Jansson (2005) for Silver birch (r_b=0.50-0.98). In contrast, division of area into 2 breeding zones has been proposed for interior spruce by Xie (2003) who found r_b values for tree height among pairs of sites within 2 suggested zones 0.84 and 0.97 in average, but r_b for pairs of trials among zones only 0.41 on average. Similar analysis has been performed by Wu and Matheson (2005) for radiata pine. Values of r_b found in my study are high among trials and might suggest that single breeding zone could be used; however, it would be in contrast to division proposed now based on climatic evidence. Therefore more data are necessary to test reliability of such conclusion. For example, studying maritime pine, Zas et al. (2004) found r_b values as low as 0.13-0.44 for height, but noted that no environmental trend was found to support division in separate breeding zones.

Perhaps particular site factors might cause a deviation – especially if testing in agricultural lands (attractive alternative, since soil is more homogenous, easier secure exact spacing, trees grow faster therefore evaluation could be done earlier) is used. Wu and Matheson (2005) noted that r_b values for pairs of trials on 'ex-pasture' lands and forest lands are higher than between trials of thise land types. However, number of trials in this experiment was not high (10) and environmental variation huge (trials distributed in different parts of Australia), so it could be just by co-incidence. Stener and Jansson (2005) found no influence on r_b values due to trial plantation site (former agricultural or forest land). Haapanen (1996), based on data from 40 pairs of Scots pine progeny trials, concluded that variation of r_b values is unpredictable and not related to site characteristics, so selections based on trials even from former agricultural lands could be used without risk to increase bias of results due to genotype-environment interaction. Data of Haapanen (1996) supports conclusion by Johnson (1997) that important for accurate progeny testing (reducing false or in some cases also discovering true genotype-environment interaction) is use of sites with high heritability values.

Genetic parameters

Growth traits (h, d, vol) in general have higher narrow-sense heritability estimated across sites than branch traits as summarized in Table 3. This conclusion is in line with earlier findings both in single site and multiple site level in Scots pine (Velling, Tigerstedt, 1984; Haapanen, Pöykkö, 1993; Haapanen et al., 1997) and other tree species (Merrill, Mohn, 1985). Single site heritability estimates for growth traits up to twice as large as across site estimates, indicating possibilities of serious bias in genetic gain estimates based on results from one test site. Heritability of branch thickness (bd1-3, bdav, bdtop, bdsum) and number of branches per whorl could be more than twice overestimated, if results from single site are used. Height up to the first living branch could be less affected by utilization of single site estimates. Mean of single site heritability estimates, weighted by standard error, used e.g. by Haapanen et al. (1997), is a good approximation of across site estimates – bias for most of traits is within the limits of standard error of respective across site estimate. Larger bias is observed for volume and some branch diameter traits (bd1-3, bdtop).

Table 3

Values of genetic parameters for branch and growth traits

Trait	h^2_i			h^2_{fam}			cv_a			cv_{pfam}		
	across sites	single site		across sites	single site		across sites	single site		across sites	single site	
		mean	max		mean	max		mean	max		mean	max
h	0.34 (0.08)	0.42	0.54	0.84 (0.20)	0.51	0.36	6.2	6.7	9.0	3.4	4.7	5.8
d	0.11 (0.04)	0.14	0.24	0.74 (0.24)	0.30	0.11	7.5	8.2	11.1	4.3	7.8	8.4
vol	0.14 (0.04)	0.21	0.32	0.71 (0.22)	0.37	0.19	16.7	20.9	26.7	9.9	17.5	19.2
hd	0.06 (0.02)	0.07	0.09	0.69 (0.27)	0.20	0.00	5.0	4.9	0.0	3.0	5.6	6.0
bd1	0.10 (0.04)	0.19	0.23	0.66 (0.25)	0.37	0.36	8.0	11.2	12.6	4.9	9.2	10.4
bd2	0.07 (0.03)	0.18	0.22	0.53 (0.26)	0.35	0.34	7.0	11.6	13.2	4.8	9.7	11.2
bd3	0.05 (0.03)	0.14	0.19	0.49 (0.28)	0.31	0.29	6.7	11.4	12.7	4.8	10.3	11.8
hgb	0.13 (0.05)	0.12	0.21	0.72 (0.27)	0.20	0.09	5.5	5.2	8.1	3.2	6.0	7.1
gc	0.04 (0.03)	0.06	0.06	0.47 (0.36)	0.13	0.09	3.2	3.9	4.2	2.3	5.6	6.5

Trait	h^2_i			h^2_{fam}			cv_a			cv_{pfam}		
	across sites	single site		across sites	single site		across sites	single site		across sites	single site	
		mean	max		mean	max		mean	max		mean	max
bn	0.06 (0.02)	0.07	0.14	0.67 (0.28)	0.19	0.08	5.7	6.7	8.5	3.5	7.6	8.4
bdav	0.07 (0.03)	0.16	0.22	0.56 (0.27)	0.33	0.26	6.8	10.6	12.2	4.6	9.3	10.5
bdtop	0.09 (0.04)	0.20	0.22	0.59 (0.25)	0.37	0.35	7.4	11.3	12.6	4.8	9.3	10.7
bdsum	0.06 (0.03)	0.13	0.15	0.54 (0.29)	0.27	0.23	7.5	11.3	11.9	5.1	11.0	12.4

Note: across sites – estimate from joint analysis of all 3 trials (standard error in parenthesis);
single site: mean – mean of single site estimates, weighted by inverse of their standard error;
single site: max – single site estimate with maximum difference (modular value) from across site estimate.

Half-sib family mean heritability, used to estimate genetic gain from backward selection, is notably higher, if estimated across sites. It underlines the importance of use of several test sites in order to obtain more exact genetic gain estimates, closer to actual result gained from utilization of selected parents in seed orchards. Use of mean of single site estimates, weighted by inverse of standard error, decreases the bias; however, in most of cases it still remains to be larger than standard error of across-site estimate.

Comparing narrow sense individual heritability and half-sib family mean heritability values across sites for growth and quality traits, it can be seen that by backward selection improvement of branch traits could be close to the same as for quality traits; however, forward selection for branch traits would result in much lower gain than for growth traits. It might be attributed to the fact, that growth traits (especially tree height) are much less affected by site fertility and competition factors than branch traits (Hynynen, 1995; Ulvcrona et al., 2007). This trend, however, is much less visible from single-site estimates (Stener, Jansson, 2005).

Coefficients of additive genetic variation (cv_a), determining potential of improvement via breeding, can be overestimated by up to half, based on single site estimates for growth traits. Slightly higher bias can be observed for branch thickness traits. In general, cv_a values for growth traits (except stem volume) are only slightly higher than for branch traits, indicating high potential of improving branch properties via breeding. It is in a line with findings by Velling (1982) and Cornelius (1994).

Difference observed in slenderness and branch diameter-stem diameter ratio is related to 0 family variance component estimates in some sites, partly related to use just of dominant and co-dominant trees for analysis. Bias of cv_a estimated from mean of single site estimates is small for height, height up to first green branch, diameter, number of branches per whorl, and branch diameter-stem diameter ratio. It is reduced also by around half compared to maximum for branch thickness. Similar trends can be observed also from values of coefficients of phenotypic variation among family means, just that the bias using single site estimates in comparison to across site estimates is notably higher.

Complex effect of all mentioned components are skewed genetic gain estimates based on results from single site compared to overall (across-sites) estimate, as presented in Table 4. Mean of single site estimates is slightly lower than across site estimates for growth traits; however, deviation based on results from single site could be as high as 73% from value of across site estimate. Similar trends have been observed for the number of branches per whorl and indicators of length of living crown. Branch diameter estimates, in contrast, are less sensitive and deviation reaches maximum 49 from the value of across site estimate. Also mean value of single site estimates is slightly higher than across site estimate.

Study material contains just 3 separate tests, so reliable comparison of efficiency using different number of test sites in comparison to infinite number of test sites could not be made. However, results calculated according to formula presented by Xie (2003) are in a line with conclusions presented in this paper as well as in studies by Lindgren (1984) and Johnson (1997) concluding that additional number of sites higher than 3 gives just a marginal increase in testing accuracy. Due to risk of complete loss of experiment (e.g. browsing damages, forest fire) all mentioned authors suggest utilization of 3-5 test sites. An additional factor, increasing necessity for more test sites, is a need to search for genotypes with wide adaptation due to the risk of Global climatic changes.

Table 4

Genetic gain by 10% selection intensity

Trait	across sites	single site	
	Δg%	Δg% mean	Δg% interval
h	10.0	8.4	5.6 - 12.2
d	11.3	8.3	3.2 - 12.7
vol	24.8	23.1	11.9 - 33.0
hd	7.2	3.9	2.0 - 3.9
bd1	11.4	12.0	10.7 - 13.5
bd2	8.9	12.1	9.7 - 13.4
bd3	8.3	11.2	10.2 - 12.0
hzz	8.2	4.2	2.2 - 8.5
gc	3.9	2.5	2.2 - 3.1
bn	8.2	5.2	1.7 - 8.0
bdsum	9.7	10.6	9.7 - 11.8
bdav	9.0	10.8	8.0 - 12.5
bdtop	10.0	12.2	10.8 - 13.1

Note: Δg% mean – genetic gain calculated from mean of single site estimates, weighted by inverse of standard error of family heritability;
Δg% interval – maximal and minimal single site estimated values of genetic gain.

Conclusions

1. Genetic correlation among sites for tree height and diameter is strong (0.80-0.94), being considerably weaker for branch traits like diameter of thickest branch (r_b=0.52-0.67), average branch diameter, and sum of branch diameters (r_b=0.41-0.49).
2. Single site narrow-sense heritability estimates for analyzed growth and quality traits are up to twice as large as across site estimates, indicating possibilities of serious bias in genetic gain estimates based on results from one test site.
3. Coefficients of additive genetic variation and coefficients of phenotypic variation among family means, determining potential of improvement via breeding, can be inflated by up to half, based on single site estimates for growth traits and double for quality traits.
4. Backward selection based on results of several trials, in contrast to forward selection or utilization of single experiment results, could lead to improvement of branch traits close to the same as for growth traits (height and diameter).
5. Further progeny testing at 4-5 test sites is recommended.

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ESTIMATION OF PRODUCTIVITY AND QUALITY OF DIFFERENT ORIGIN SCOTS PINE IN LATVIA

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Abstract

The productivity and quality of different origin Scots pine (*Pinus sylvestris* L.) progenies at the age of 43 were estimated. The investigation was carried out in 1964. The seeds from six stands growing on mineral and peaty soils in different environmental conditions were sowed. The thinning was done in 2006. The following growth and quality characters were investigated: height of the trees, diameter at breast height, stem volume, standing volume, branch-free tree length, branch thickness, branch angle, stem straightness. The growth and quality differences of the progenies depending on the seed origin were estimated. The environmental conditions of the Zvirgzde origin place and the test locality were similar. The progeny of the Zvirgzde stand showed a superiority in the growth traits (height, diameter, stem volume) as well as good stem quality and high quality of the assortment outcome in thinning. The progeny of the swamp stand (Tireli) had low values in all investigated traits. A significant influence of the environmental conditions of the seeds origin place on the growth and quality of the progeny was found out. Environmental conditions of seeds origin locality and place of forest regeneration have to be similar to avoid decrease of progeny stand's growth and quality.

Key words: Scots pine, origin, productivity, stem quality.

Introduction

Scots pine is the most common tree species in Latvia. Pine stands cover approximately 40% of the total area of the Latvian forests, and it is a common species in the whole territory. The quantitative and the qualitative fluctuation of the characters of the Scots pine are determined both by genotype and by ecological conditions that are in a steady mutual interaction. Scots pine is a species with a large ecological valence in relation to almost all natural environment factors (Liepa et al., 1991; Правдин, 1964). Therefore, its geographical distribution is very wide, and the occurrence area covers varied ecological circumstances. There are several edaphic ecotypes for Scots pine in Latvia. Pine grows in dry, poor littoral and inland dunes, in more and less fertile sand soils, in peat soils of different level of fertility, as well as in swampy areas. In optimal conditions – in fresh, light clayey sand soil in *Myrtillosa* or *Hylocomiosa* forest types pine can reach a height of 42 meters and 700 m^3 ha^{-1} of standing volume in rotation age. In these growths stems of pines are slim, exceptionally straight, crowns are relatively narrow, with a peaked tops and comparatively thin branches (Гайлис et al., 1974).

It has been observed during the ecotype research, that the best growing progeny is the one whose seeds have been collected in growing conditions similar to the site of cultivation because pine has adapted to the particulal environmental circumstances during the evolution (Dreimanis, 1979; Вересин, 1960; Пихельгас, 1971). By comparing the same families in *Vacciniosa* and *Cladinoso- callunosa*, it has been clarified that in *Vacciniosa* the standing volume is substantially larger for pine progeny of *Hylocomiosa* origin, but in *Cladinoso- callunosa* - for pine progeny of *Vacciniosa* origin (Dreimanis, 1993). During the research work in Lithuania (Pliūra and Gabrilavičius, 1998) such kind of pine population has been observed whose progeny grows significantly better or significantly worse than others in any forest site types, as well as populations that have growing precedence only in good or in very opposite – only in bad growing conditions. Therefore, by selection of the best populations for practical purposes, the adaptation peculiarities should be taken into consideration. By analysing the general principles of the tree seed transportation (Zobel and Talbert, 1984), it has been

pointed out that it is not recommended to move origins from basic soils to acid one and v.v. One of the first ecotype trials was arranged by A.Tjurin in the region of Brjansk in 1913, by using pine seeds of growths from dry forest of the 3rd site index and peaty forest of the 5th site index (Dreimanis, 1989). Progeny of peaty forest growth have showed a lower level of survival of 9-11% than the progeny of mineral soils' growth. During the tests in Byelorussia (Поджарова, 1977) in the forest site type like *Vacciniosa* it has been found out that in the age of 10 pine progeny of the forest type like *Cladinoso-callunosa* are behind the ones of the forest type like *Hylocomiosa* in the height by 17-21%, but the height of progeny of peaty soils` growth is only 58% from the height of progeny of the forest type like *Hylocomiosa*. The research of E.Pihelgas (Пихельгас, 1971) in Estonia proves that the growing of the pine stand depends on the origin of seeds. The progeny of the most productive growths of higher site index in mineral soils grow faster in comparison with progeny of growths of lower site index (especially on peaty soils). Progeny of growth on peaty soil at the age of 12, grown in mineral soils, reach 64% of the height of pine progeny of the 2nd site index growth. Progeny of growth on peaty soil suffer also more from diseases. By moving seeds to less favourable growing conditions, generation of progeny is characterised by elevated productivity, but by moving seeds from more severe to more favourable conditions, generation of progeny is characterised usually by a slower growing, but by a better preserving and quality (Вересин, 1963). On the whole survival, growing, stability, quality and productivity of progenies' generation is connected with the ecological conditions of the seed origin site. For the forest regeneration it is advisable to use seeds that are collected in forest growths that have grown in similar ecological conditions (Вересин et al., 1985).

In the middle of the 20th century pine seeds of unknown origin were used for forest regeneration in Latvia. Usually they were collected in the forest cutting areas, but very often also from low, branchy trees growing on edges of the fields, in swamps and dunes, paying no attention to the origin of the seeds. By progressing of the forest selection, scientists had to convince foresters about the importance of the choice of suitable seed material. In order to clear the suitability of pine seeds growing in different ecological conditions for reforestation needs, in the 60-ties of the 20th century in Latvia the first trials of ecotypes were arranged. The aim of this article is to survey the differences of productivity and quality of various pine ecotypes' progenies.

Materials and Methods

The forest trial was laid in 1964 by forest selectionists under the leadership of J.Gailis. The trial was situated in the territory of the present- day Riga- Ogre Regional Forest District (geographical coordinates 56°50.448 N 24°34.676 E) on the poor mineral soil with little amount of humus (forest type *Vacciniosa*). The seeds from six Scots pine stands growing in different environmental conditions on mineral and peaty soils were sowed:

- the seeds from the 2nd site index stand (forest type *Vacciniosa*) growing on dry mineral soil (Zvirgzde),
- the seeds' sample from seeds` material used for practical forest regeneration at the former Ogre Forestry (Ogre),
- the seeds from the 1st site index stand (forest type *Hylocomiosa*) growing on dry mineral soil (Sabile),
- the seeds from the 2nd site index stand on a seaside dune (Mangali),
- the seeds from the 5th site index stand of swamp in the distance of 700-1000 metres from a border of a swamp (Tireli),
- the seeds from the 5th site index stand (forest type *Sphagnosa*) growing on a wet peaty soil between stands growing on mineral soils (Purvajs).

The trial was established in six replications, four of them were suitable for research. The area of parcels occupied by the progeny of each of six origin pines in one replication is 20x30 metres, with the exception of origin Purvajs, progeny of which was sowed in parcels of 10x30 metres. The previous measurements in this trial were done in age of five, twelve and twenty one year. The height, diameter, survival and standing volume of each origin`s progeny were estimated (Гайлис, 1972; Dreimanis, 1989).

The even thinning by the generally accepted silvicultural principles was done in 2006 before the measuring of the trees in age of 43 years. During the cutting works the borders of parcels were exactly noticed and the thinning assortments (small dimension logs, pulpwood, fire-wood)

were measured in each parcel separately. In order to estimate the obtained amount of timber assortments the following compactness coefficients were used: 0.56 for small dimension logs, 0.52 for pulpwood, 0.70 for fire-wood. After the thinning all growing trees were numbered and measured in every parcel.

The following growth and quality features were investigated:

- height of the trees,
- diameter at breast height,
- stem volume,
- standing volume,
- branch-free tree length,
- branch thickness by three points scale, allotting one point to trees with relatively thin branches, two points – with medium branches, but three points with thick branches;
- branch angle by three points scale, allotting one point to trees with right branch angle, two points – with more acute branch angle, and three points – with exceptionally acute branch angle;
- stem straightness by three points scale, allotting one point to straight trees, two points – to trees with weak bends, but three points to crooked trees.

Using the measurements of height of the trees and diameter at breast height the stem volume was calculated by the method of I.Liepa (1996):

$V=\psi*L^{\alpha}d^{\beta 1gL+\varphi}$ (1),

where V – stem volume, m^3;

L – stem length (in this case – tree height), m;

d – diameter at breast height, cm;

ψ, α, β, φ - coefficients depending on the tree species.

The average values of measurements ($\bar{x}$) and the coefficients of variation (s%) were estimated for features of each origin`s progeny. Using one-way analysis of variance (ANOVA) for the quantitative features, the significance of the seeds` origin factor and the differences of the progeny depending on the seed origin were estimated. The progeny that had grown from seeds used for practical forest regeneration activities (origin Ogre) was used for control. In order to estimate the significance of the seeds` origin factor and the differences between the progeny quality depending on the seed origin, non–parametric methods (Kruskal Wallis-H test and Mann Whitney U-test) for attributes were used by applying the software SPSS.

Results and Discussion

The productivity and quality of different origin Scots pine progeny at the age of 43 were estimated. The tree height was an important feature that had influenced the productivity of the stand. Therefore, the height was often used as the main criterion to estimate the trial. The height was not depending on the location of trees in the trial so much, than the diameter, basal area and standing volume, still in a sparse wood the stems of the trees were more taper than in a dense stand. The average height of the different origins` progeny varied from 17.2 m (Tireli) to 20.4 m (Zvirgzde), average data of trial – 18.4 m (Table1).

Table 1

Average Measurement Data for the Different Origins` Progeny at the Age of 43 Years

Origin	Number of trees per ha	Height		Diameter, $d_{b.h.}$		Stem volume		Branch-free tree length	
		$\bar{x}$, m	s%	$\bar{x}$, cm	s%	$\bar{x}$, m^3	s%	$\bar{x}$, m	s%
Zvirgzde	700	20.43	4.4	20.93	19.7	0.35	41.6	1.75	51.7
Ogre	746	18.49	5.1	19.26	21.7	0.27	47.3	1.25	63.9
Sabile	758	17.88	5.3	18.46	18.5	0.24	40.0	1.23	65.2
Mangali	683	18.19	5.7	19.31	21.3	0.27	47.0	1.23	73.7
Tireli	614	17.18	6.0	17.64	22.7	0.22	48.0	1.15	77.4
Purvajs	775	17.92	5.3	18.35	20.6	0.24	46.0	1.23	69.0
Mean	713	18.35	5.3	18.99	20.7	0.27	45.0	1.31	66.8

The coefficient of variation on the average of a trial was 5.3%. The progeny of seeds used for practical forest regeneration activities (origin Ogre) were taken as a control in order to compare height of different origin progeny at different age (5; 12; 21; 43 years). The mean height of the Ogre progeny was assumed as 100% (Figure1). The progeny of the 2nd site index stand growing on mineral soil of medium fertility (Zvirgzde) showed a better growth than the control progeny at all ages. The relative height of the Zvirgzde`s progeny reached 107- 113% in comparison with the control progeny. The progeny of the 1st site index stand growing on the mineral soil of a high fertility (Sabile), the progeny of the 2nd site index stand of the seaside dune (Mangali) and the progeny of the 5th site index stand on the peaty soil between the stands on mineral soils (Purvajs) had grown on the same level as the control progeny at all ages and reached the relative height values of 91- 99% in comparison with the control progeny, with the exception of the Mangali progeny at age of 12 years (83%). The lowest values of the height in the trial showed the progeny of the 5th site index stand of swamp (Tireli), which relative height values at 5; 12; 21 and 43 years were 85; 86; 83 un 93% in comparison with the control progeny`s height.

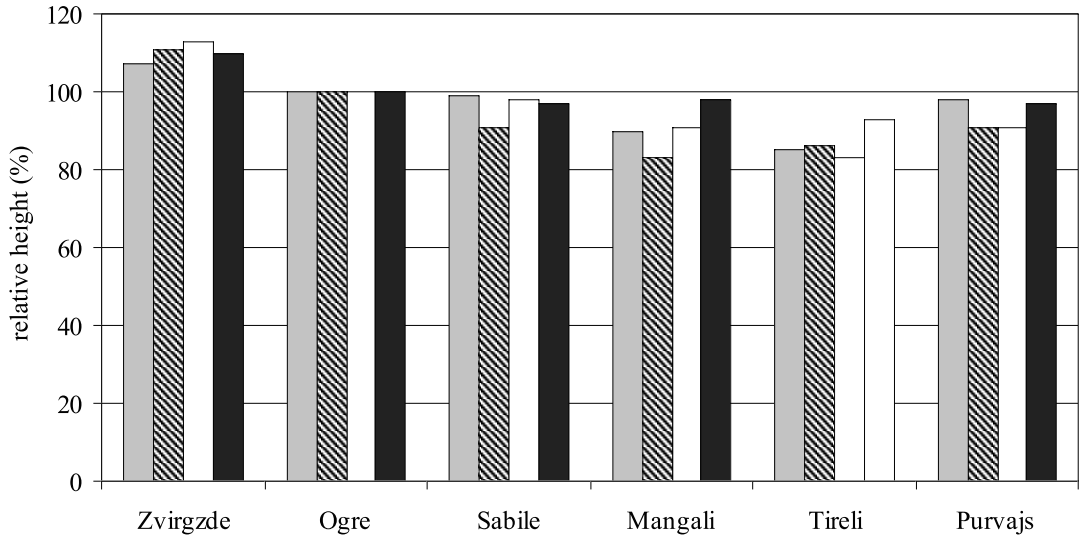

Fig.1. The relative height (%) of different origin`s progeny at the different age.

5 years 12 years 21 year 43 years

The influence of the environmental conditions of the seeds' origin place on the height of the progeny was significant at the age of 43. Significant differences between almost all origin`s progeny average values of height were found out (Table 2).

Table 2

Differences Between the Height, Diameter and Stem Volume of the Different Origins` Progeny

Origin	Avarage measurement	Differences between the values of the different origins` progeny					
		Ogre	Zvirgzde	Mangali	Sabile	Purvajs	Tireli
Height, m							
Ogre	18.49		-1.94*	0.30	0.61*	0.57*	1.31*
Zvirgzde	20.43	1.94*		2.24*	2.55*	2.51*	3.25*
Mangali	18.19	-0.30	-2.24*		0.31*	0.27	1.01*
Sabile	17.88	-0.61*	-2.55*	-0.31*		-0.04	0.70*
Purvajs	17.92	-0.57*	-2.51*	-0.27	0.04		0.74*
Tireli	17.18	-1.31*	-3.25*	-1.01*	-0.70*	-0.74*	
Diameter, $d_{b.h.}$, cm							

Origin	Avarage measurement	Differences between the values of the different origins` progeny					
		Ogre	Zvirgzde	Mangali	Sabile	Purvajs	Tireli
Ogre	19.26		-1.67*	-0.05	0.80	0.91	1.62*
Zvirgzde	20.93	1.67*		1.62*	2.47*	2.58*	3.29*
Mangali	19.31	0.05	-1.62*		0.85	0.96	1.67*
Sabile	18.46	-0.80	-2.47*	-0.85		0.11	0.82
Purvajs	18.35	-0.91	-2.58*	-0.96	-0.11		0.71
Tireli	17.64	-1.62*	-3.29*	-1.67*	-0.82	-0.71	
Stem volume, m^3							
Ogre	0.27		-0.08*	0.00	0.03	0.03	0.05*
Zvirgzde	0.35	0.08*		0.08*	0.11*	0.11*	0.13*
Mangali	0.27	0.00	-0.08*		0.03	0.03	0.05*
Sabile	0.24	-0.03	-0.11*	-0.03		0.00	0.02
Purvajs	0.24	-0.03	-0.11*	-0.03	0.00		0.02
Tireli	0.22	-0.05*	-0.13*	-0.05*	-0.02	-0.02	

** α=0.05*

The mean height of the Zvirgzde origin progeny exceeded the height of the control origin progeny significantly (by 1.9 m), but the mean height of the Purvajs, the Sabile and in particular the Tireli origins` progeny (by 1.3 m) were behind the height of the control origin progeny significantly. The mean height of the Mangali origin progeny was statistically equal to the height of the control origin progeny. The greatest values of the significant differences were observed by the Zvirgzde and the Tireli origins` progeny.

The average diameter of different origins` progeny varied from 17.6 cm (Tireli) to 20.9 cm (Zvirgzde), the average data of trial – 19.0 cm (Table 1). The coefficient of variation on the average of trial was 20.7%. By comparing the average diameter of different origins` progeny, the results were similar as in the height estimation. The highest values of average diameter reached the progeny of Zvirgzde and the lowest – the progeny of Tireli, but the progeny of other origins ranged a little differently by the diameter than by the height. The significant influence of the seeds' origin factor on the diameter of the progeny was found out. The progeny of the origin Zvirgzde showed a significantly higher value of average diameter than the control origin (by 1.7 cm), but the progeny of the origin Tireli – a significantly lower value of the average diameter (by 1.6 cm). The mean diameter of the other origins` progeny were statistically equal to the diameter of the control origin`s progeny (Table 2).

The estimation of the average stem volume of different origins` progeny showed the results similar to the estimation of the height and diameter. The values of the stem volume of different origins` progeny differed significantly. The progeny of the origin Zvirgzde showed a significantly higher value of average stem volume than the control origin (by 0.08 m^3), but the progeny of the origin Tireli – the significantly lower value of average diameter (by 0.05 m^3). The values of the average stem volume of the other origins` progeny were statistically equal to the control origin progeny (Table 2).

The stem quality of Scots pine was determined by the branch-free tree length, branch thickness, branch angle and stem straightness. The branch-free tree length varied from 1.2 m (Tireli) to 1.8 m (Zvirgzde) (Table 1). By this feature only progeny of origin Zvirgzde differed significantly from other origins` progeny and showed the highest value. The values of the branch-free tree length of the other origins` progeny were statistically similar. This character - the branch-free tree length – had a great coefficient of variation – 67% on the average of trial. Probably it was too early to judge about this character at the age of 43.

The progeny of the Ogre and the Tireli origins had the highest values of the relative branch thickness – on the average 1.51 point and only about 50% of trees with estimation of 1 point. The branches of the Zvirgzde origin progeny were the relatively thinnest – 1.30 point on the average and 72% of trees with estimation of 1 point (Table 3). The results of the Kruskal Wallis H-test confirmed the significance of seed origin factor influence. The Mann Whitney U-test results showed that the relative branch thickness

of the Ogre origin progeny was significantly higher than the other progeny branch thickness (except the Tireli origin). The relative branch thickness of the Zvirgzde origin progeny was significantly lower than the Ogre and the Tireli progeny branch thickness and statistically equal to other origins` progeny.

Table 3

Comparison of the Quality Traits of Different Origins` Progeny

Origin	Average value, points	Percentage (%) of the trees with estimation		
		1 point	2 points	3 points
Branch thickness				
Zvirgzde	1.30	72.0	26.2	1.8
Ogre	1.51	52.0	45.3	2.8
Sabile	1.38	63.7	34.6	1.6
Mangali	1.33	71.3	24.4	4.3
Tireli	1.51	54.3	40.3	5.4
Purvajs	1.37	66.7	30.1	3.2
Mean	1.40	63.3	33.5	3.2
Branch angle				
Zvirgzde	1.27	73.2	26.2	0.6
Ogre	1.37	62.6	37.4	0.0
Sabile	1.14	85.7	14.3	0.0
Mangali	1.14	86.0	14.0	0.0
Tireli	1.38	62.8	36.4	0.8
Purvajs	1.22	78.5	21.5	0.0
Mean	1.25	74.8	25.0	0.2
Stem straightness				
Zvirgzde	1.31	72.6	23.8	3.6
Ogre	1.37	66.5	29.6	3.9
Sabile	1.40	63.2	33.5	3.3
Mangali	1.29	73.2	24.4	2.4
Tireli	1.37	65.9	31.0	3.1
Purvajs	1.17	83.9	15.1	1.1
Mean	1.32	70.9	26.2	2.9

Stem quality depends on the branch angle, too. If this angle was acute, it negatively influenced the quality of the board. The progeny of the Sabile and the Mangali origins had a branch angle close to the right (1.14 point), the progeny of the Ogre and the Tireli origins had a more acute branch angle (1.37 and 1.38 points), but the progeny of the Zvirgzde had a branch angle value (1.27 points) similar to the average branch angle value (1.25 points) of the trial (Table 3). The results of the Kruskal Wallis-H test confirmed the significance of the seed origin factor influence. The progeny of the Sabile and the Mangali origins` had significantly better estimation of the branch angle values than the progeny of almost all other origins.

The progeny of the origin Purvajs had the straightest stems – 1.17 points and 84% of trees with estimation of 1 point (Table 3). The seed origin factor significantly influenced the stem straightness of the progeny. The stems of the Zvirgzde origin progeny were comparatively straight, but the progeny of the origin Tireli had a stem straightness lower than the average value of the trial.

During the thinning, the obtained timber assortments in every parcel were measured. The amount and percentage of each kind of assortment (small dimension logs, pulpwood, fire-wood) for different origins` progeny were estimated.

For all origins` progeny, the greatest part of the obtained timber volume was the pulpwood – about 50% (Table 4). The outcome of small dimension logs of the Zvirgzde, the Ogre, the Sabile and the Mangali origins` progeny differed a little (18- 24%), but for the progeny of the Tireli origin this value

was smaller – only 11% of the total outcome. The progeny of the Zvirgzde, the Ogre, the Sabile and the Mangali had a similar fire-wood outcome (24-29%), but for the progeny of the Purvajs and the Tireli this amount was higher (about 40%). So the important differences of the quality and value of the thinning assortment between the different origins` progenies were observed.

The removed and standing volume, as well as the total volume (before the thinning) of each origins` progeny were estimated (the absolute values, $m^3$ $ha^{-1}$ and the percentage). The differences in the area of parcels were taken into consideration when the calculation was done. The comparison of volumes of different origins` progeny was showed in Table 5 and Figure 2.

Table 4

The Assortment of the Removed Volume of Different Origins` Progeny

Origin	Small dimension logs		Pulpwood		Fire-wood		Total
	m^3	%	m^3	%	m^3	%	m^3
Zvirgzde	6.3	20	15.9	51	8.9	29	31.1
Ogre	3.3	18	9.8	53	5.5	29	18.6
Sabile	4.9	24	9.9	48	5.7	28	20.5
Mangali	4.4	18	14.2	58	6.1	24	24.7
Tireli	1.0	11	4.6	49	3.6	40	9.2
Purvajs	1.2	16	3.3	45	2.8	39	7.3

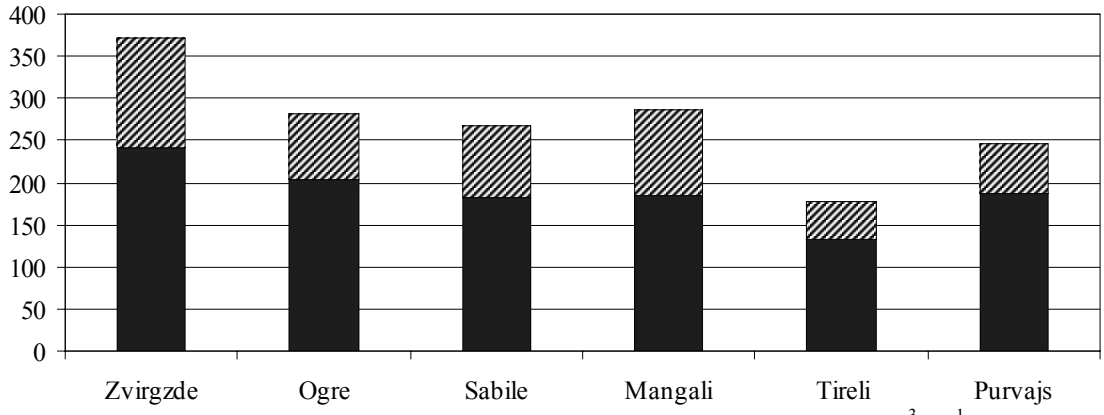

Fig. 2. The comparison of the volume of different origins` progeny (m^3 ha^{-1}).

■ standing volume ▨ removed volume

It was better to compare the volume values of different origin progenies by using the amount per hectare (m^3 ha^{-1}) because the parcels were not of the same size. The progeny of the origin Zvirgzde had the highest values of the standing (243 m^3 ha^{-1}) and also the removed (129 m^3 ha^{-1}) volume. The progeny of the origin Tireli had a comparatively small amount of standing (133 m^3 ha^{-1}) and removed (44 m^3 ha^{-1}) volume. The standing volume of the progeny of the origins Sabile, Mangali and Purvajs was similar. The progeny of the origin Zvirgzde had the highest total volume. The total volume of the origins Mangali, Ogre, Sabile and Purvajs progenies differed a little from each other, but the progeny of the origin Tireli had the smallest total volume. The total volume of the progeny of the origin Zvirgzde (372 m^3 ha^{-1}) exceeded the total volume of the progeny of the origin Tireli (177 m^3 ha^{-1}) twice.

Table 5

The Estimation of the Volume of Different Origins` Progeny

Origin	Removed volume			Standing volume			Total volume		
	m^3	m^3 ha^{-1}	%	m^3	m^3 ha^{-1}	%	m^3	m^3 ha^{-1}	%
Zvirgzde	31.0	129.3	26	58.2	242.5	21	89.2	371.8	23
Ogre	18.6	77.5	15	48.7	203.0	18	67.3	280.5	17
Sabile	20.5	85.3	17	43.7	182.2	16	64.2	267.5	16
Mangali	24.7	102.8	21	44.2	184.3	16	68.9	287.0	18
Tireli	9.2	43.9	9	28.0	133.2	12	37.2	177.1	11
Purvajs	7.3	60.8	12	22.3	186.1	17	29.6	246.9	15
Total	111.3	X	100	245.2	2X	100	356.5	X.9	100

The environmental conditions of the Zvirgzde origin place and the test locality were the most similar. The progeny of the Zvirgzde origin showed the highest productivity. The progeny of Tireli (from the very different environmental conditions) had low values in all investigated traits.

Conclusions

1. The significant influence of the environmental conditions of the seeds' origin place on the growth and quality of the progeny was found out.
2. The environmental conditions of the Zvirgzde origin place and the test locality were the most similar in comparison with the environmental conditions of other origins. The progeny of the Zvirgzde origin showed the superiority in the growth traits (height, diameter, stem volume). The progeny of the Tireli origin (from the very different environmental conditions) showed the significantly lower values of quantitative traits.
3. The significant influence of the environmental conditions of the seed origin place on the quality traits of the progeny was found out as well. The progeny of the Zvirgzde origin had the best average value of the branch-free tree length and the relative branch thickness. The values of the branch angle and stem straightness of the Zvirgzde origin progeny were similar with the average values of the trial. The progeny of the Tireli origin showed the lowest values of the branch-free tree length, the branch thickness and the branch angle; the stem straightness was lower than the average value of the trial.
4. The analysis of the relative height of the different origins` progenies at the age of 5, 12, 21 and 43 years showed that the progeny of the Zvirgzde origin had the highest values and the progeny of the Tireli origin had the lowest values at all investigated ages in comparison with the control progeny. After the thinning, at the age of 43 the differences of the tree height had decreased but the common tendency had remained.
5. The standing volume of the progeny of the Zvirgzde origin (243 m^3 ha^{-1}) exceeded the standing volume of the progeny of the Tireli origin (133 m^3 ha^{-1}) almost twice. The estimation of the assortment after the thinning showed that the progeny of the Zvirgzde origin had the 20% outcome of the small dimension logs, but the progeny of Tireli – 10% from the total outcome volume.
6. The environmental conditions of the seed origin locality and the place of the forest regeneration have to be similar, in order to avoid the decrease of the progeny stand's growth and quality.

Acknowledgements

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THE ANALYSIS OF SILVER BIRCH (*BETULA PENDULA* ROTH.) STANDS IN STATE AND PRIVATE FORESTS IN LATVIA

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Abstract

In Latvia, birch is the second most widespread tree species, the share of birch is higher in private forests. The Forest Research Inventory that was launched in 2004 provides credible and up-to-date information about all forests of Latvia irrespective of the ownership. The data from first three years' data base of this Project has been used in the present study. The aim of this study was to analyse birch stands in state and private forests concentrating on different aspects: mixture degree, origin of the stand, productivity and quality of the stand. 735 sample plots were selected from the database for the analysis. The proportion of the birch stands in the private forests was slightly higher than in the state forests. There were more mixed stands in the state forests than in the private ones. The standing volume was higher in the mixed stands while the opposite was true for the current annual volume increment of birch. The main regeneration method in both the state and private birch stands was natural regeneration from seed. Artificial regeneration was used only rarely in the private birch stands. The productivity did not differ significantly between the state and private forests; the same was true for the quality, expressed by the outcome of veneer logs. The stand quality differed significantly among site types, being the highest in the forests on dry mineral soils and the lowest in the forests on drained peat soils.

Key words: birch stands, productivity, quality, mixture degree, state forests, private forests.

Introduction

In Latvia, the pine stands currently account for 37%, spruce stands for 18%, and birch for 30% of the total forest area. (Meža nozare Latvijā, 2007) There are differences in the distribution of main tree species in state and private forests: the share of the deciduous trees is higher in the private forests. (Meža nozare Latvijā, 2007) The high proportion of birch cannot be explained only by inappropriate decision-making on the part of forest managers since many birch stands have emerged naturally on former farmlands abandoned during and after WWII (Zalitis and Zalitis, 2007). Due to non-market orientated forest management during the soviet period in Latvia, almost no research about establishment and management of birch stands was carried out. It ended up in shortage of information about birch stands in Latvia at the end of 20th century when Latvia became independent and market orientated. The interest towards birch timber rose since then mainly because of well-developing birch plywood industry that has also made investments in research projects putting efforts on establishing highly productive birch stands in Latvia.

However, the most part of all research projects regarding birch has been carried out in the state forests, mainly due to the lack of reliable information regarding private forests. (This statement does not apply to the research projects related to the establishment and juvenile growth of the birch stands, while these studies are often carried out on the former agriculture lands belonging to the private owners or companies). There is also no up-to-date information about the productivity and quality of the private birch stands, even more – there is no noticeable research carried out regarding the problems connected with growth, productivity and quality of birch stands.

In 2004 a long-term project - Forest Resource Inventory - was launched with a purpose to provide high-precision data about forests in Latvia irrespective of the ownership. This project is presently one of the priorities of the silviculture and forest policy in Latvia and is directly financed by the

state since 2007. Therefore, it is necessary to increase the scientific value of this project by analyzing the data from a broader point of view.

The aim of this paper was to analyze the birch stands in state and private forests comparing different characteristics: mixture degree, origin of the stand, productivity and quality that in this case is expressed by the outcome of veneer logs. Following zero hypothesis was tested: the stand characteristics (in this case mixture degree, origin of the stand, productivity and the outcome of veneer logs) do not differ significantly in state and private forests.

Material and methods

In this research the data from Latvia forest resource inventory collected in 2004, 2005 and 2006 was used. I have personally taken part in the collection of these data according to the methodology shortly described below.

The network of hidden sample plots for Forest resource inventory is to be established within the period of 5 years and will cover the entire territory of Latvia. These sample plots are combined into squares 250 meters x 250 meters. The distance between these squares is 4 kilometers. Each sample plot includes a circle with an area of 500 m^2, where all trees, stumps and deadwood with diameter 14.1 centimeter and greater are measured. In the central part of the sample plot (100 m^2), all trees, stumps and deadwood with diameter 6.1 centimeter and greater are measured. Finally, all trees, stumps and deadwood with diameter 2.1 centimeter and greater are measured in the first quarter of this 100 m^2 sample plot. The diameters of the trees are measured at the height of 1.3 meters from the root collar. After the trees of the sample plot are divided into stand elements, the height of 5-7 trees per element is measured to create a height curve. These trees are also used to determine the annual radial increment of the last 5 and 10 years and the age of the stand.

In order to test the abovementioned hypothesis, the data from the data base of forest resource inventory were selected as follows:

1. Land category. Only sample plots on the forest land were selected;
2. Tree species. Only stands with main tree species birch were selected;
3. The area of the sample plot. At least 75% of the area of the sample plot had to be on the forest land;
4. Number of the trees in the stand. At least 100 trees per hectare had to be in the sample plot.

According to the above-mentioned criteria, 735 sample plots were selected for the further analysis. The data normality was tested with one-sample Kolmogorov-Smirnov test; in all cases, it proved to be normal. Therefore, parametrical methods were chosen for the further data processing: independent samples t-test and one-way ANOVA.

In this paper, the mixture degree was compared at the stand age 60-80 years; the origin of the stand (plantation, natural regeneration from seed, coppice) at the stand age 5-30 years. The stand productivity was in this case expressed by two parameters: the total standing volume of the dominant stand, $m^3 ha^{-1}$, and the current mean annual volume increment of birch (in the period of last 10 years), $m^3 ha^{-1} year^{-1}$. The total standing volume of the dominant stand was tested in the age class 60-80 years and the current mean annual increment - in the age class 20-40 years.

The outcome of veneer logs was tested in the stands with a mean diameter 18-34 cm according to the method elaborated during the long-term project held in LSFRI 'Silava' – 'The growth and stem quality of purposefully managed young birch stands in Latvia'. During this research, 460 sample trees in 23 sample plots in 16 State Forestries were selected for the estimation of the outcome of veneer logs in the stand. Following equation (1) was generated:

$$KV\% = 0.59D + 0.98H - 13.8 \qquad (1)$$

where KV% - the outcome of the veneer log, % of the total standing volume;

D, H – mean diameter and height of the stand (18.0 cm<D<34.0 cm) (Zalitis *et al,*. 2003).

Results and Discussion

The comparison of the birch stands according to the ownership shows that there are slightly more private birch forests than state birch forests (Fig.1).

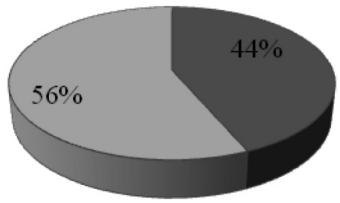

Fig.1. The ownership structure of birch stands in Latvia:
state forests private forests.

This difference could be explained with historical background of land management in Latvia and also describes the overall tendency – there are more broadleaved stands in private than in state forests.

Comparing the mixture degree of birch stands in state and private forests it was found out that there were more mixed stands in the state-owned forests than in the privately owned ones (Fig.2).

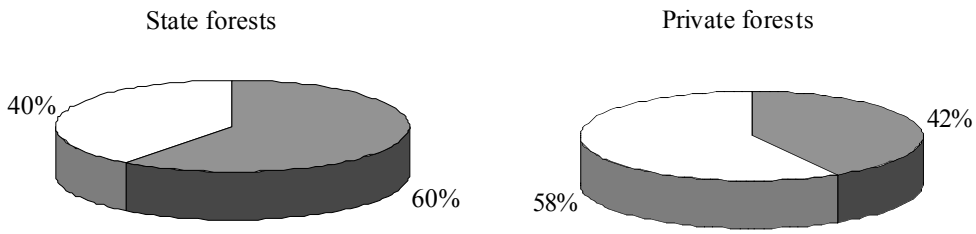

Fig 2. The proportion of pure and mixed stands in the state and private birch forests:
mixed stands pure stands.

This could have an explanation that a typical private forest owner usually carries out thinnings in his forest more frequently than it is done in state forests. Usually, there are more broadleaves left in the stand after the thinnings because the conifer timber is more valuable for the forest owner. From the other side, there is a slight trend that lately forest owners in Latvia are becoming more and more educated and are regarding their forest properties more like long-term investment.

The mean values of the standing volume of mixed and pure birch stands are represented in figure 3.

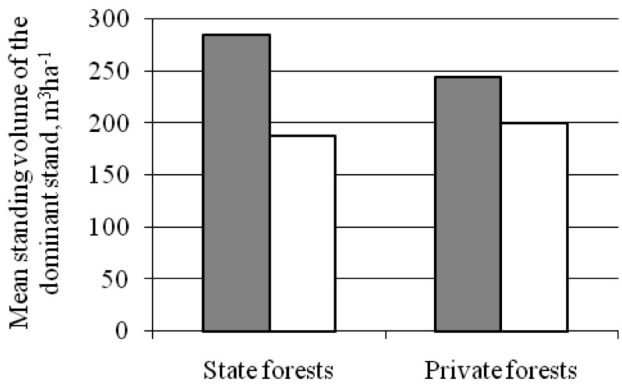

Fig.3. Comparison of the mean standing volume of the dominant stand in pure and mixed state and private birch forests:
mixed stands pure stands.

Figure 3 also represents the trend that the mean standing volume accumulates more in mixed stands. It can be explained with the presence of conifers in the tree species' mixture at the end of the rotation period. The difference between the standing volume in pure stands in private and state forests most likely originates from the larger mean tree diameter in the private forests - 29.0 cm, whereas in state forests it is only 26.3 cm. It corresponds well with the above mentioned assumption that a typical private forest

owner manages his forest more intensively.

Figure 4 shows the mean annual volume increment of birch in pure and mixed stands both in state and private forests.

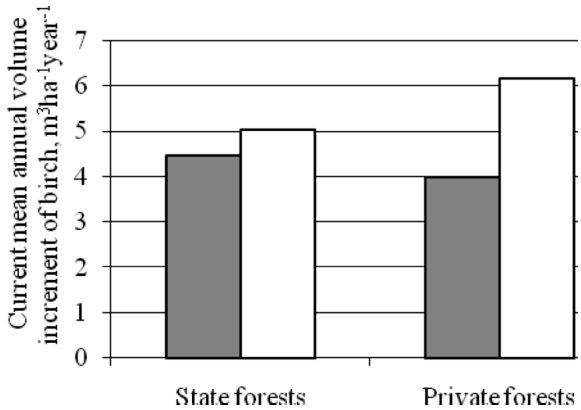

Fig. 4. Comparison of the current mean annual volume increment of birch in pure and mixed state and private birch forests
mixed stands pure stands.

Species mixture obviously influences the annual increment of birch negatively and the difference of this variable in private and state forests leads us to the same conclusion as above – cutting down the conifers in birch-conifer stand increases the annual increment of the remaining stand.

Both in state and private forests natural regeneration from seed is the main regeneration method in the birch stands. (Fig.5) In state forests 12% of the stands are regenerated as plantations while in private forests – only 1%. Regeneration from coppice is more common in private forests than in state forests.

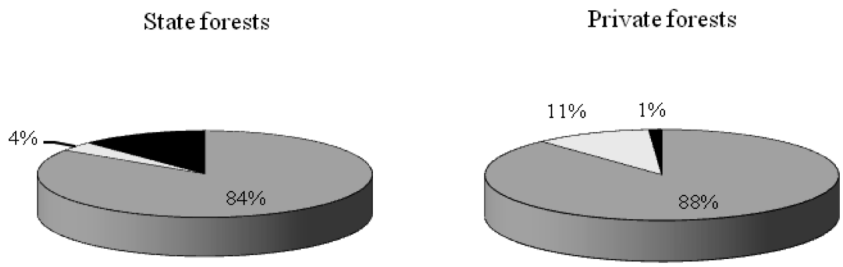

Fig. 5. The distribution of stands according to the regeneration method in state and private birch forests:
natural regeneration from seed coppice plantation.

The distribution of regeneration methods shows us that there is marked difference between plantation areas in state and private forests. Most probably, this is so because the establishment of plantation is the most costly part of whole forest management cycle and not all private forest owners have an opportunity for such investment. In my opinion, the results of this study could be different, if the afforested former agriculture lands were included in the analysis as well.

The productivity indicators proved to be rather similar in state and private forests. The analysis of the annual increment in the age class 20-40 years shows that there are no significant differences (α=0.05) between state and private forests and also between different site types, whereas the total standing volume of the stand differed in stands growing on dry mineral and drained peat soils (peat layer is more than 20 cm) – p=0.001. In the forests on dry mineral soils the value of the mean standing volume of the dominant stand was 266 $m^3 ha^{-1}$, while in the forests on drained peat soils – only 178 $m^3 ha^{-1}$. No significant difference in the standing volume of state and private birch stands was discovered.

The analysis of the stem quality of the birch stands in Latvia within diameter class 18-34 centimetres showed that the average outcome of the veneer logs was 22.3% in state forests and 21.9% in private forests and 23.4% and 20.8% on dry and drained soils, respectively. There were no significant (α=0.05) regional differences, whereas there were significant differences among the site types. The results of multiple comparisons are shown in Table 1.

Table 1

Differences of the outcome of veneer logs in different site types; p-values of one-way ANOVA

Site type	Forests on dry mineral soils	Forests on drained mineral soils	Forests on drained peat soils
Forests on dry mineral soils	-	0.021	0.000
Forests on drained mineral soils	0.021	-	0.005
Forests on drained peat soils	0.000	0.005	-

The significant differences were detected in all groups of variables – the outcome of the veneer logs was greater in stands growing on dry mineral soils than on drained mineral and peat soils, but there was also a difference between both drained site types. First of these two statements agrees with another one stated by the researchers of LSFRI 'Silava'.

The researchers of LSFRI 'Silava' are also in opinion that the percentage of the outcome of the veneer logs fluctuates between 8 and 45 percent and gives an average outcome of 27.7 %. More homogenously established sample plots during the Forest Resource Inventory could explain the difference in results.

The obtained results from this study show that there are no significant differences in stand characteristics between state and private forests. The zero hypothesis stated before holds true.

Conclusions

1. A little more than a half of all birch stands in Latvia are owned and managed by private forest owners;
2. There are more mixed birch stands in state forests than in private forests in Latvia. The mixed stands are also more productive at the age 20-40 years irrespectively from the ownership;
3. Both in state and private forests natural regeneration from seed is the main regeneration method in the birch stands. Low percentage of artificially regenerated birch stands in private forests can be explained with high establishment costs of the plantation.
4. The total standing volume of 60-80 years old birch stands differs significantly among site types irrespectively from the ownership; the most productive stands are located on dry mineral soils.
5. The outcome of veneer logs KV% differs significantly among the site types, the highest veneer outcome is in the forests on dry mineral soils, the lowest – in the forests on drained peat soils. The ownership structure does not influence this result.

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PRODUCTIVITY OF NORWAY SPRUCE STANDS IN STATE AND PRIVATE FORESTS OF LATVIA

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Abstract

In Latvia, almost 50% of all forests are privately owned. Due to hard economic situation in the 1990ies, many private forests have suffered from illegal forestry operations and overexploitation. One of economically most important tree species for private forest owners is Norway spruce. In this study the productivity of state-owned and private spruce forests was compared, assuming that the stand productivity of private forests should be lower compared to those owned by the state. Data gathered in the Forest Resource Inventory in 2004, 2005 and 2006 was used for the analysis. Total standing volume of the dominant stand and the current mean annual volume increment (CMAI) of spruce were used as main productivity indicators. The mean values of the main stand characteristics were found to be rather similar in state and private forests. The only significant differences were discovered in the mean diameter and CMAI of spruce in 60-90 years old stands; in both cases the values were higher in private forests. Site type and mixture degree were tested as the possible influencing factors. Although there were differences in the site type distribution between state and private forests, the influence of this factor on the CMAI of spruce proved to be insignificant. It was found out that the CMAI of spruce depended significantly on the mixture degree. The proportion of mixed stands in the state forests was considerably higher than in the private forests; presumably therefore the value of the CMAI in the state forests was significantly lower.

Key words: Norway spruce stands, productivity, current mean annual increment, state forests, private forests.

Introduction

Forestry is very important for the welfare of Latvian people. According to expert evaluation, the contribution of forestry sector to the GDP presently amounts to 5%. Around 50 thousand people are employed in forestry; furthermore, in many regions of the country wood-processing is the leading branch of industry. (Meža nozare Latvijā, 2007)

In Latvia, as a result of land restitution and privatization begun shortly after the state independence was regained in 1990, almost 50% of all forests are now privately owned. (Meža resursi, 2008) During the 1990s collapse of many branches of industry forced a large number of people to face serious economic constraints, especially in the rural areas. In a number of cases forests provided a quick solution and an easy source of income for the private owners; unfortunately it often led to illegal forestry operations and overexploitation of the forests. In 1998 the total felled volume in private forests exceeded that of the state forests, in the following years the difference steadily increased and already in 2002 the felling intensity in private forests was twice as high as that in the state forests. (Meža nozare Latvijā, 2004; Meža nozare Latvijā, 2006) During the last years economic activity in the privately owned forests has decreased; in 2006 the share of wood felled in private forests made up 55% of the total felled wood volume in the country. (Meža nozare Latvijā, 2007)

Norway spruce (*Picea abies* (L.) Karst.) is one of the most widespread tree species in Latvia. According to the data of Latvian State Forest Service, forests dominated by spruce take up 18.2% of the total forest area. (Valdošo koku sugu sastāvs, 2008) More than one third of all spruce-dominated stands belong to private owners (Figure 1).

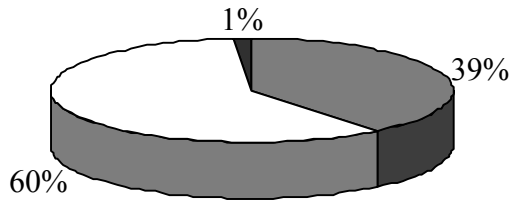

Figure 1. Ownership structure of the spruce-dominated forests (Meža statistika, 2007):
■ - private owners; □ - state; ■ - local authorities.

Economically spruce is very important, especially for the private forest owners. For example, one fourth of the total wood volume felled in 2000 in the final cuttings came from private spruce forests; whereas from state-owned spruce forests – only 5%. (Meža statistika, 2001) Until 2004 the timber volume logged in the final fellings from the other spruce forests several times exceeded the timber volume logged in the final fellings from the state-owned spruce forests; at the same time thinnings in the spruce forests of other owners were carried out much less intensely than in those owned by the state (Figure 2).

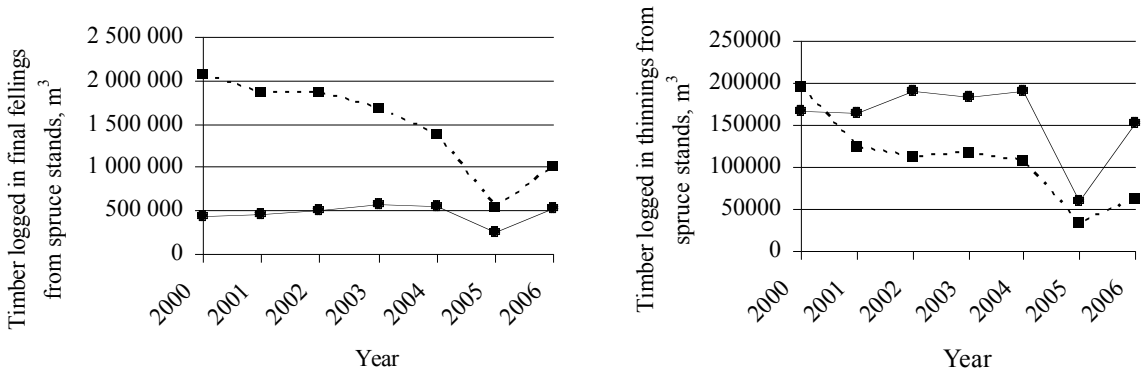

Figure 2. Timber volume logged in final fellings and thinnings in state and other spruce forests (Meža statistika 2001-2007):
●——● - state forests; ◆- - -◆ - other forests.

The above-mentioned facts allow concluding that private spruce forests have been rather intensely exploited during the last decade. At the same time the intensity of thinnings, one of the most important measures to ensure a fine future development of the forest stands, has been low in the private forests compared to those owned by the state. Therefore it is possible that the further development of the spruce forests under private possession is different from those which are owned and managed by the state. It is most likely that the productivity of the private spruce forests is lower than that of the state forests.

In Latvia, the majority of forestry research projects are carried out in the state forests, partly because the information regarding private forests is incomplete. It is possible to obtain approximate data from the Forest Register, where information submitted by all forest owners is gathered. Although it is the duty of the forest owner to carry out the inventory in his property once every ten years, there are no sanctions against those who do not, except some restrictions to economic activities. Also Forest Management Plan is not mandatory but only one prerequisite to receive state and EU support for the development of forest management (Meža likums, 2000). Therefore it is most likely that there has been no up-to-date inventory in those private forests where there has been no economic activities during last 15 years.

In 2004, the Latvian Forest Resource Inventory was launched. Like in many other European countries, in this project data is gathered in all forests irrespective of the owner. Thus the Forest Resource Inventory provides statistically credible and up-to-date information regarding the present situation in all Latvian forests.

This paper attempts to reveal possible differences in the growth of state-owned and privately owned spruce stands comparing the most informative indicator of the present forest condition – stand productivity. It is a part of the doctoral thesis "Productivity and growth potential of pure Norway spruce (*Picea abies* (L.) Karst.) stands on fertile sites".

Material and Methods

In this study data from Forest Resource Inventory gathered in 2004, 2005 and 2006 has been used. The full cycle of Forest Resource Inventory is carried out within five years covering the country with a regular grid of hidden sample plots. These sample plots are located with the help of Global Positioning System (GPS) according to previously computed coordinates. All measurements and calculations of the stand parameters are carried out in accordance with a methodology confirmed by the Agriculture ministry of Latvia.

At the present stage of the Forest Resource Inventory data about 10 064 sample plots are available, 2544 of these are established in 2004, 3670 – in 2005, 3850 – in 2006. According to the aim of the study following criteria were used to select sample plots:

1. The type of the sample plot. Permanent sample plots which will be re-measured every five years were selected.
2. The land category. Sample plots located in the forest were selected.
3. The area of the sample plot. Sample plots with the area of at least 400 m^2 (or 4/5 of the total sample plot area) were selected to avoid accidental exclusion of those sample plots that contain forest infrastructure objects (fire-breaks, ditches).
4. The proportion of the dominant species. Sample plots where the proportion of spruce is at least 50% of the total standing volume of the dominant stand were selected.
5. The number of trees. Sample plots with at least 100 trees ha^{-1} (5 trees sample $plot^{-1}$) were selected.

According to the criteria mentioned above 540 sample plots were selected for the further analysis, 366 of them were located in state forests, and 174 – in private forests.

The stand productivity is most explicitly expressed by two parameters - the standing volume of the stand and current annual volume increment. (Антанайтис и Загреев, 1969; Matuzānis un Tauriņš, 1971) In this study the total standing volume of the dominant stand (m^3 ha^{-1}) and the current mean annual volume increment (CMAI) of spruce of the dominant stand (m^3 ha^{-1} $year^{-1}$, over last ten years) was used. These parameters were analyzed in two age groups: 30-50 years old stands and 60-90 years old stands.

The data distribution was tested with one-sample Kolmogorov-Smirnov test; in all cases it proved to be normal. The productivity differences in state and private forests were analyzed using t-test and one-way ANOVA. Following zero hypothesis was defined. H_0: productivity indicator (total standing volume of the dominant stand and current mean annual volume increment of spruce of the dominant stand, respectively) does not differ significantly in state and private forests.

Results and Discussion

The age distribution of the spruce stands was uneven; especially in the state forests the amount of 20-40 years old stands strongly exceeded the amount of the stands in other age classes. (Figure 3)

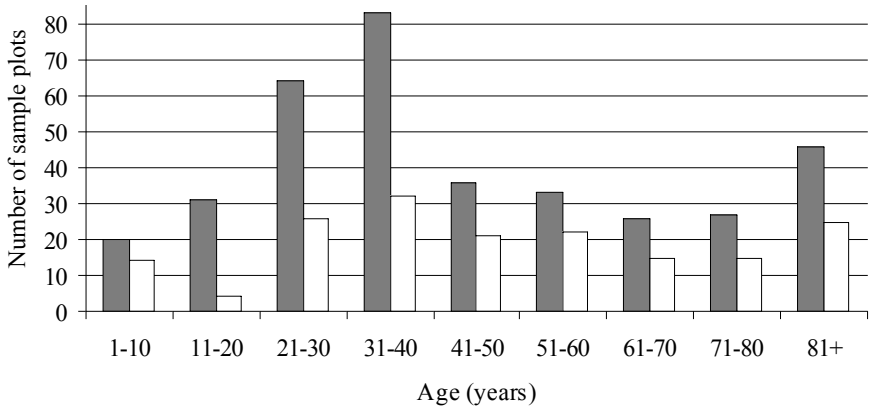

Figure 3. Age structure of the analyzed state and private spruce stands:
■ - state forests; □ - private forests.

The trend of the age class distribution in the state forests revealed by this study corresponded well with the data provided by the Joint Stock Company 'Latvijas valsts meži'. (Fakti par mežu, 2008) The main reason for having so many young stands is believed to be expansive establishment of the spruce stands during the 1960s. Many sites suitable for pine were regenerated with spruce then; partly due to strong browsing pressure of elk mainly causing damages to pine stands and partly due to unjustified assumption that spruce stands require less careful attendance. Very little number of 11-20 years old spruce stands in the private forests most likely reflects the situation in the 1990s when the forest regeneration after the felling was very often inadequate. The regeneration rate of the private spruce forests seems to have improved during the last decade; one explanation might be now available state and EU forest management and afforestation support programmes.

In order to obtain a general idea about the differences in the productivity of state and private forests some most informative mean stand characteristics were compared. The mean number of trees is greater in the state forests; these differences increase with stand age. Other stand parameters are very similar both in state and private forests. The numbers are presented in Table 1.

Table 1

Main stand characteristics of the state and private forests in the analyzed age groups

Stand characteristics	30-50 years old		60-90 years old	
	State forests	Private forests	State forests	Private forests
Mean number of trees ha^{-1}	928	825	648	474
Mean diameter of the dominant tree species, cm	18.0	19.3	24.7	28.4
Mean height of the dominant tree species, m	16.3	16.9	21.6	23.0
Mean basal area, $m^2 ha^{-1}$	23.3	22.3	26.4	26.0
Mean standing volume of the dominant stand, $m^3 ha^{-1}$	203.4	204.6	277.9	285.6
CMAI of spruce, $m^3 ha^{-1} year^{-1}$	8.7	9.3	6.6	8.8

The striking similarities between the mean values of the main stand characteristics in state and private forests were somewhat unexpected. An independent samples t-test was performed to test whether the existing differences of state and private forests were significant (Table 2).

According to the results there were no significant differences in the stand characteristics including productivity parameters of state and private forests in the age group of 30-50 years. In the age group of 60-90 years two parameters differed significantly in state and private forests – mean diameter of the dominant tree species ($p=0.016$) and CMAI of spruce ($p=0.020$). However, contrary to what was expected, the parameter values were in both cases higher in the private forests. The fact that the trees are thicker and grow better in the private forests was repeatedly confirmed when the mean volume of 60-90 years old single tree in state and private forests was calculated. It was greater in a private forest stand – 0.603 m^3 (0.429 m^3 in the state forests, respectively).

Table 2

The significance of the differences between mean stand characteristics in state and private forests; p-values of the independent samples t-test

Stand characteristics	30-50 years old	60-90 years old
Mean number of trees ha^{-1}	0.338	0.258
Mean diameter of the dominant tree species, cm	0.254	0.016
Mean height of the dominant tree species, m	0.465	0.220
Mean basal area, $m^2 ha^{-1}$	0.547	0.837
Mean standing volume of the dominant stand, $m^3 ha^{-1}$	0.952	0.744
CMAI of spruce, $m^3 ha^{-1} year^{-1}$	0.464	0.020

Further analysis was carried out in the age group where significant productivity differences were detected: in 60-90 years old stands. As the tree diameter directly influences the CMAI, only the latter was examined further. Some factors that might have influenced the previously discovered productivity differences in state and private forests were tested. Firstly, site type distribution of 60-90 years old state-owned and private spruce forests was compared. The results of this comparison are presented in figure 4.

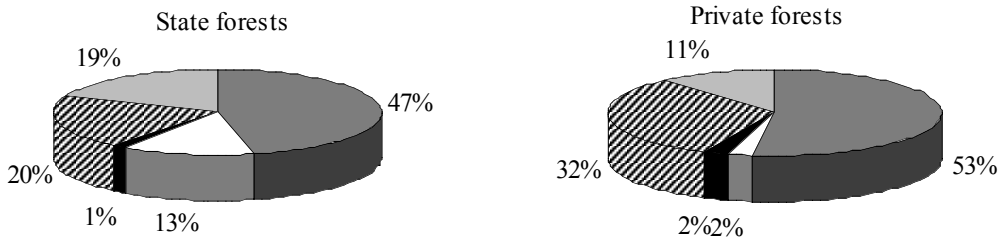

Figure 4. Site type distribution in state-owned and private 60-90 years old spruce forests: ■ - forests on dry mineral soils; □ - forests on wet mineral soils; ■ - forests on peat soils; ▨ - forests on drained mineral soils; ■ - forests on drained peat soils.

Some differences were rather obvious. For example, the percentage of forests on dry mineral soils was higher in private forests but the contrary was true for the forests on wet mineral soils. The total amount of forests on drained sites was rather similar both in state and private forests. To clarify if there is a relation between the site type and CMAI of spruce, one-way ANOVA was performed. No significant influence of the site type on the CMAI was found although in all site types this parameter was higher in the private forests, only in forests on peat soils the values referring to state and private forests were rather similar (Figure 5).

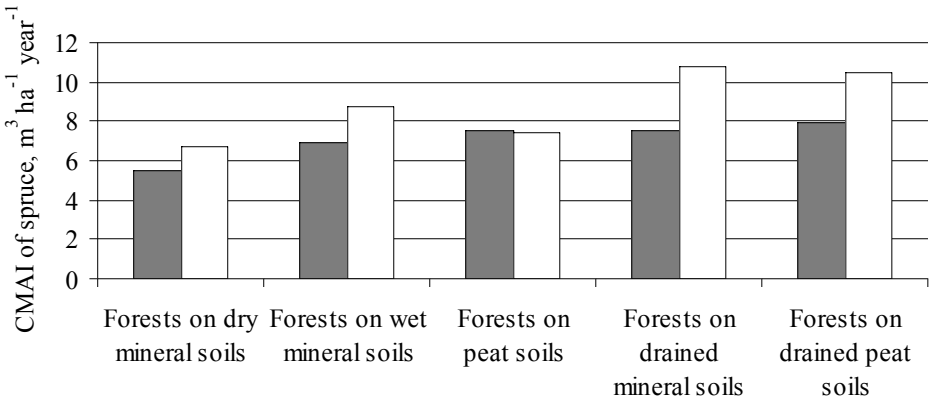

Figure 5. Current mean annual volume increment of spruce in 60-90 years old state and private forests on different site types: ■ - state forests; □ - private forests.

Evidently, private spruce stands retain a better growth rate in all site types except forests on peat soils. Another very interesting conclusion can be drawn from this graph: spruce stands of the age group including also stands of the felling age and older on average retain a growth rate above 5 m^3 ha^{-1} $year^{-1}$, in private drained forests even above 10 m^3 ha^{-1} $year^{-1}$. This aspect seemed worthwhile of a more thorough examination therefore mean values of CMAI in 80-90 years old spruce stands were calculated. The results were 5.5 m^3 ha^{-1} $year^{-1}$ in state forests and 9.0 m^3 ha^{-1} $year^{-1}$ in private forests. According to the legislation the felling age for spruce is 81 year. Consequently these are often still highly productive spruce stands that are cut down. On the other hand, unexplained loss of productivity in 30-50 years old spruce stands has recently been reported together with a suggestion to give up the rotation age as the only criterion for the final felling of spruce and build this decision rather upon the present productivity of the stand. (Zālītis un Lībiete, 2003; Zālītis un Lībiete, 2005; Libiete and Zalitis, 2007) The results obtained in the present study repeatedly support this point of view.

Another factor that could influence the differences of the CMAI of state and private spruce stands was the share of spruce in the dominant stand. All spruce stands were divided in mixed (the share of spruce 50-74% of the total standing volume of the dominant stand) and pure stands (the share of spruce 75-100% of the total standing volume of the dominant stand). The percentage of the mixed spruce stands was considerably larger in state forests than in private forests, 64% and 45%, respectively.

Next the CMAI in both mixture groups was compared. Both in state and in private forests its value was higher in pure stands (Figure 6).

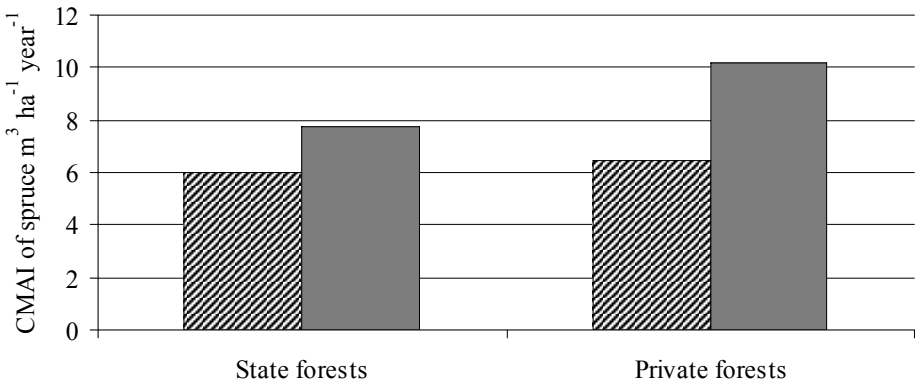

Figure 6. Comparison of current mean annual volume increment of spruce in state and private forests depending on the mixture degree:
▨ - mixed stands; ■ - pure stands.

Independent samples t-test was once again performed to test if the differences of the CMAI in mixed and pure spruce stands were significant. The results were affirmative: the tested productivity parameter depended strongly on the mixture degree both in state forests (p=0.014) and private forests (p=0.018). Accordingly an explanation for higher CMAI in private spruce stands compared to state-owned spruce stands had been found.

There is another possible explanation to the fact that private spruce stands grow better. Even though the official statistics of the State Forest Service report much less intense thinnings in the private forests than in those owned by the state this information is somewhat doubtful. Compared to state forests, private forests have certainly been more subject to illegal forestry operations which do not necessarily involve clearfelling. During the last decade some private spruce stands may have been heavily thinned far exceeding the allowed thinning intensity. The remaining few trees in such stand are now able to utilize the available light and nutrient resources most efficiently and thus strongly increase their current annual increment. Norway spruce is known to be a tree species which extremely fast adapts itself to favourable conditions (Zviedris, 1960). However, this is presently only an assumption; broader information and more research are needed to confirm it.

Conclusions

1. The age distribution of the spruce stands proved to be uneven; especially in the state forests the amount of 20-40 years old stands strongly exceeded that of the other age classes. The age structure also suggested that the regeneration rate of the private spruce forests has improved during the last decade.
2. The main characteristics of the state and private spruce stands were found to be very similar in both analyzed age groups. The only significant differences were detected in the mean diameter and current mean annual volume increment (CMAI) of spruce in 60-90 years old stands; in both cases values were higher in the private forests.
3. The site type distribution differed rather much between state and private forests; however, no significant influence of the site type on the CMAI was discovered.
4. The percentage of mixed spruce stands was considerably higher in state forests; the CMAI proved to depend significantly on the mixture degree. Accordingly the difference of the CMAI in state and private spruce forests could be explained by the higher proportion of pure stands in private forests.
5. It was discovered that both state and private spruce stands often retain a high growth rate after the rotation age is reached. Therefore we may suppose that many still highly productive spruce stands are clearcut according to existing regulations.
6. The productivity indicators (total standing volume of the dominant stand and current mean annual volume increment of the spruce of the dominant stand) did not differ significantly in 30-50 years old forests but in 60-90 years old forests only current mean annual volume increment of the spruce of the dominant stand differed significantly. Thus the zero hypothesis of the study could only partly be rejected.

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GREY ALDER (*ALNUS INCANA* (L.) MOENCH) STRUCTURE

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Abstract

Grey alder occupies 190.6 thousand ha or 6.8% of forests in Latvia. Stand structure has influence on its productivity and dynamics. Materials for the studies were collected in the period from 2005 to 2007. For the investigation 47, grey alder stands, representing various ages, site index and density conditions from Jelgava, Bauska, Ogre, Aizkraukle, Jēkabpils, Valmiera, Talsi and Krāslava regions were used. The majority of these stands have not been managed previously and have been originated from shoots. A total of 11 – 30 - year - old grey alder stands were investigated using a 6 - tree sample plot method. Trees were grouped in 2 cm diameter classes according to breast height diameter. Trees according to reduction numbers were grouped in natural diameter classes. In 11 – 15 - year - old stands trees were within 4 - 5 two centimeter diameter classes, in 16 - 30 – year - old stands – within 6 - 12 classes. The proportions of trees in smallest and largest diameter classes not exceed 1 - 3%. The distribution of grey alder trees in natural diameter classes in 2/3 of cases match up with theoretical Tjurin distribution, resemblance was not detected in cases, when there are large proportions of thin trees in stand. Cumulative percent values of the number of trees and stand volume are were not dependent on site index. Relationship between cumulated value of the number of trees (y) in percents and cumulated value of stand volume (x) was described by parabolic equation ($R^2 = 0.997$, $p < 0.05$). Fifty percent from stand volume were made up from 70% of thinnest trees. Regression equations describing dependence of tree height, height of live crown base, and length of crown from tree diameter were developed.

Key words: breast height diameter, height, number of trees, stand volume, crown.

Introduction

Climatic changes nowadays are hazardous for human society. As a result of human activity, concentration of greenhouse gasses in the atmosphere has been increasing and, consequently, warming up of the Earth surface and atmosphere is going on. In order to decrease concentration of greenhouse gasses, utilization of the biomass as renewable resource is recommended in heat production, replacing fossil fuels like coal and petroleum. CO_2 from burning process of biomass has a neutral effect on environment, which is considerably reducing the amount of hazardous emissions and their negative influence on atmosphere. The utilization of biomass in heating could be an environmentally friendly and economically efficient solution. Biomass of grey alder in future could be more widely used in heat energy production. Firewood, woodchip and wood processing wastes in a form of woodchips, pellets or briquettes is the most popular form of renewable fuel at the moment (Daugavietis, 2006).

Productivity of alder stands is influenced by nodules bacteria on the roots of a tree that are fixing nitrogen from the atmosphere. Nodules are characterized by a relatively high nitrogen concentration, but they accumulate well phosphorus too and to same extent also potassium, magnesium and iron. The presence of grey alder enriches the soil with nitrogen and phosphors; it is facilitated in the processs of symbiosis. Grey alder has a positive influence on total microbiological activity and diversity in soil. It is increasing the stock of phosphorus in soil in a form that plants can easily assimilate (Редько and Титов, 1986; Uri et al., 2002).

In the forests of temperate zone, grey alder is not a conflict-species, rather than soil enriching species. It is increasing the diversity of stands of commercially valuable tree species (Ingestad, 1987; Granhall and Verwijst, 1994; Arveby and Granhall, 1998). Grey alder has been used for soil improvement in Scots pine plantations in nutrient-poor, sandy soils. Falling leaves and decaying roots of grey alder

create additional amount of nutrients in soi, which produces favorable conditions for a productive growth of above mentioned species (Kärki, 1999; Johanson, 1999; Mauriņš and Zvirgzds, 2006).

The structure of forest stand influences its productivity and dynamics. In higher density stands trees have increased photosynthetic activity. Tree height overcomes several peaks and depression phases of increment. The first phase – steep increase of tree height increment starting after root layer closure in the stand. The second phase starts at crown closure point or slightly later. The mentioned height increase phases are followed by a period of depression period. The length of depression period is dependent on initial stand density: if the initial density is higher, depression period is longer. It shows that the height increment of trees is a wavy process (Кайрюкштис et al., 1988). An increasing stand density is followed by decrease in mean diameter and increase of proportion of suppressed trees (Юодвалькис and Баркаускас, 1988). The productivity of tree can be characterized by crown contact coefficient. With increasing crown contact coefficient the diameter increment of tree is decreasing (Атрохин and Стирбис; 1975).

This study is concentrated on the analysis of the structure of grey alder stands that are older than 10 years – age group that has not been included in P. Mūrnieks (1950, 1963) investigations carried out a half century ago in order to describe growth dynamics of grey alder in Latvia. The research results of the dynamics of tree number and diameter distribution in grey alder stands are covered in previous research paper (Miezīte and Dreimanis, 2007). The main emphasis of this paper is on the distribution of the number of trees in natural diameter classes (Sarma, 1948; Анучин, 1960).

The aim of the study: to characterize the structure of grey alder stand.

Research tasks:

- to investigate distribution of the number of trees and stand volume by diameter classes in grey alder stands;
- to investigate relationships between tree diameter and crown parameters of grey alder.

Materials and Methods

The investigation has been carried out in 47 grey alder stands in Jelgava, Bauska, Ogre, Aizkraukle, Jēkabpils, Valmiera, Talsu and Krāslava regions. The numbers of trees, their diameter and yield were obtained. The majority of stands used in the investigation was un-thinned and originated via sprouting.

Grey alder stands at the age of 11 - 30 years were investigated using a 6 - tree sample plot method (Kramer and Akča, 1982; Miezīte and Dreimanis, 2007). The diameter of trees was measured with precision of 0.1 cm and trees were grouped in 2 cm diameter classes. Trees according to reduction numbers have been grouped in natural diameter classes, denoted with decimal numbers. For example, trees with reduction number values in interval 0.46 – 0.55 were included in natural diameter class 0.5, but trees with reduction number values 0.96 – 1.05 - in diameter class 1.0 (Анучин, 1960). Reduction numbers used for investigation of grey alder diameter structure were calculated according to formula:

$$R_d = \frac{D}{D_g}, \text{ where} \quad (1)$$

D – breast height diameter of tree, cm;

D_g – average breast height diameter in stand, cm (Анучин, 1960).

Descriptive (inventory) parameters of grey alder stands were calculated according to methods described in monographs of Sarma (1948), Анучин (1960), Liepa (1996), and Kramer and Akča (1982).

For each stand, cumulative percentage values of the number of trees by diameter classes were calculated, starting with thinnest trees. With the help of graphics of cumulates, the proportion of number of trees corresponding to yield cumulate from 10 to 50%.

The length of crown of grey alder was calculated as a difference between the tree height and height to base of green crown.

The analysis of variance, regression and correlation has been performed using SPSS and MS Excel programs (Arhipova and Bāliņa, 2003). The resemblance between empirical data and theoretical (Tjurin) distribution was checked using chi-square test (Liepa, 1974).

Results and Discussion

Stand structure influences the position of trees in the stand, their crown development, height and

radial increment, stem volume, and yield. Stand yield is dependent on diameter distribution. High proportion of suppressed trees of 4th and 5th Kraft class is a sign of intensive differentiation, potential die-back of trees and decrease of stand productivity. Yield of dead tress can exceed the yield of live trees, and total stand yield can start to decrease. A large number of trees reduce growth speed of every particular tree, its green crown and increment. High proportion of thin trees is reducing productivity of the cutting work.

Distribution of the number of trees and yield in diameter classes

Distribution of the number of trees in diameter classes has a particular importance due to the following reasons. Firstly, conclusions can be drawn about equality of the size of trees and level of differentiation in a stand. Secondly, information can be used for modeling of different processes and as a support tool for management decisions. Grey alder stands so far have been rarely investigated and the lack of information about the mentioned aspects is considerable. In grey alder stands, in contrast to the other tree species, practically no thinning has been carried out and there follows the development of natural trend, without human intervention.

In praxis, to characterize the stands, trees are grouped in 2 or 4 cm diameter classes. Research results demonstrate that the distribution of number trees in diameter classes in every stand is individual. It is dependent on the position of trees in a stand, light conditions, used nutrient assimilation area, length of green crown of trees and other factors. Environmental factors primary influence radial increment.

In the youngest, 12 - 15 - year - old, stands, trees are within 4 - 5 two centimeter diameter classes. The thickest trees of a stand exceed the thinnest by 8 – 10 cm. In this age, the highest number of diameter classes is found in the stands with the highest average diameter. In marginal diameter classes, the number of trees can be just 1 - 3% from the total number of trees. In older, 16 - 30 - year - old, stands, trees can be grouped in 6 - 12 two centimeter diameter classes. It means that the differentiation of trees is continuing and diameter differences are increasing. From the 32 stands analyzed in this age group, trees can be grouped in 5 diameter classes only in 3 stands. In two stands there are trees in 12 diameter classes; in marginal classes the proportion of trees does not exceed 1 - 3% from total. Tight relationship was found between the average diameter of a stand (x) and the number of diameter classes (y), which can be described by linear regression equation: $y = 0.5009x + 1.5994$, coefficient of determination $R^2 = 0.63$ ($p < 0.05$). If average diameter of a stand exceeds 17 cm, trees can be grouped in 12 diameter classes. Connection between stand age and number of diameter classes can be described by regression equation $y = 0.2302x + 2.4599$ ($R^2 = 0.49$). The number of diameter classes is dependent more on stand average diameter than on age.

Trees according to their reduction numbers can be grouped in natural diameter classes (formula 1) that are denoted with decimal numbers. Distribution of trees in natural diameter classes is dependent on average diameter of stand. It creates an option to compare stands not depending on their age and average diameter. The studies of professor Tjurin show that in mature homogenous stand the thinnest trees are in natural diameter class 0.5, but the thickest in natural diameter class 1.7 (Анучин, 1960). Similar distribution of a number of trees has been found in stands of all tree species and ages. Sarma (1948), referring to previously mentioned investigations, points out, that in stands with average diameter lower than 25 cm, trees can be grouped in larger numbers of natural diameter classes in an interval from 0.4 to 2.0. Data about the distribution of trees in natural diameter classes in 21 - 30 –year - old stands are summarized in Table 1. In majority of 17 analyzed sample plots, the thinnest trees are in natural diameter class 0.4 - 0.6, but in 3 stands - also in diameter classes 0.2 - 0.3. The thickest trees are in diameter class 1.4 – 1.7, except in one stand. It can be concluded that diameter distribution in grey alder stands is shifted towards smaller diameter classes. Only in one stand tree diameter reduction numbers are in an interval from 0.24 to 1.99. Average percentage distribution of the number of trees in natural diameter classes in all 17 stands tightly correlates with theoretical distribution ($R^2 = 0.90$). The relationship is linear.

Distribution of the number of trees in diameter classes in 12 stands out of 17 is in accordance with theoretical (Sarma, 1948) distribution. Empirical chi-square value is lower than the theoretical one ($p < 0.05$). Deviation form theoretical distribution has been found in stands with large number of trees in low diameter classes (sample plots 06 - 16 and 06 - 08) and in stands with low proportion of

thick trees (sample plots 06 - 22, 06 – 09, and 06 - 23). It can be explained by marked differentiation of trees due to the growth resources, especially light. During the life-span of a stand, the distribution of trees in diameter classes is changing, because, if a tree diameter is increasing only by few millimeters, it already belongs to a different diameter class. Even in the natural diameter class 1.0, where stand average diameter is situated, the number of trees can differ several times. Most of trees are in natural diameter classes from 0.7 to 1.3.

Thinning intensity is characterized by proportion of the stand volume of fallen trees. In low intensity cuttings, where small yield of suppressed trees is felled, not prevented. Direct determination of stand volume, which must be cut, is not possible and additional calculations are necessary. It is much easier to mark certain numbers of trees that correspond to given cutting intensity.

Table 1

Distribution of the number of trees in natural diameter classes, in percent

Age	Site index[1]	D_g, cm [2]	Natural diameter classes											Chi-square
			... 0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6 ...	
24	1. A	16.0	9.5	8.9	15.5	8.9	16.7	21.1	9.4	3.9	3.9	1.7	0.5	13.67*
21	1.	12.2	9.6	8.3	13.3	17.8	13.9	19.4	7.2	3.3	3.6	1.8	1.8	10.56*
24	1.	8.1	22.8	11.1	6.1	10.6	12.2	8.9	8.3	8.9	4.4	5.0	1.7	28.75
25	1.	8.9	23.4	9.4	6.1	18.3	5.6	8.9	11.1	3.9	5.6	2.8	4.9	40.10
25	1.	13.1	9.5	7.8	13.9	17.2	16.1	17.2	8.3	2.2	3.9	2.2	1.7	12.53*
22	2.	10.9	3.9	12.8	10.6	19.5	18.9	13.9	15.6	0	2.8	2.0	0	23.86
25	2.	13.2	9.5	11.1	11.7	18.3	10.6	14.4	12.2	5.0	4.4	2.2	0.6	8.15*
26	1. A	14.6	7.3	8.3	13.3	12.2	26.1	9.4	13.3	5.0	3.4	1.7	0	19.03*
29	1. A	16.9	11.1	8.3	8.9	15.0	19.4	18.9	10.6	3.9	1.7	1.7	0.5	19.87*
30	1. A	18.0	1.2	8.3	13.3	20.0	21.1	19.4	11.7	5.0	0	0	0	31.67
30	1. A	18.6	5.0	12.2	17.8	9.4	22.2	12.2	9.4	6.1	1.7	2.8	1.2	11.56*
30	1. A	15.0	1.6	6.1	20.0	18.9	20.0	20.6	1.1	10.6	1.1	0	0	40.58
26	1.	13.5	10.0	8.3	15.6	9.4	20.0	12.2	11.1	10.6	1.1	0.6	1.1	21.49*
30	1.	14.3	6.6	5.6	17.8	15.0	18.9	15.6	11.1	7.8	0.5	1.1	0	16.41*
26	2.	12.3	7.2	9.4	12.2	21.7	15.0	19.4	4.4	3.9	3.3	2.3	1.2	15.11*
29	2.	12.6	5.3	9.2	15.9	21.4	16.4	13.0	7.2	7.2	2.4	1.1	0.9	8.24*
30	2.	13.2	18.7	11.0	7.3	14.7	10.0	9.6	13.2	5.9	4.1	5.0	0.5	19.90*
Theoretical value (Sarma, 1948)			5.6	12.1	15.4	15.7	15.0	11.7	8.7	6.1	3.9	2.1	2.0	-

** distribution of the number of trees in diameter classes fits to theoretical distribution*

[1] according to tabulated values by...../

[2] D_g - average breast height diameter in stand, cm

Analysis of distribution of the number of trees and stand volume in diameter classes allows to estimate their cumulated values (Fig.1).

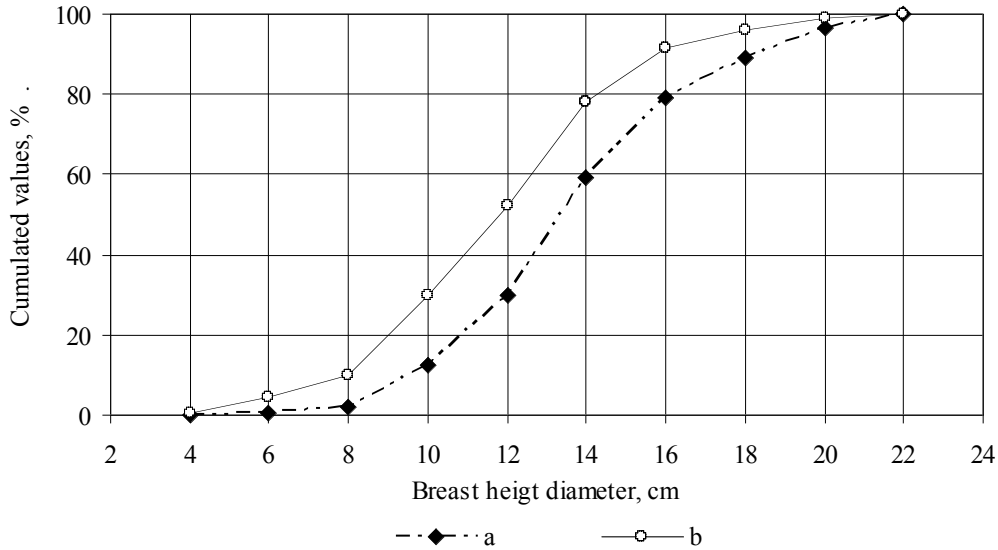

Fig. 1. Cumulated values of the number of trees and stand volume in sample plot 06 – 30: a – cumulate of stand volume, %; b – cumulate of tree number, %.

It has been found that in all stands the cumulated value of stand volume is smaller than cumulated value of the number of trees in corresponding diameter class. Cumulated value of stand volume 30% corresponds to the cumulated value of the number of trees - 53%. It means that 53% of the thinnest trees in stands build up 30% of stand volume. Connection between cumulated values has been found from the figures and summarized in Table 2.

Table 2

Cumulated values of the number of trees in percents

Statistical parameters	Cumulated values of stand volume, %				
	10	20	30	40	50
	Cumulated values of the number of trees, %				
Minimum	16	30	41	25	62
Maximum	31	45	58	67	76
Average	24.7	39.3	51.0	61.1	69.7
Standard deviation	3.48	3.79	3.98	3.33	2.88
Standard error	0.54	0.59	0.62	0.52	0.45
Coefficient of variation	14.1	9.6	7.8	5.5	4.1

Site index of a stand practically has no important influence on the correspondence between cumulated values of the number of trees and cumulated values of the stand volume. Differences between minimal and maximal values of the cumulated number of trees among site index 1a and 1 in most of the cases is in interval 8 - 15. In site index 2, stands differences are bigger in interval 12 - 17. In all site indexes, 10% of the stand volume are made up from 25% of the thinnest trees, but 20, 30, 40, and 50% of the stand volume are made up from 39, 51, 61, and 70% of the thinnest trees, respectively. From this it can be concluded that 50% of stand volume in a stand is formed from 70% of the thinnest trees. In average intensity thinning, aimed to cut 30% of the stands volume, half of the suppressed trees must be cut. The percentage of the cumulated number of trees (y) can be calculated from parabolic equation $y = -0.0069x^2 + +1.6521x + 3.2384$, depending on cumulated value of stand volume (x). Determination coefficient of equation $R^2 = 0.997$, $p < 0.05$. Cumulated stand volume 50% corresponds to 62 - 76% of thinnest trees of a stand. The highest coefficient of variation for the cumulated

number of trees in stands of the first and the second site index is 10% stand volume cumulated value and is in interval from 13.9 to 15.3%. With increasing cumulated value of stand volume, coefficient is decreasing. For the cumulated stand volume value 50%, it is 4.1% (Table 2).

Crown structure in grey alder stands

Green crown of tree determines wood increment (Ebert, 1994; Eberts, 1996). Larger crowns ensure higher increment and increase the value of a stand. Height to crown base in different grey alder stands is dependent on the diameter of tree. Height to live crown base is increasing with the increasing of tree diameter. The same is true also in relation to the length of the crown. Dependence of tree height on its diameter in grey alder stand can be described by parabolic equation: $y = -0.0138x^2 + 1.2161x + 2.3734$ ($R^2 = 0.91$). Height of live crown base (for trees in diameter 4 - 26 cm) can be calculated according to empirical parabolic equation: $y = -0.007x^2 + 0.6942x + +2.2467$ ($R^2 = 0.83$). For trees in a particular stand, the height of live crown base usually is in interval 2 – 3 m and differs little for the thickest and thinnest trees. Absolute and relative crown length is higher for the thickest trees in stand.

Parabolic equation, $y = -0.0068x^2 + 0.5218x + 0.1267$, stands for relationship between crown length and tree diameter. The coefficient of determination: $R^2 = 0.80$. It means that 80% from the total dispersion of tree crowns are determined by tree diameter. Connection between tree height, height to crown base, and length of crown is statistically significant ($p < 0.05$).

Conclusions

1. Empirical linear regression equations, describing dependence of the number of diameter classes on stand age an average diameter, have been found.
2. Cumulated values of the number of trees and stand volume are not dependent on site index of a stand.
3. Parabolic equation is describing length of grey alder green crown in connection with its diameter.

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ORGANIC FERTILIZERS AND WOOD ASH IMPACT ON GROWTH OF ENERGY CROPS IN PEAT – A LABORATORY STUDY

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Abstract

Willows (*Salix sp.*) and reed canary grass (*Phalaris arundinecea* L.) (RCG) are fast growing perennial energy crop and potential cultures for recovering of cutaway peat lands. Cut away peat land soils are characterized by high acidity (pH_{KCl} 2-3), high NH_4^{+1}, and lack of P and K. Wood ash could be good liming agent and resource of potassium. Waste water sewage sludge (WWSS) compost is effective fertilizer and source of phosphorus. The objective of the study was to investigate the effect of application of WWSS compost and wood ash fertilizers of different doses on ingrown of willow cuttings and RCG in potted cultures. The wood ash addition of 10 g l^{-1} and 20 g l^{-1} to WWSS compost mix with peat from used query in proportions 1:1 and 4:1 were tested. The length of shoots and dry mass of shoots and roots were assessed to determine the effect of fertilization on growth of crops. Chemical analyses of growing media were performed to determine the content of main nutrient elements and pH_{KCl} changes during season. The positive effect of fertilization on growth of crops was observed – an optimum dose for willows is (10 g l^{-1}) equivalent to 10 t_{DM} ha^{-1} wood ash with mix of WWSS compost with peat. RCG produces more biomass in growing media containing largest doses of wood ash and WWSS compost premix. The willows produced bigger amount of biomass and accumulated more nutrients from growing media than RCG.

Key words: peat, fertilization, willow, reed canary grass, organic fertilizer, wood ash, compost.

Introduction

In Latvia are available large amounts of waste water sewage sludge (WWSS) to be used as fertilizer for plantation forests according to EU Soil policy (LVA, 2007). Cut away peat lands with thick peat layer in Riga region belongs mainly to 'Rīgas meži'Ltd. Now areas are set-aside lands and municipality are looking for the best way to manage these areas. These studies are model of possible ways of ameliorating of such kind of areas. Willows and reed canary grass (*Phalaris arundinecea* L.) (RCG) are perennial crops with very short rotation period. It is possible to get biomass for energy from RCG in the first year, but maximum of yield is the second year. The next five years' yield is less or more stabile; only after every 7 years it is necessary to re-establish plantations. Yield of RCG is about 4 – 7 t_{DM} ha^{-1} of biomass. Willows have a three year harvesting cycle; average productivity should be at least 9 t_{DM} ha^{-1} (Ericsson et al., 2006).

Soils of peat lands are usually acid with good supplement of N, but there is a K and P deficit. WWSS contains P, but it is necessary to use minerals or wood ash for K supply and liming of soil in peat (Hytonen, 1998). Willows *(Salix sp.)* are adapted to wide growth conditions, but acid and wet soils with low aeration are less suitable for willows. Cut away peat lands with thick peat layer usually are too acid for willow cultivation (Hytonen, 1995; Hytonen, 1998; Tahvanainen and Rytkonen, 1999; Puttsepp 2004). Willows are adapted to neutral soils, for production of biomass, and a high supplement of phosphorus and potassium is necessary. Wet and nitrogen rich mires have developed a potassium deficiency that causes a growth reduction (Kaunisto, 1992).

Possibility of fast growing willows species to accumulate in biomass large amounts of nutrient elements (such as N, P and K) it 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 and for production of energy wood in addition too (Weih, 2004). Finland has large experience in establishing energy wood plantations and is most

competent in peat land afforestation (Hytonen, 1995; Hytonen and Wall, 1997; Tahvanainen and Rytkonen, 1999). In the late 1990's, nutrient recycling became current in Finnish forestry because of the requirements of the new environmental legislation and the new landfill directives (Moilanen et al., 2004). Use of WWSS 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 by recycling organic and mineral matter and improvement of soil chemical properties before cultivation of plantations, at the same time decreasing the established cost (Gemste and Vucans, 2006). In Poland, initiative of growing willow plantations comes from waste water sludge producers and managers. In Latvia these questions are still in the initial stage (Лаздиня и др.; 2006, Lazdiņa et al., 2007). In Poland, the main reason for WWSS use as the fertilizer in willow plantations is lower price of sludge compared to minerals (Komorowski et al., 2005). The effects of water soluble K and N fertilizers are faster but of shorter duration than those of P fertilization – only 10-20 years on nitrogen rich sites (Kaunisto, 1992). Wood ash is a good alternative to commercial P and K fertilizers in drained pine mires. Stand nutrient status and growth are enhanced over a longer period of time than with commercial P and K fertilizers (having phosphorus as raw phosphate and potassium as KCl) on both nitrogen rich and nitrogen poor sites (Moilanen et al., 2004). In Latvia, wood ash and WWSS are easy available and could compete with minerals. The year 2008 is the first year when owners of abandoned lands could get support for willows plantation establishing. The interest in WWSS and wood ash usage as fertilizer for fast growing woody crops comes from small municipalities of Latvia.

During the last ten years, suitability of wood ash for forest fertilization and cut away peatland reclamation has been studied in the Baltic States and Nordic countries. In Lithuania it was observed that a wood ash dose of 5.0 t ha^{-1} changed the chemistry of forest litter and increased pH, and total concentrations of most of the macronutrients were found after 2 years. In contrast, total N concentrations decreased due to ash application. Wood ash increased the number of ammonifying, denitrifying microorganisms and cellulose decomposers in the forest litter 3 months after application. Wood ash slightly reduced total length of fine roots and number of root tips 1 year after treatment. The highest degree of fine roots' vitality was found in the plots treated with highest doses of wood ash. No changes in ground vegetation diversity were found after the wood ash and N application (Ozolinčus et al., 2007). Like wood ash, small doses of WWSS 3-5 t_{DM} ha^{-1} are recommended in the present studies in Latvia and Lithuania, because, depending of treatment technology, the dry solids of sludge may contain 100-500 g kg^{-1} of nitrogen and 50-400 g kg^{-1} of phosphorus. The WWSS and compost may also be used as a fertilizer in tree nurseries and in green lining of towns and cities (Gradeckas et al., 1998; Kāposts et al., 2000).

Scientists of the Latvia State forest research institute 'Silava' have good experience of WWSS usage in afforestion of unfertile sites and dunes. Optimal ais application of 3-4 kg per planting spot directly on spot. Growth of trees increases by 30-60%, and application improves survival of trees (Kāposts et al., 2000). Colleagues from Lithuania have similar results that utilizing of sludge in cut away peat lands for growing forests on short rotation along with willows, deciduous trees and their hybrids is very perspective. The biomass productivity of the most perspective tree species in the fifth year of growth reached 12.9 t_{DM} h^{-1} and is not less than necessary biomass increment for willow plantations. Fertilization is necessary for improvement of peat soil, and the cheapest fertilizer is waste water sludge. Such kind of fertilizer contains heavy metals. Peat possesses bigger absorbing properties of heavy metals than mineral soils, and stops them from migration into deeper soil layer and ground water (Gradeckas et al., 1998).

Composts of WWSS contain less heavy metals and has less hygienic risk. Composting is one of the oldest solid waste treatment methods, and the principles of composting process is well known. From the environmental point of view, it is not a good policy to transport biodegradable material from one site to another for storage. To minimize the generation of waste, it is necessary to study composting as solution to recycle organic and mineral nutrient elements (Veijalainen et al., 2007).

The objective of the study is to investigate the effect of application of WWSS compost and wood ash fertilizers of different doses on ingrown of willow cuttings and RCG in potted cultures and changes in the content of main nutrient elements and pH_{KCl} in growing media during vegetation season.

Materials and Methods

In current paper, the impact of different doses of waste water sewage sludge (WWSS) compost mix with peat and wood ash on fast growing willow (*(Salix schwerinii x S. viminalis) x S. viminalis*) clone *Torhild* and reed canary grass (*Phalaris arundinecea* L.) (RCG) biomass production and substrate chemical properties changes of the main nutrient elements N, P and K during the vegetation season had been studied. Different substrates were mixed from wood ash (pH_{KCl} 12) from a small boiler house and WWSS compost (N 16 g kg^{-1}; P 205 g kg^{-1}, and K 61 g kg^{-1}) taken from 'Meliorators J'Ltd. blend with peat from cut away peat land were made.

Seven different substrate variants were tested during the vegetation season of 2006 and 2007. The experiment was done in potted culture with 3 l of substrate. Four - 20 cm long - cuttings of *Torhild* were planted in each pot, in total 60 cuttings in 15 pots for each variant. In six pots for each variant, 20 seeds of RCG were sown, in total 120 seeds for all variants (10 kg ha^{-1}). Peat (T) from cut away peat land - turbary -was mixed with WWSS compost (Ko) in proportions 4:1 and 1:1, and then wood ash (A) was added in doses equivalent to 10 t_{DM} ha^{-1} or 20 t_{DM} ha^{-1} (Table 2).

Table 1

Substrate mixes of potted cultures (willow clone Torhild and RCG)

T	T4Ko1	T4Ko1A10	T4Ko1A20
Control peat	four portions a peat with one portion of compost	four portions a peat with one portion of compost with wood ash (10 g l^{-1}) equivalent to 10 t_{DM} ha^{-1}	four portions a peat with one portion of compost with wood ash (10 g l^{-1}) equivalent to 20 t_{DM} ha^{-1}
	T1Ko1	T1Ko1A10	T1Ko1A20
	peat and compost in equivalent doses	peat and compost in equivalent doses with wood ash (10 g l^{-1}) equivalent to 10 t_{DM} ha^{-1}	peat and compost in equivalent doses with wood ash (10 g l^{-1}) equivalent to 20 t_{DM} ha^{-1}

The experiment was carried out in Olaine nursery.

Substrate samples were collected in May before establishing and in September after finishing of the experiment in 2006 and 2007. Chemical analyses of N, P, K, and pH_{KCl} were done in Latvia State forest research institute 'Silava' Soil laboratory. Soil acidity (pH_{KCl}) was tested according to LVS ISO 10390. In the laboratory, substrate samples were dried (< 40 °C), milled and sieved through 2 mm sieve according to LVS ISO 11464 standard. Sieved samples were mixed for testing of chemical properties.

In dried samples were tested: ammonium form of nitrate $N\text{-}NH_4$ by colorimetric method with Nesler reagent in 0.1 n NaCl extract (Pāvule, 1978; LVS ISO/TS 14256-1); plant nutrient elements phosphorus (P) by colorimetric method in 0.2 n HCl solution (Manual IIIa, 2003); and potassium (K) by Atomic Absorption Spectrometer in CH_3COONa solution (An Analyst User Manual CD, 2004) .

Growth of willow clone *Torhild* was characterized by the height increment and dry matter of shoots and roots during the vegetation season every two weeks and in the end of vegetation season. Dry mass of RCG was determined at the end of vegetation season. Sprouts and roots were dried till constant mass in 100°C in thermostat and then weighted.

Means were compared for significant difference at 0.05 level. The survey was done in October of 2006 and 2007. Data statistical analysis T-test, one way ANOVA, and correlation analysis were done by software SPSS. Data statistical analysis by Kolmogorov-Smirnov test approved the normality of data distribution.

Results and Discussion

The previous experiments hadshowed that limiting factor for willows and reed canary grass (*Phalaris arundinecea* L.) (RCG) in cut away peat areas are soil acidity and lack of potassium and phosphorus (Lazdina et al., 2007). It was observed that large doses of wood ash neutralize peat acidity as well as enriche it with nutrient elements, wood ash application significantly increases soil extractable phosphorus, potassium, calcium, and magnesium concentrations (Park et al., 2005). In current laboratory study, both wood ash applications stimulated growth of perennial fast growing energy crops, and addition of compost had positive effect too.

The addition of WWSS compost to substrate had lees effect on pH value than combination of wood ashes and compost. During vegetation season, acidity of substrate without addition of wood ash slowly decreased, especially in top layer of substrate. Wood ash addition significantly decreased acidity of substrates. Wood ash premix stabilized pH value of substrate, which could be the effect of ash buffer trait (Figure 1).

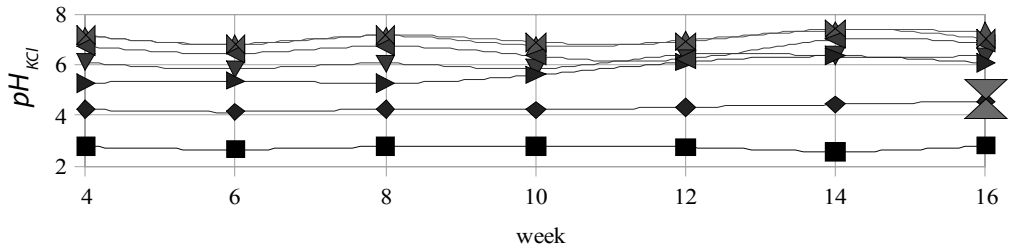

Figure 1. Changes in pH_{KCl} of substrate:

T; T4Ko1; T4Ko1A10; T4Ko1A20; T1Ko1; T1Ko1A10; T1Ko1A20; T top.

WWSS compost premix neutralizes peat till optimum pH for most of Latvia's deciduous tree species, including willows. Premix of wood ash equivalent 20 t_{DM} ha^{-1} had alkaline effect on all substrates. The mix of composts and peat in similar proportion with premix of ash equivalent 10 t_{DM} ha^{-1} had a similar effect (Figure 1). Studies of other scientists show that wood ash applications in *Salix purpurea* 3 - year - old plantations significantly increased soil pH in the 0-10-cm soil layer from 6.1 in the control to 6.9 and 7.1 in the 10 and 20 t ha^{-1} treated plots (Park et al., 2005), like in our experiment.

RCG produced more biomass in pots with enriched substrate, above - ground biomass production did not correlate with higher doses of wood ash and addition of WWSS composts. It was observed that correlations between wood ash addition and decreasing of root dry mass were the same as in woody crop experiments (Figures 2 and 3).

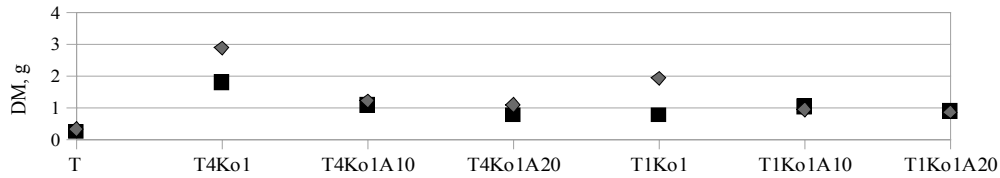

Figure 2. Dry mass (DM) development of RCG at the end of vegetation season:

above ground DM g; root DM g.

Roots of willow clone *Torhild* cuttings planted in peat (control) were allocated only in top layer of substrate. In the top of control substrate, pH_{KCl} achieved almost 5, which is more optimal for root development. In alkaline substrates (wood ash - 20 t_{DM} ha^{-1}), a lot of roots were allocated in the bottom of pot. Lithuanian scientists have found that wood ash reduces total length of fine roots and number of root tips 1 year after treatment in pine stands (Ozolinčius et al., 2007). We found similar tendency in root developing of willow cuttings with wood ash additive in some variants. A gregter effect of wood ash premix on willow clone Torhild shoot growth than on root development was obserwed (Figure 3).

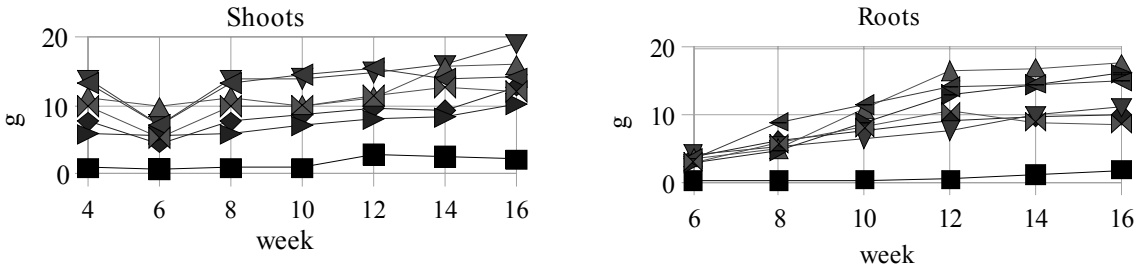

Figure 3. Dry mass (DM) development of willow clone Torhild shoots and roots during vegetation season:

T; T4Ko1; T4Ko1A10; T4Ko1A20; T1Ko1; T1Ko1A10; T1Ko1A20.

WWSS composts and wood ash during vegetation season stimulated growth of willows, but differences were significant only between control and other variants. Faster growth of willow shoots was observed in substrates with wood ash addition (Figure 4). Figure 4 demonstrates mean data of shoot growth during season. Irregularity of trends could be explained by withering and rushing up of sprouts during summer.

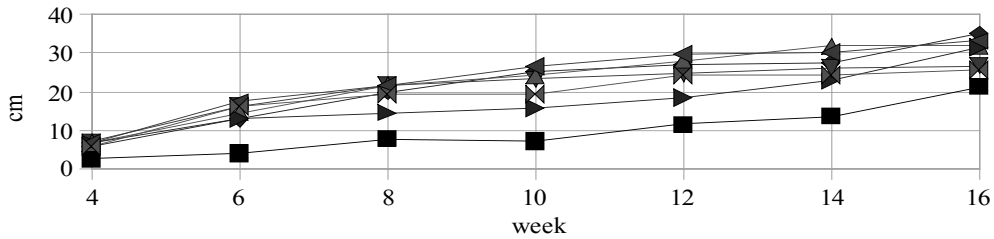

Figure 4. Average height of willow sprouts during the vegetation season:

T; T4Ko1; T4Ko1A10; T4Ko1A20; T1Ko1; T1Ko1A10; T1Ko1A20.

At the end of vegetation season, there significant differences in sprout count from cutting among different variants (P<0.001) were observed but not among sprout height(Figure 5). Production of more sprouts from willow cuttings in substrates with wood ash premix explain why more biomass were produced in such growth conditions. Willow clone *Torhild* had only one sprout from cutting in most cases of the control variant, but addition of WWSS compost lead to increase of sprout count from 2 to 3, which is optimal for energy crop cultivation. Average sprout count increased when wood ash was added - in these variants each cutting produced 4 or more sprouts. An opposite effect has been found by other scientists in the experiment with wood ash fertilizing in USA; increase of size of stems of *Salix purpurea;* however this effect was balanced by a decrease in the number of stems (Park et al., 2005). Willows in field conditions had tendency to produce larger amount of sprouts on alkaline soils, substrates with wood ash premix were more alkaline, and willow cuttings produced more sprouts, like in field conditions.

Significant correlations between willow sprouting and content of phosphorus, potassium, and peat acidity (Table 2) were observed, but no correlations were found between shoot height and substrate chemical properties.

Table 2

Willow shoots growth, substrate pH and macronutrients Pearson correlations (N=255)

	Height, cm	Number of sprouts	InitiallN, g kg^{-1}	InitiallyP, g kg^{-1}	InitiallyK, g kg^{-1}	Initially pH $_{KCl}$	Final N, g kg^{-1}	Final P, g kg^{-1}	Final K, g kg^{-1}	Final pH$_{KCl}$
Height cm	1.000	-0.086	-0.058	0.079	-0.010	0.016	0.000	0.091	0.008	0.035
Number of sprouts	-0.086	1.000	-0.344**	0.578**	-0.030	0.591**	0.011	0.512**	-0.571**	0.587**
Initially N, g kg^{-1}	-0.058	-0.344**	1.000	-0.652**	0.756**	-0.186**	0.236**	-0.471**	0.590**	-0.290**
Initially P, g kg^{-1}	0.079	0.578**	-0.652**	1.000	-0.295**	0.562**	-0.214**	0.971**	-0.407**	0.678**
Initially K, g kg^{-1}	-0.010	-0.030	0.756**	-0.295**	1.000	0.066	0.509**	-0.134*	0.222**	-0.002
Initially pH $_{KCl}$	0.016	0.591**	-0.186**	0.562**	0.066	1.000	0.327**	0.570**	-0.354**	0.975**
Final N, g kg^{-1}	0.000	0.011	0.236**	-0.214**	0.509**	0.327**	1.000	-0.204**	0.217**	0.339**
Final P, g kg^{-1}	0.091	0.512**	-0.471**	0.971**	-0.134*	0.570**	-0.204**	1.000	-0.275**	0.679**
Final K, g kg^{-1}	0.008	-0.571**	0.590**	-0.407**	0.222**	-0.354**	0.217**	-0.275**	1.000	-0.285**
Final pH$_{KCl}$	0.035	0.587**	-0.290**	0.678**	-0.002	0.975**	0.339**	0.679**	-0.285**	1.000

* Correlation is significant at the 0.05 level (2-tailed). ** Correlation is significant at the 0.01 level (2-tailed).

Sprouting of cuttings had negative correlation with potassium in substrates at autumn, and rushing of sprouts lead to decreasing of potassium in substrates. There were observed Negative correlations between nitrogen and phosphorus content in substrates were observed in spring.

Substrates were mainly enriched with phosphorus with WWSS and wood ash addition. Positive correlations of phosphorus and soil alkalinity could be explained by presence of element in ash and compost.

At the end of vegetation season, significant changes in nitrogen, and phosphorus content in substrates (P<0.001) as well as in proportions of N, P and K (Figure 5), especially in top layer of peat (control), were observed.

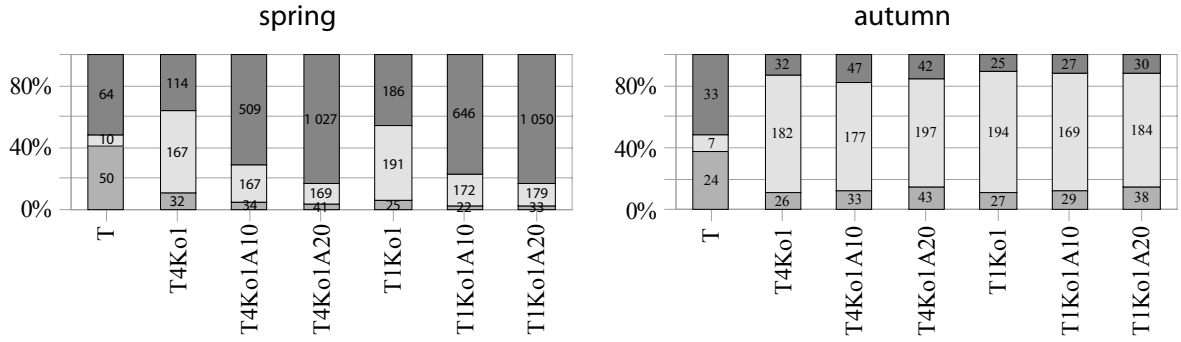

Figure 5. Macronutrient (N, P and K) content and proportion changes during the vegetation season:

N g kg^{-1}; P g kg^{-1}; K g kg^{-1}.

Plants had been uptaken nutrients for biomass production, especially nitrogen. In some substrates, potassium content in autumn was observed higher than in spring. Tendency o plants to accumulate nutrients in roots before the cold season to reach higher cold resistance and presence of necrotic tissues of roots in substrates could explain higher concentration of potassium in some substrate samples.

Above - ground biomass of willow shoots and substrate phosphorus concentration showed positive correlation, RCG above - ground dry mass correlated with substrate acidity, but root dry mass - with amount of phosphorus (Table 3).

Table 3

Willow and RCG biomass accumulation and substrate properties Pearson correlations

	Above - ground biomass, $_{DM}$ g	Root, $_{DM}$ g	N, g kg^{-1}	P, g kg^{-1}	K, g kg^{-1}	pH_{KCl}	Compost addition	Wood ash addition
Willow clone Torhild								
Above ground biomass, $_{DM}$ g	1.000	0.284	-0.453	0.783*	-0.687	0.751	0.399	0.741
Root , $_{DM}$g	0.284	1.000	-0.346	0.531	-0.208	0.402	0.517	0.198
RCG								
Above - ground biomass, $_{DM}$ g	1.000	0.243	-0.445	0.659	-0.696	0.796*	0.697	0.730
Root, $_{DM}$ g	0.243	1.000	-0.606	0.799*	-0.434	0.685	0.610	0.334
* Correlation is significant at the 0.05 level (2-tailed)								

Despite the well known fact that potassium is the element most affected by wood ash treatment at all soil depths (Park et al., 2005; Ozolinčus et al., 2007), no significant effect of this element was observed. Wood ash and composts are sources of phosphorus - this could be one of the reasons why we observed higher biomass production in substrates where combination of both fertilizers was used. In Finnish research papers, wood ash is mentioned as one of cheapest and most effective sources of phosphorus for long term effect (Hytonen, 1998; Hytonen, 2003; Moilanen et al., 2004). Results of the research allow drawing up a conclusion that WWSS composts and wood ash application and digging into soils of cut away peat lands could be good solution of waste management and biomass production for green energy.

Conclusions

1. Soils from abundant peat cutaway areas are too acid for cultivation of perennial crops - willows and reed canary grass.
2. Addition of WWSS compost to peat in similar proportions decreased soil acidity for 1 – 2 units. Addition of wood ash (doses equivalent to 10 - 20 t_{DM} ha^{-1}) decreased substrate acidity for 3 – 4 units.
3. WWSS composts, wood ash and peat mix are suitable substrate for growing of willows and RCG. In cutaway peat areas, WWSS composts and wood ash must be ploughed into soil. Surface fertilizing is ineffective.
4. Wood ash and WWSS compost different proportions show significantly different effect on willows shoots and roots development and production of RCG biomass.
5. The best combination was the mix of peat with WWSS compost in similar doses and 10 g l^{-1} (equivalent to 10 t_{DM} ha^{-1}) of wood ash, but production of RCG biomass was significantly stimulated by 20 g l^{-1} (equivalent to 20 t_{DM} ha^{-1}) of wood ash.
6. The content of phosphorus correlated with RCG root biomass, willow shoot height and biomass, but substrate acidity correlated with RCG browse biomass.

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STRUCTURE AND ECOLOGY OF ASH FOREST COMMUNITIES *PRUNO-FRAXINETUM* IN LATVIA

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Abstract

The vegetation of *Pruno-Fraxinetum* plant communities was described in 2004 – 2005 according to the Braun-Blanquet method throughout Latvia, in forests where common ash *(Fraxinus excelsior L.)* are dominant species in tree layer on moist soils. Classification of relevés (in total 52) by two way indicator species analysis (TWINSPAN) resulted in two variants of this association: typical variant (*typicum*) and variant with *Filipendula ulmaria*. Ellenberg indicator values were used to find out the relationship of flora with climatic (light, temperature, continentality) and edaphic (soil reaction, nitrogen, moisture) factors. Canonical correspondent analysis (CCA) was used to find out differences between two variants of *Pruno-Fraxinetum.* Results of this research have shown that these forests have complicated structure (form four vegetation layers, high species richness), which mainly depends on moist, rich eutrophic soils, usually with presence of limes. Main differential soil factors in ecological analysis are gradients of soil richness: moisture and nitrogen regimes. The influence of other factors was less expressed. Due to the human influence, especially drainage, the moist ash forests are decreasing and the species composition is changed. As *Pruno-Fraxinetum* forests in Latvia lie on the northern border of its distribution, the species composition differs from forests in the rest Europe; species characteristic determined by floodplain forests in Central Europe are absent.

Key words: *Pruno-Fraxinetum*, species composition, Ellenberg indicator values, Latvia.

Introduction

As in most of Central and Northern Europe, substantial change in forest cover has taken place in Latvia. Under the influence of economic activities (clearings for crop fields, trade and manufacturing), forests of Latvia, including deciduous forest, were destroyed at the end of the eighteenth century (Sarma, 1959; Priedītis, 1999). Currently they already are part of cultural landscape (Gläser, 2001) and natural vegetation there is relatively rare, except in some bunches of trees between fields (Tabaka, 2001).

Pruno-Fraxinetum is moist ash-alder forests association that is characteristic for many regions of the lowlands of Central Europe. Usually these forests are located on moist sites with high seasonal variable groundwater level (Oberdorfer, 1953). Not as much they could be found in flooding valleys of rivers and on the spring rich slopes of mountains (Wallnöfer et al., 1993). A range of *Pruno-Fraxinetum* communities of local occurrence were described in many countries of Europe: Germany (Härdtle, 1995; Passarge and Hofmann, 1968; Dierschke et al., 1987), Austria (Wallnöfer et al., 1993), and Netherlands (Maas, 1959). In the Great Britain and Scandinavia the forests of this association are different and are named as *Alnus-Fraxinus-Lysimachia* in British islands (Rodwell, 1991), *and Fraxinus excelsior-Anemone nemorosa* and *Alnus glutinosa-Ulmus glabra* communities in Denmark (Lawesson, 2000).

Several authors have pointed out in recent studies that the existence of many populations of woodland species nowadays is highly dependent on broad-leaved forests remnants (Härdtle et al., 2003). Therefore, lowland moist forests are characterized by high richness in the herbaceous plants and moss species.

In Latvia, *Pruno-Fraxinetum* communities mostly are typically for plains. Not always their location is related to alluvial lands or slopes rich in springs. In greater areas they are typical for Zemgale Plain. In Zemgale Plain which is well known as region with rich soils (different types of soils containing carbonates) presence of *Fraxinus excelsior, Quercus robur* and *Padus avium* is observed in almost all forest types.

It explains in essence the localization of *Pruno-Fraxinetum* plant communities widely described in Europe in this region. Only few communities of this association might be found in other regions of Latvia, where unlike in Zemgale Plain, they occupy river alluvial lands and lowlands between slopes of hills.

The main purpose within the framework of this study was characterization of structure and species composition of ash forest communities *Pruno-Fraxinetum,* as well as determination of the main factors causing differences in species composition among both variants.

Materials and Methods

The research was based on moist ash woodlands investigations carried out throughout Latvia during 2004 – 2005. Localities of vegetation relevés were selected considering the main distribution areas of ash forests in Latvia where phytosociological relevés representing *Pruno-Fraxinetum* plant communities were taken as basic material. Overall, 52 relevés on 9 localities and in six nature regions of Latvia (Fig.1) were described; most of them in Rietumzemgale in the main region of distribution of ash forests (parish of Zaļenieki – Saulītes and Degu forests, parish of Bukaiši, parish of Dobele-Lejasstrazdi, parish of Rundāle-Vecrundāle, Mazbērstele), and only six relevés in other nature regions.

All phytosociological investigations followed the Braun-Blanquet approach (Dierschke, 1994; Pakalne and Znotiņa, 1992), and cover-abundance of all species in four vegetation layers (E3 – trees, E2 – shrubs and undergrowth, E1 – herbs and dwarf shrubs, tree seedlings and shrubs, E0 – mosses on soil) was estimated in a percentage scale 0-100%. For each plot an area of 400 m^2 (20x20m) was chosen.

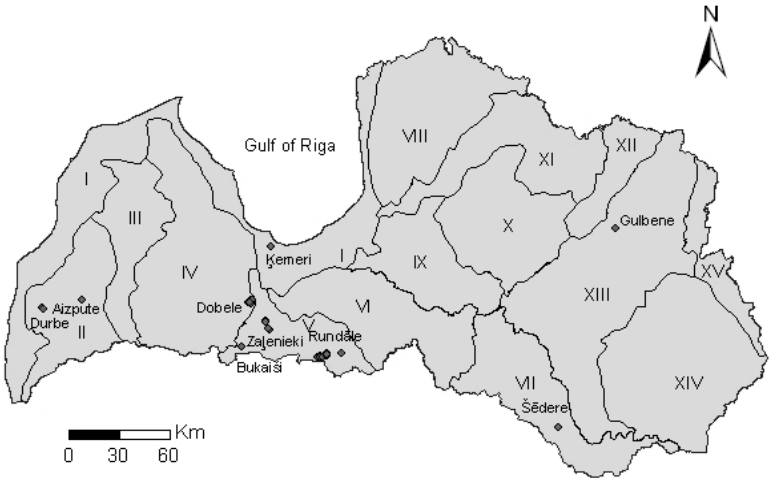

Figure 1. Investigated localities with Pruno-Fraxinetum plant communities.

Nature regions (by Ramans, 1994): I – Piejūra; II – Rietumkursa; III – Venta zeme; IV – Austrumkursa; V – Rietumzemgale; VI – Austrumzemgale; VII – Augšzeme; VIII – Ziemeļvidzeme; IX – Dienvidvidzeme; X – Vidzemes augstiene; XI – Gaujas zeme; XII - Austrumvidzeme; XIII - Aiviekstes zeme; XIV – Latgales augstiene; XV – Austrumlatgale.

The data base was created in TURBO(VEG) (Hennekens, 1995). All data of *Pruno-Fraxinetum* communities was classified by species composition using two way indicator species analysis TWINSPAN (Hill, 1979). Considering the amount of species, mean Ellenberg indicator values for plant communities were calculated.

Ecological diversity (gradients) for *Pruno-Fraxinetum* plant communities was analysed using a canonical correspondence analysis (CCA) with software Pcord 4 (McCune and Mefford, 1999). Calculated Ellenberg indicator values were used to interpret ecological gradients connected with ordination axes.

The nomenclature: Gavrilova and Šulcs for vascular plants (Gavrilova and Šulcs, 1999), and Āboliņa for mosses (Āboliņa, 2001).

Results and Discussion

Classification of plant communities of Pruno-Fraxinetum

In Latvia, *Pruno-Fraxinetum* plant communities of floodplain forests *Alno – Ulmion* occupy lowlands that are rich in nutrients and mostly loamy soils with good hydrological regime. The largest areas with typical representatives of these communities are in the Zemgale Plain (Rietumzemgale). Just some of this phytocenosis occurred in the Rietumkursa Upland, Piejūra Lowland, Augšzeme Upland, and Aiviekste Land. Therefore all described phytocenoses of ash are similar, which is confirmed also by classification TWINSPAN. As a result of classification, only two variants were determined: variant *typicum* (40 relevés) on moist and fertile soils, and variant *Filipendula ulmaria* (12 relevés) on more moist soils (Fig. 2).

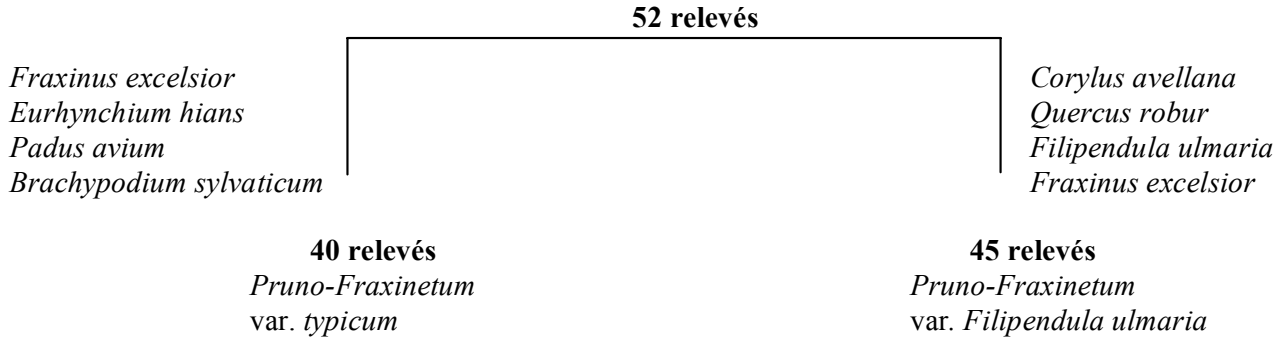

Figure 2. Two-way indicator species analysis results of the TWINSPAN classification.

Structure of vegetation

Table 1 gives an overview on the composition of species in both variants of *Pruno-Fraxinetum*. The total number of native tree species of *Pruno-Fraxinetum* plant communities is 11. In both variants of the composition, the dominant species are *Fraxinus excelsior* (Table 1). In variant *Filipendula ulmaria,* in addition to ash also *Quercus robur* and *Populus tremula* are formed, but only in one relevé *Ulmus laevis*, *Alnus glutinosa,* and species of boreal forests *Picea abies* were identified.

The amount of other species which is typical for other deciduous forests is non-significant. *Fraxinus excelsior* and *Quercus robur* have rather high presence also in shrub and herb layer, which indicates good natural regeneration of these two species (Table 1). Unlike *Pruno-Fraxinetum* forest plant communities in the Central Europe, in Latvia, as mentioned above, characteristic species of these forests *Alnus glutinos* - is missing. In the Northern direction, *Alnus glutinosa* is replaced by *Alnus incana*, which is leading within this association (Rodwell and Dring, 2001). The absence of *Alnus glutinosa* is also related to the drainage in the arable land (Lawesson, 2000), as a result of which the groundwater level is declined and several moist-loving species disappear in adjacent forest phytocenosis.

The shrub layer alike the tree layer in these phytocenosis is irregularly developed (Table 2). If in a typical variant bush layer is well developed, then in *Filipendula ulmaria* variant it is scarce. Almost always *Padus avium* ranges in both variants: in the typical variant – 100%, but in variant with *Filipendula ulmaria* 75% of all relevés. Less common there are *Sorbus aucuparia* and *Corylus avellana,* as well as *Euonymus europaea* which is typical for Zemgale plain. If the variants are taken separately, besides ash and bird-cherry, *Quercus robur*.

Table 1

Species composition and richness of moist ash forests (*Pruno-Fraxinetum*)

Variants		I*	II*
Number of relevés		40	12
Mean number of species in relevé		26	31
Trees			
Fraxinus excelsior	E3	100	100
	E2	65	92
	E1	65	33
Quercus robur	E3	3	58
	E2	63	50
	E1	28	50
Alnus incana	E3	3	17
	E2	13	33
Populus tremula	E3	8	33
	E2	15	42
	E1	0	8
Betula pendula	E3	3	17
	E2	5	8

Variants		I*	II*
Number of relevés		40	12
Mean number of species in relevé		26	31
D_I			
Padus avium	E2	100	75
Campanula trachelium	E1	43	8
Stachys sylvatica	E1	80	33
Brachypodium sylvaticum	E1	90	42
Humulus lupulus	E2	40	8
Glechoma hederacea	E1	33	8
Fissidens taxifolius	E0	38	0
D_{II}			
Filipendula ulmaria	E1	58	100
Geum rivale	E1	48	75
Deschampsia caespitosa	E1	35	75
Rubus idaeus	E1	10	58
Athyrium filix-femina	E1	0	25
Impatiens noli-tangere	E1	0	17
Festuca gigantea	E1	8	25
Calamagrostis canescens	E1	0	25

Number of relevés		40	12
Mean number of species in relevé		26	31
Other species			
Rubus caesius	E1	93	92
Carex sylvatica	E1	93	83
Aegopodium podagraria	E1	88	50
Paris quadrifolia	E1	70	67
Lysimachia nummularia	E1	50	75
Sorbus aucuparia	E2	43	75
Euonymus europaea	E2	40	25
Veronica chamaedrys	E1	40	42
Ranunculus cassubicus	E1	38	67
Viola riviniana	E1	38	50
Malus sylvestris	E2	35	42
Scrophularia nodosa	E1	33	25
Corylus avellana	E2	30	75
Melica nutans	E1	0	17
Juncus effusus	E1	0	17
Neottia nidu-avis	E1	0	17
Carex elongata	E1	0	17
Vicia sepium	E1	5	42
Ranunculus repens	E1	5	17
Equisetum pratense	E1	3	25
Ranunculus acris	E1	3	8
Carex remota	E1	0	17
Crepis paludosa	E1	30	42
Rhamnus cathartica	E2	28	0
Variants		I*	II*
Poa nemoralis	E1	25	67

Number of relevés		40	12
Mean number of species in relevé		26	31
Other species			
Frangula alnus	E2	13	17
Primula veris	E1	13	33
Maianthemum bifolium	E1	13	42
Taraxacum officinale	E1	13	8
Polygonatum multiflorum	E1	10	17
Galeobdolon luteum	E1	10	17
Ribes spicatum	E2	10	0
Cerastium holosteoides	E1	10	0
Epilobium hirsutum	E1	10	0
Oxalis acetosella	E1	10	25
Mycelis muralis	E1	10	17
Myosotis palustris	E1	10	0
Fragaria vesca	E1	8	50
Viburnum opulus	E2	8	8
Geum urbanum	E1	8	8
Elymus caninus	E1	8	17
Epilobium montanum	E1	8	8
Hypericum maculatum	E1	8	17
Dactylis glomerata	E1	8	25
Platanthera chlorantha	E1	5	17
Dryopteris carthusiana	E1	5	25
Lysimachia vulgaris	E1	5	25
Cirsium palustre	E1	5	8
Galium palustre	E1	5	33
Variants		I*	II*
Mosses:			

Cirsium oleraceum	E1	25	17
Asarum europaeum	E1	23	25
Valeriana officinalis	E1	23	0
Crataegus curvisepala	E2	23	25
Mercurialis perennis	E1	23	0
Grossularia reclinata	E2	18	0
Galeopsis bifida	E1	18	0
Moehringia trinervia	E1	18	8
Angelica sylvestris	E1	18	17
Ribes nigrum	E2	15	33
Hypericum hirsutum	E1	15	17
Urtica dioica	E1	15	33
Anemone nemorosa	E1	15	25
Dryopteris filix-mas	E1	13	8
Viola mirabilis	E1	13	25

Plagiomnium undulatum	E0	90	66.7
Eurhynchium hians	E0	93	83
Eurhynchium angustierete	E0	65	67
Cirriphyllum piliferum	E0	43	25
Rhytidiadelphus triquetrus	E0	18	25
Thuidium tamariscinum	E0	15	25
Brachythecium rutabulum	E0	10	16.7
Thuidium philibertii	E0	8	8
Calliergonella cuspidata	E0	8	8
Plagiochila porelloides	E0	5	8
Ctenidium molluscum	E0	3	8
Plagiomnium affine	E0	3	8
Atrichum undulatum	E0	0	33
Plagiomnium ellipticum	E0	0	17
Rhizomnium punctatum	E0	0	17

There are not included sporadic species. E1 –tree layer; E2 – shrub layer; E1 – herb layer, E0- moss layer. Definition of frequency (%) according to Dierschke (1994):
** I - var. typicum; II - var. Filipendula ulmaria.*

Euonymus europaea and *Humulus lupulus* are well differentiated in the bush layer of typical variant, but species of class *Querco-Fagetea* and order *Fagetalia*, such as *Corylus avellana*, *Quercus robur,* and *Malus sylvestris,* as well as species widely distributed in all Europe, touch as *Sorbus aucuparia*, *Populus tremula,* and *Ribes nigrum,* with high occurrence in the variant *Filipendula ulmaria* are met.

In understory of both phytocenose also basiphiluos species that need nitrogen rich and carbonate containing soils grow – *Rubus caesius, Aegopodium podagraria*, *Paris quadrifolia*, *Stachys sylvatica*, *Campanula trachelium*, and *Mercurialis perennis* (typical variant), as well as moisture-loving species – *Filipendula ulmaria*, *Geum rivale, Crepis paludosa, Calamagrostis canescens, Deschampsia caespitosa* etc. (variant with *Filipendula ulmaria*). Differences between both variants are mainly in richness and diversity of species. In the second *Pruno-Fraxinetum* variant, higher species richness in one relevé – on average 35 species (Table 2) – is met. Also higher richness of hygrophytes might be observed there.

Table 2

Mean projective cover (%) and number of species of *Pruno-Fraxinetum*

Factor/ Variant	I*	II*
Cover of tree layer, %	67	37
Cover of shrub layer, %	63	40
Cover of herb layer, %	61	80
Cover of moss layer, %	74	37
Mean number of species in relevé	26	35
Total number of species	127	119

** I – var. typicum, II – var. Filipendula ulmaria*

Upon evaluation of the floristic composition of moister *Pruno-Fraxinetum* variant, it is obvious that it includes not only species typical for forest, but also many species that are typical for moist and wet meadows (*Geum rivale, Filipendula ulmaria, Crepis paludosa, Calamagrostis canescens, Lysmiachia vulgaris*) (Ābele, 1969; Härdtle et al., 2003).

When comparing both variants, moss layer is better developed in typical variant (74%) where most dominant species are *Plagiomnium undulatum* (90%), *Eurhynchium hians* (93%), and *E. angustierete* (65%), but relatively frequently also *Cirriphyllum piliferum* (38%). In the second variant, projective cover of moss is almost two times less (33%), though more species, are here. Without above mentioned species in this variant relatively frequently such species as *Atrichum undulatum* (33%), *Thuidium tamarascinum* (25%), and *Rhytidiadelphus triquetrus* (25%) are found.

From the species composition in general it might be concluded that there is less species richness in Latvia's *Pruno-Fraxinetum* forests than in Central Europe.

Ecology

Environmental factors are described by Ellenberg indicator values (Ellenberg et al., 1992). The values of analysed ecological factors in both described *Pruno-Fraxinetum* variants in most cases differ little (Table 3). In general, plant communities are located on nutrients rich, neutral, with nitrogen deep soils, where mostly partly shade loving, oceanic and suboceanic species grow.

Table 3

Ellenberg indicator values for the variants of the association *Pruno-Fraxinetum*

Variant	Light	Temperature	Continentality	Moisture	Reaction	Nitrogen
var. typicum	5.08	4.69	3.89	6.02	6.87	6.44
var. Filipendula ulmaria	5.36	4.76	4.22	6.49	6.69	5.9

When analysing relevés by CCA, correlation axis shows main environmental factors according to calculated Ellenberg values. Plant communities of association *Pruno-Fraxinetum* mainly correlate with gradients of soil moisture and nitrogen content (Tables 3 and 4). The first axis represents a gradient for nitrogen, but the third - for soil moisture. Other environmental factors have relatively small influence on the gradient of species richness and distribution of relevés in ordination space (Table 4). Therefore, it might be concluded that the species richness in a separate relevé increases in proportion with the increase of moisture and nitrogen content in soils.

Table 4

Intra-set correlation of six Ellenberg indicator values with canonical correspondence analysis (CCA) axis 1-3

Variable	Axis 1	Axis 2	Axis 3
1 L - light	0.283	0.346	0.026
2 T - temperature	0.323	0.199	0.091
3 K - continality	0.350	0.025	-0.181
4 M - moisture	0.354	0.014	0.597
5 R - reaction	0.045	-.366	0.204
6 N - nitrogen	-0.605	-0.03	0.064

The higher is amount of moisture and nitrogen in soils, the higher is species richness in plant communities. By ordination one can also see that both relevés of variants of *Pruno-Fraxinetum* little overlap each other, which indicates that the moister variant could be contact community between variant *typicum* of *Pruno-Fraxinetum* and ash-alder forest community *Carici remotae-Fraxinetum* belonging to wetlands (Priedītis, 1999).

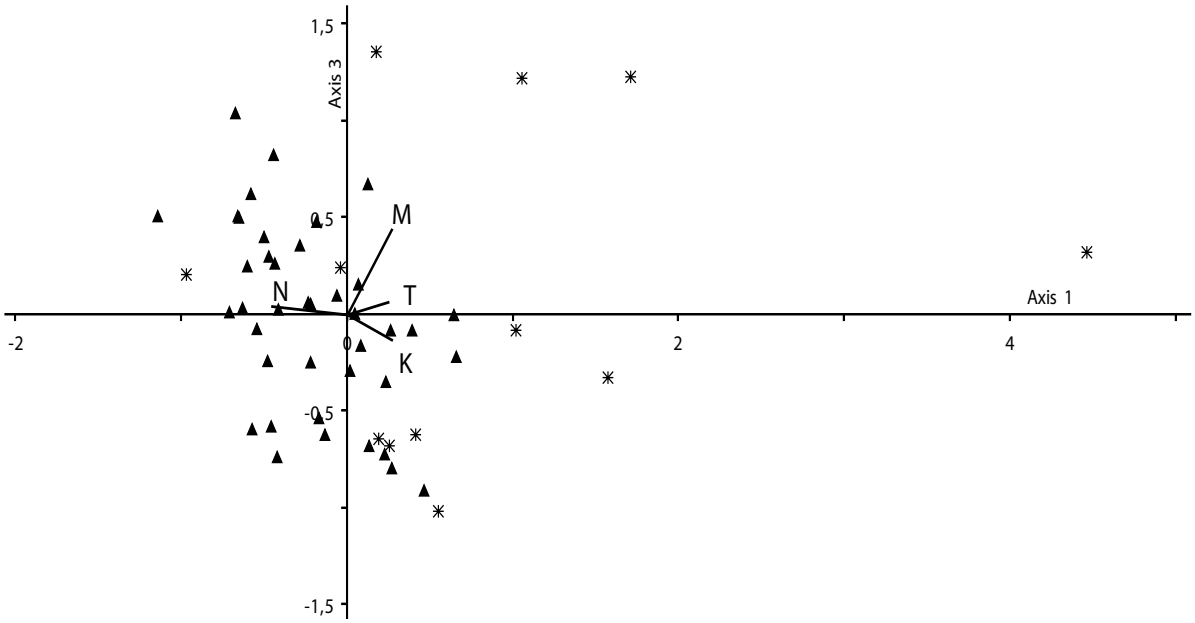

Figure 3. CCA ordination of Pruno-Fraxinetum communities (M – Ellenberg moisture value, L – light value, R - soil reaction value, T - temperature value, N - nitrogen value):
▲ – var. typicum; ✳ - var. Filipendula ulmaria.

Conclusion

In the analysis of *Pruno-Fraxinetum* communities there exists direct connection between vegetation structure and environmental factors. Both Ellenberg indicator values, and ordination with canonical correspondence analysis (CCA) point to that. Considering the fact that *Pruno-Fraxinetum* communities mostly are located in Zemgale Plain where ash forests occupy fragmented and small areas between arable lands, it can be said that these phytocenose are under anthropogenic influence. It could be the reason why typical species for association *Pruno-Fraxinetum* are missing there and why there is not as high species richness as elsewhere in these phytocenose of Europe.

In Latvia, moist ash forests are located on the northern border of ash forests distribution area. This factor also has influence onthe species composition of these forests. Comparing with similar ash forest plant communities in Central Europe, species with wide ecological amplitude, for instance, *Ranunculus cassubicus, and Sorbus aucuparia*, appear in *Pruno-Fraxinetum* communities of Latvia, but black alder (*Alnus glutinosa*) is replaced by grey alder (*Alnus incana*).

Acknowledgements

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OPTIMIZATION OF HARVESTING SITES MAXIMAL PURCASE VALUE CALCULATION
I. USE OF FOREST INVENTORY DATA

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Abstract

In forest harvesting process, a logging company and a forest landowner who have various goals concerning forest stands purchase value are involved. The logging company wants to maximize the profit on lower price, but forest landowner - to extract maximum income. Calculating the forest stands value prior to harvesting it is possible to achieve mutually acceptable price. This article describes question statement and primary research of prior calculated and harvested volume difference for further study of forest stands purchase value algorithm optimization. Harvested volume from feed-back data and prior calculated forest stands volume were compared to obtain the difference and understand the economical importance for optimization of harvesting sites maximal value calculation algorithm. For primary study, forest stands prior harvesting calculation model from the logging company was used. Results from prior harvesting calculations were compared with data after harvesting to achieve information about the precision of calculation model. Obtained results showed significant difference between prior calculated and harvested volumes, which in financial matter cause losses to the logging company. Compared to total harvested volume, negative cutting difference was 7% from volume, which in financial terms with annual harvesting of 1 million m^3 make loss of ~2.3 million €.

Key words: forest stands value, harvesting, algorithm optimization.

Introduction

Development of information and communication technologies has been causing the establishment of new markets that require change within all economic sectors. In addition, globalization has been resulting in new supply as well as selling markets. Even the markets for wood and forest products have been changing tremendously from a seller's market structure into buyer's market structure within which international competitiveness is an essential factor of success (Heinimann, 2000). A forest industry company, which buys the forest for further processing in round wood and delivery till final end user, the main factor for renlarg its competitiveness and increases factor of success are the costs. These companies mainly are customer oriented which means that before buying and processing the forest, they already know customers specification of raw material (species, length, diameter and quality repayments) and the price which they are willing to pay for delivered material.

Competitiveness and success of such companies depend on how good they evaluate the forest – volume outcome, costs of harvesting, forwarding and delivery, and earnings from sold raw materials. Logging companies behave like any company in any other sector; i.e., tries to maximize its profit (Kivinen, 2007). This means that the price for forest stand should be as low as possible.

Forest landowner, on the other hand, usually wants to extract the maximum income from his/her forest resource (Kivinen, 2007). For this reason before buying the forest it is important to calculate the maximal value of the forest stand which would be proportionate to pay, so that the logging company works with profit and forest landowner receives relevant income from his forest.

By calculating the optimal price it is possible to predict approximate expenses that will be related to this forest sites harvesting, forwarding and transportation depending on costumers which have different prices and needs concerning the types and characteristics of round wood they are willing to buy.

The main objective of the study is to improve algorithm of forest stands maximal values calculation by integrating prospective forest operation and delivery, as well as indirect costs and prospective revenues from sold round materials.

This calculation involves forest inventory (Glossary of Forestry Terms, 2008) data which describes the location and character of forest cover including tree size, age, and volume and species composition. However, in the real world, data used in the analysis often come from forest inventories that are opened to errors (Arce et al., 2002). Therefore for in the end of operational work, feed-back from the harvested stand should be done about the volumes and costs which occurred in operational process for reduction of errors from forest inventory and improvement of the algorithm.

Material for study was used from forest inventory and a Latvian logging company, which every day work is connected with buying of forest stands from landowners. The company has developed forest stands optimal values calculation prior to harvesting for internal use - this calculation was used as a basis. For the study, forest inventory data from mature coniferous, broadleaf and mixed forest was used. Forest inventory data consist of stands characteristics area, total volume, forwarding distance, volume differencing by species and diameter classes. In order to optimize forest stands optimal value, a research is needed in the connection of harvester and forwarder, transportation costs depending on wood assortment and location of a forest stand. The study can be divided in four mutually supportive researches:

1) Customer - required assortments, price and location;
2) Costs of harvesting, forwarding and transporting by assortments;
3) Forest inventory data;
4) Optimization of maximal price algorithm.

Customer required assortments, price and location.

Global forest market works like any other market in any other sector, but the most important thing is how the forest market, and companies in it, is organized in individual countries. There are several different ways how the forest market is organized; mainly it depends on forestry traditions and laws.

Forestry laws and traditions determine the methods of selling/buying forest lands and standing timber. For better understanding of the way how the tree bucking is done and why there is a need for forest stands maximal values calculation, there should be made existing forest lands and standing timber selling/buying model.

Whether the bucking process takes place in the forest or at mill yard, and whether it is done manually or mechanically, the key question remains the same: what log types (i.e., timber assortments), lengths, diameters, grades (qualities) and other attributes should a tree stem be cut into? The answer to this question can be regarded as one of the most important decisions in timber harvesting and in the whole wood supply chain from forest to final customer/consumer product (Usenius, 1986).

The model would help to understand positions of forest landowners, logging companies and product end users in the wood supply chain and their interconnection in formation of round wood assortments and their price in Latvia. This model will be made from the perspective 'from end customer to forest', because properties of the round wood to a large extent determine what end products and quantities can be produced from stem and thus the value of the stem (see, e.g., Fobes, 1960, Smith et al., 1961), since the end users know what kind of product they want to get, they are the best estimators what kind of properties should have the round wood.

Cost of harvesting, forwarding and transporting by assortments.

Stand size, stand density, volumetric shares of each wood assortment and mean distance from site to the road side, distance from harvesting site to the mills (Uusitalo, 2008) influence costs of harvesting, forwarding and transporting of round wood assortments.

Productivity of cut-to-length (CTL) system depends on the forest stand, site and operational factors such as ground conditions, slope, operators motivation and skill, branch size, operational layout, tree size, tree form, log assortments processed, numbers of unmerchantable and merchantable trees per unit area, hauling distance, undergrowth density and machine design (Brunberg et al., 1989; Spinelli et al., 2002; Stampfer, 1999; Makkonen, 1991; Richardson, 1989). Harvesting productivity is closely related to the tree size and stand characteristics (Bulley, 1999).

The logging company provides study with data of already calculated costs of harvesting and

forwarding by assortments to their used machinery types. Transporting costs of the assortments are directly connected to the location of end user and forest stand. The logging company provides research with data of 1 m^3 assortments transporting costs, which will change depending on end users and stand location.

Forest stands inventory data.

The logging company prior to buying the forest land or standing timber as any other company evaluates the offered product. It can be done in two ways: providing their own forest inventory or using already existing seller's inventory. Private forest landowners mainly are using inventory principle of 'Latvian state forest'.

Logging companies are buying large amount of forest stands and they don't have enough capacity to make inventory in every offered forest stand. To evaluate these stands from the perspective of potential round wood assortment outcome, dependant expenses and incomes and price which would be proportionate to pay for it, there is the need for using forest inventory data.

Based on the long time experience, logging companies for internal use has made forest stands evaluation model which is based on forest inventory data for estimation of potential round wood assortment outcome in terms of volume in m^3. For better understanding of forest inventory use for estimation of potential round wood assortment outcome, there should be done more extended study of 'Latvian state forest' provided forest inventory data and logging companies used forest stands evaluation model.

Optimization of maximal price algorithm.

Forest stands optimal values calculation prior to harvesting which will be used as a basis for optimization of maximal price algorithm contains large amount of data which should be examined. Initially, control of the input data (forest inventory) and costs calculation of harvesting, forwarding as well as transport should be made. For checking the data, feed-back data from harvester computer system, end user invoice of delivered assortments and total economical report of specific forest stands will be used. Comparing prior harvesting calculation with feed-back data it would be possible to recognize the weak point in optimal values calculation and make further research to obtain maximal price algorithm.

This article describes question statement of the whole planned study and for demonstrating the importance of the study this article presents part of primary research from above-mentioned *Forest stands inventory data*.

Materials and Methods

To obtain primary mutual relations, prior calculated and harvested round wood volume outcome were compared. From the logging company, data of accidentally selected 40 with harvester cut forest stands were collected. The data consist of information of prior harvesting forest stands value calculation and total economical report (feed-back data) of each stand after harvesting.

Prior harvesting forest stands value calculation has been done based on forest stands inventory data provided from 'Latvian state forest'. This inventory data consist of information about area, total volume, mean stem, forwarding distance, volume differencing by species and diameter classes.

Diameter classes in forest inventory are divided as large, medium, thin timber, and firewood. Large timber for pine and spruce starts from 14 cm, medium – 10 cm, thin – 6 cm, firewood – 3 cm at DBH (diameter at breast height); accordingly for birch and alder it is 18, 12, 6 and 3 cm at DBH.

Feed-back data consist of information about volumes in the stand, volumes differencing by assortments and end users, as well as information on harvesting profitability. Forest stands harvesting feed-back data were used to calculate harvested volume in each stand.

Harvested volume from feed-back data and prior calculated forest stands volume were compared to obtain the difference and understand the economical importance for optimization of harvesting sites maximal value calculation algorithm. All data were filtered using MS Excel program.

Results and Discussion

For the research, 40 forest stands were used. They were compared to get general overview of the difference between prior calculated harvesting volume and volume calculated from feed-back data. The total harvested volume of 40 stands from feed-

back data was 36 000 m³. The difference between total prior calculated and total harvested volume was on average 4%, which makes 1600 m³ (Fig. 1). Average volume on one forest stand is 40 m³, which doesn't make a significant influence on each stands value, but is important on total value.

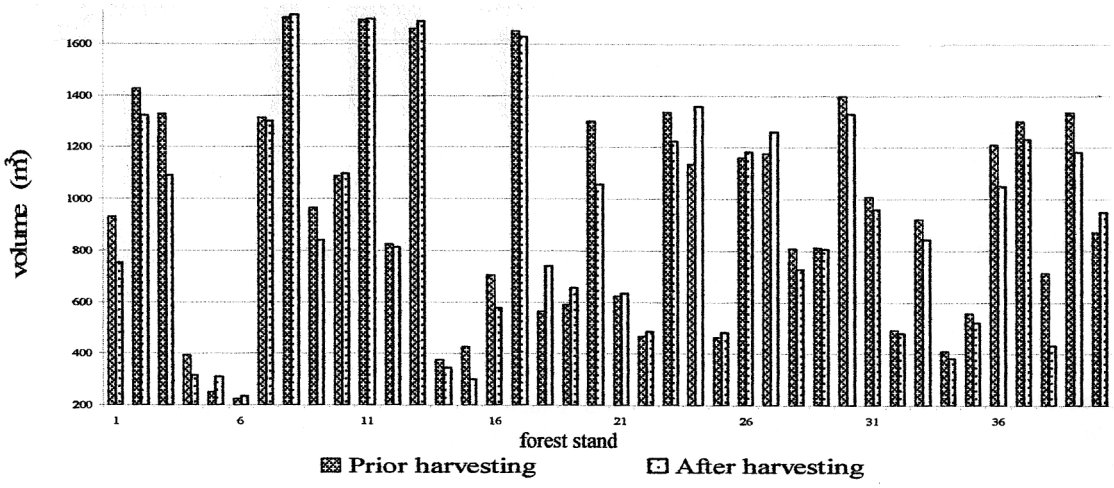

Figure 1. Difference between prior calculated and real harvesting volume outcome.

Data of prior calculated and harvested volume comparison was sorted by the type of cutting difference – negative or positive. Negative – when prior calculated volume is higher than real harvested volume, and positive - when real harvested volume is higher than prior calculated volume.

From 40 forest stands, 25 stands or 63% were with the negative relation to the real harvested volume, which resulted in difference of 7% or 2400 m³ from total harvested volume (Fig. 2). Converting it in terms of money on each separate forest stand, it doesn't make essential influence, but as the total harvesting volumes reach several thousands or millions of m³ it should be considered as significant profit loss.

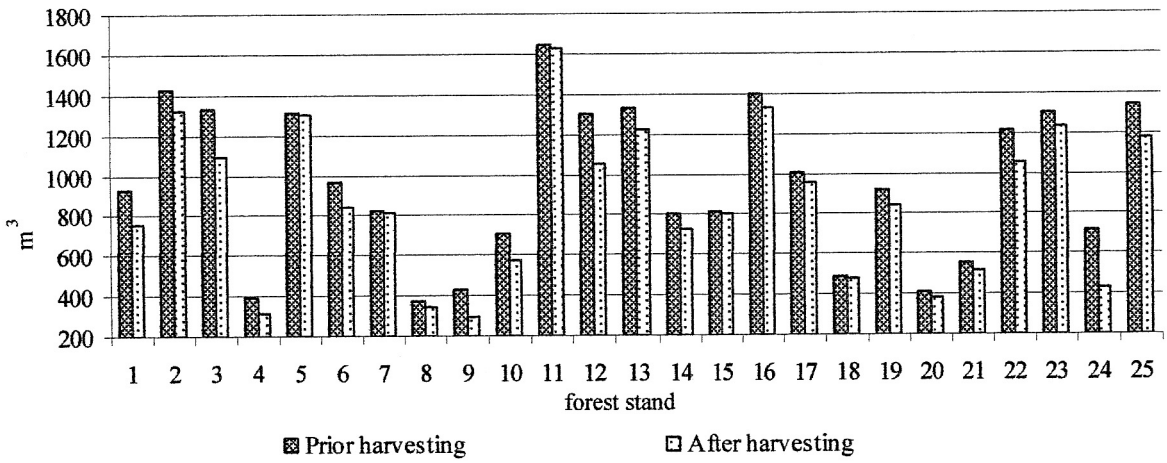

Figure 2. Difference between prior calculated and harvested volume.

Assuming that annual production volume of a logging company is 1 million m³, the difference of 7% results in 70 000 m³. In financial terms if the mean market price of round wood is 23.58 LVL m⁻³ (Latvijas valsts meži, 2008), then converting to Euro 33.55 € m⁻³ (Latvijas Banka, 2008) harvesting volume calculation difference of 7% results in the loss of ~ 2,3 million €.

The difference of 7 % between prior calculated and feed-back data could be influenced by the

factor that data of forest stands for primal analyses were used undivided by treatments – clear-cut or thinning. Data analysis by separate treatments could give interpretation of prior calculated and feed-back data difference. To insure that results from selected data are referable there is a need to increase the amount of investigated forest stands. Data of harvested volume in each forest stand should be supplemented with more expanded information of stands characteristics to analyse reason of difference between prior calculated and feed-back data.

Further studies might include analyses of species composition in a forest stand and assortment result in prior calculated and feed-back data to establish their influence on calculated and harvested volumes.

Conclusions

Comparing data from 40 forest stands total calculated volume prior to harvesting and harvested volume was with 4% difference, which makes on average 40 m^3 difference on one stand. This would not be considered as animportant difference, but on big harvesting volumes it gives significant profit loss.

From all 40 forest stands used for the study, 63% were with negative cutting difference by comparing the harvested volumes, which means that the real harvested volumes in these stands were lower than prior calculated volume. If these forest stands were bought based on prior volume calculation, the price of the stands were higher than profit.

Compared to total harvested volume, the negative cutting difference was 7% from the volume, which in financial terms with annual harvesting of 1 million m^3 makes loss of ~2,3 million €.

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THE ENERGY WOOD RESOURCE AVAILABILITY FROM COMMERCIAL THINNINGS IN LATVIA

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Abstract

The article presents the part of PhD studies of the energy wood harvesting technologies in thinning, and its development possibilities. A possibility for energy wood procurement and use in Latvia as a good amount of not used energy, including estimation of how much wood for energy purposes could be available in Latvia is analyzed.

Research has been made in two parts using forest stands cutting area in three different ages to get an average volume of energy wood per ha. First part of the research has been done in a 60 years old forest stand cutting area in the way that total chips volume is measured and then recalculated to the thinning area. The average volume from studied forest stand was 20.32 m^3 ha^{-1}.

The second part of the study shows that from a 30 – 45 years old forest stands cutting area by the measuring possible removal tress, the energy wood volume could be 23.74 – 33.5 m^3 ha^{-1}. Including the slash from this forest stands cutting area the possible volume of wood for energy purposes could be ~ 33 – 47 m^3 ha^{-1}.

The calculations also have been done to study available energy wood resources from whole forest stands thinning area. Totally the available energy wood volume in Latvian conditions is 0.85 million m^3 yr^{-1}.

Key words: thinning, harvesting, energy wood.

Introduction

Forests are Latvia's main renewable resource. This is clear if one looks at how much of Latvia's land is afforested provisional data from a statistical inventory show that forestland and former agricultural land which now satisfies the identification criteria for a forest cover of 3.6 million hectares or 55.9% of the national territory (Forest Sector in Latvia 2007, 2007). The amount of cut timber in Latvia has been stable over the last five years between 10 and 12 million m^3 of timber annually. In 2007, the amount was 12.82 million m^3, from which 5.75 million m^3 in state owned forests, and 7.07 million m^3 in other owner forests (Valsts meža dienests, 2008).

The clear cutting volume makes approximately 79% and thinning 20% (Saliņš, 2002) from the total volume, which results in 10.3 million m^3 from clear cut and 2.69 million m^3 from thinning. This is the present state of situation - the result of influence from the Soviet Union time in Latvia, which could be explained by two factors. First factor – when Latvia was a part of the Soviet Union, forests were planted in higher density than now, second factor – in the private forest, in last 15 years there has been a lack of thinning activities, because of a very low or no profit, which makes the harvesting of thinning as uninteresting activity for the private forest landowner.

Nowadays the situation has rapidly changed. Energy wood thinning has become a feasible treatment of young and dense stands. There is a statement from EU that most of energy must be produced from renewable recourses and in year 2010 it must reach 49.3% (Enerģētikas attīstības pamatnostādnes, 2007).

The clear cuts are most common type of harvesting - the main emphasis of energy wood extraction has been made on this type of harvesting. To make a clear cut, the forest should grow for almost 80 to 100 years (coniferous forests). During this time several thinning operations are made and harvested volume which is undervalued as potential energy resource. There are investigated several factors which make harvesting of energy wood in thinning interesting to private forest landowners. Energy chips collected from thinning are with

higher heat capacity than from clear-cut. A higher fire risk can occur if the small trees from thinning are note collected and carried away from the stand (Graudums, 2006).

As the question is stated about the practical possibilities of energy wood harvesting, several methods and machines have been developed over the past 20 years. Several methods have been developed for a particular situation but there is no method that is suitable for all circumstances (Kaufman, 2006).

The objective of the study is to find the most cost efficient energy wood harvesting technology using regular harvesting machinery. The study is divided in three mutually subordinate researches:

1. Estimation of energy wood volume available from thinning (that is shown in this paper);
2. Comparison of available techniques and technologies for Latvian conditions taking in to account the most common technique in Scandinavian countries;
3. Recommendation for efficient energy wood harvesting technique under Latvian conditions.

The research will be made in cooperation with second largest harvesting company in Latvia and the Latvian state forestry research institute 'Silava'.

Materials and Methods

The study was made in four different thinning stands in central part of Latvia - Vidusdaugava forest district (section 4, 5, 6) and Riga forest district (section 138). The research, only area with commercial thinning was used, because there are more possibilities to work with machinery. The age of stands was set from 30 – 60 years. Normally the first commercial thinning is done by the age of 30 – 50 years (Lazdāns, 2007), but in many cases variation is 30 – 70 years. Also the tree species composition was set as mixed coniferous stands with some amount of broad leaves, mainly birch (*Betula pendula*, *Betula pubescens*). The forest growth condition and ground condition was taken in to consideration. That show the energy wood collection availability, what could be 66 % from all forest area (Silava, 2007). The total thinning study area was 100.5 ha.

Two measuring methods were used. The first research was carried out in a way that the energy wood volume was measured after collecting and chipping the wood, but for the second study - by establishing a number of sample plots already after mechanized thinning. In the sample plots, trees which were cut manually and were not suitable for commercial wood (pulpwood) were counted. The volume was estimated after measurements and calculations.

The first research was made in the spring of the year 2007, in two 60 years old stands, where the cutting was done manually. The research was made in such a way because there are a very few situations when harvesting companies collect energy wood from thinning, and that was the opportunity to get real energy wood volumes in such structure and age of stands. In the stand, the dominant species was pine (*Pinus silvestris*) and spruce (*Picea abies*), undergrowth was spruce, birch and some species of broadleaved bushes.

Total area of study was 44.9 ha (Stand 1) and 24.5 ha (Stand 2). The area contained several separate harvesting sites. Forest inventory data indicate that before commercial thinning, pre-commercial thinning was made in the bought stands. The total round wood assortment volume from Stand 1 was 1561.7 m^3 and from Stand 2 - 872.2 m^3.

During harvesting strip roads were established in both stands and undergrowth was cut. In all stands slash was collected - branches, tops of trees and undergrowth. Afterwards the assortments were forwarded; slash was carried away and piled in large stacks. During three month slash was drying and after chipped.

At the end of the year 2007 and at the beginning of 2008, second research was made in two stands of the age of 30 – 40 years. In both stands the dominant specie was pine with mix of birch and undergrowth of spruce. The size of 30 – 35 years old stand was 20 ha (Stand 3), and size of 35 – 40 years old stand – 10.1 ha (Stand 4); the area contained several separate harvesting sites. The total harvested round wood assortment volume from Stand 3 was 1208.5 m^3 and from Stand 4 580.7 m^3. The forest inventory data show that there was no pre-commercial thinning made before this harvesting. All the trees in the stands were cut using machinery, but before the harvesting all undergrowth were cut manually and left on the ground. The sample plots in the stands were made in between strip roads of size 18 X 10 m. The distance between sample plots was 30 m (Figure 1).

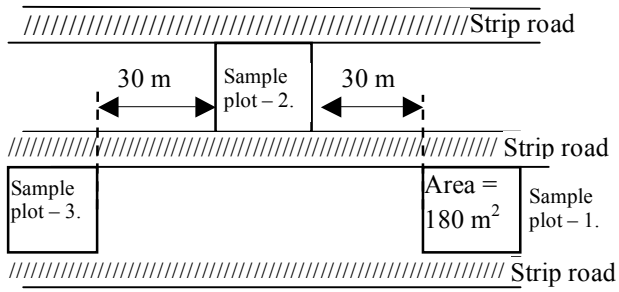

Figure 1. Location of the sample plots for energy wood estimation in a stand.

Size of the sample plot was chosen basing on the harvesting machine boom length – 10 m, because the tinning was made using machinery. The distance between strip roads were 18 m. Totally, 20 sample plots were established in Stand 3 and 12 sample plots in Stand 4. The sample plot groups were spread evenly troughout all stand.

After finished logging operations, tree height was measured using 'Suunto PM-5/1520' tree height measurement instrument; the average height of trees in Stand 3 was 9 m. Measuring was also carried out for all manually cut small size trees which were not suitable for commercial use, with average length of 8 m.

In Stand 4, the average height of trees was 8 m. The diameters were measured only for manually cut small size trees which were not suitable for commercial use. The measurement was done with calliper at breast height, which was detected as 1.3 m from the felled tree cutting surface. To define a measured trees volume the tree volume table was used (Meža rokas grāmata, 1995).

All the measurements in Stand 3 and Stand 4 were done by the method listed above by the reason that it can show precise volumes of possible energy wood removal. During the research all the data were collected and processed in MS Excel programs.

Results and Discussions

From the first research done in Stand 1 and Stand 2, the total energy wood volume was 1410 m^3 of chips. The volume deviations by the stands were set as 830 m^3 from Stand 1 and 580 m^3 from Stand 2 (Table 1).

Table 1

Energy wood volume from Stand 1 and Stand 2

	Area of stand, ha	Round wood volume, m^3	Energy wood volume, m^3	Energy wood m^3 ha^{-1}	Energy wood/ round wood, %
Stand 1	44.90	1561.70	830.00	18.49	53.15
Stand 2	24.50	872.20	580.00	23.67	66.50
Total	69.40	2433.90	1410.00	20.32	57.93

Table 1 shows that energy wood volume per ha in Stand 1 was 18.49 m^3 and in Stand 2 - 23.67 m^3. The percentages of energy wood according to total harvested round wood volume are more than half – 53.15% and 66.50% respectively. This suggests that from 60 years old mix stands it is possible to get a 50 – 60% of energy wood according to round wood volume.

In the second research done in Stand 3 and Stand 4, a sample plot of total area of 5760 m^2 was established. In Stand 3 the sample plot area was 3600 m^2 (0.36 ha), and in Stand 4 the area was 2160 m^2 (0.216 ha). Totally in all plots, 1096 trees were counted and measured. Distribution of trees, diameter and volume by stands is seen in Table 2.

Table 2

Distribution of trees, diameter and volume by stands

Diamers, cm	Stand 3		Stand 4	
	trees	volume, m^3	trees	volume, m^3
6	129	1.29	130	1.3
7	203	2.03	155	1.55
8	240	5.52	91	2.09
9	140	3.22	8	0.18
Sum	712	12.06	384	5.12

Table 2 shows that the most of all trees fit to diameter from 7 cm to 8 cm. This diameter class form also the biggest part of total volume.The available energy wood volume per each stand sample plot total area is 12.06 m^3 in Stand 3 and 5.12 m^3 in Stand 4.

From these results it is possible to calculate the available energy wood volume per 1 ha. Converting the area to percents the sample plot in Stand 3 is 36% of 1 ha, and in Stand 4 is 21.6% of 1 ha, which means that the calculated energy wood volume in sample plots is relevant to the area unit. Consequently, the available energy wood volume from Stand 3 is 33.5 m^3 ha^{-1} and from Stand 4 - 23.74 m^3 ha^{-1}.

Comparing the volume per ha in both stands, the available energy volume in Stand 3 is higher. It could be by the reason that there occurs less mortality and the stand is younger. The available energy wood volume from the whole Stand 3 is 670 m^3 and from Stand 4 - 239.8 m^3.

The comparison of energy wood volume and harvested round wood volume shows that it could be possible to remove energy wood volume that is half of harvested round wood volume (Figure 2).

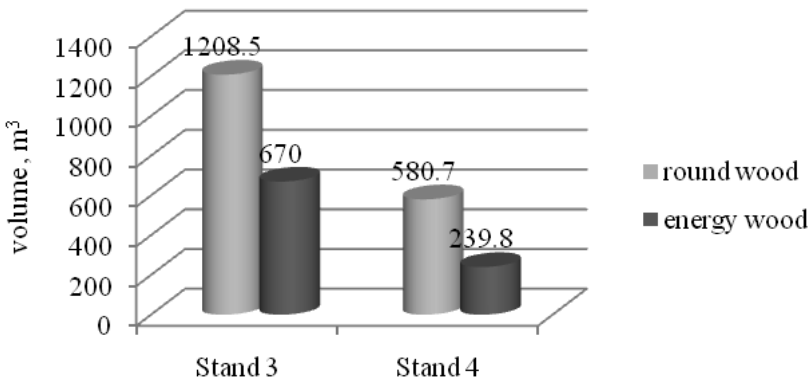

Figure 2. The volume comparison by stands.

The previous researches give a percentage of branches and tops from the whole tree - some 15 – 20% (Saliņš, 2002), which suggest that the volume of branches and tops could be 11 m^3 ha^{-1}. This means that total energy wood volume from thinning of the age of 30 – 40 years could be 33 – 47 m^3 ha^{-1}. Some of the researches show estimate calculation of energy wood volumes from young stands, which is 30 – 110 m^3 ha^{-1} (Lazdiņš, 2007). The results from Stand 3 and Stand 4 are useful for estimation of total energy wood volume from thinning if all slash is collected.

Summing all the data about the energy wood volumes from this research it is possible to estimate the average volume from 1 ha, which is 32.8 m^3 in stands of the age of 30 – 60 years.

Relating the results for whole Latvian thinning, which in year 2006 was 38981 ha (Koku ciršanas dinamika, 2008) and from them available area of energy wood collecting is 66% (25727 ha). Recalculate the available area in to volume, using the average volume per ha from research, that would be ~ 0.85 million m^3 yr^{-1}. Results from this research give an over view of the energy wood availability from thinning in Latvia.

Conclusions

The first research showed that the slash carried away from 60 years old mix stand produced energy wood volume of 20.32 m^3 ha^{-1}.

The second research showed the possible volume of wood for energy procurements from 30 – 40 years old stands. The volume in these stands was from 23.74 m^3 ha^{-1} to 33.5 m^3 ha^{-1}.

If the branches and tree tops in 30 – 40 year old stands are taken in to consideration, the volume of energy wood makes 33 – 47 m^3 ha^{-1}.

Relating calculation for whole Latvian thinning, which in the year 2006 occupy 36981 ha, than total available energy wood volume in Latvia is 0.85 million m^3 yr^{-1}.

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THE EFFECT OF RAINFALL ON ACTIVITY OF THE SEWAGE CO-SYSTEM IN RIGA

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Abstract

The human influence on hydrological cycle has created many surface problems in the Riga city. Rainfall amount increases year after year as a result of global warming and bad water exchange. Solid covering of squares and greened areas is one of the most significant results of urban development causing larger rainwater runoff from the territories and calling for the necessity to drain rain water rapidly in a short time. This phenomenon is observed in the last years due to the fast construction development and simultaneous expansion and improvement of streets and court yards. The main problem matter is the still existing old sewage co-system which encounters difficulties to work with full capacity during long term rainfall.

Thus justifiable steps have to be taken in order to discover new engineering solutions to prevent overflow of streets in Riga during rains. To enquire into the matter, rain intensity in Riga, influence of rainwater on streets, overflowing of collectors, and operation of pumping stations are studied in this paper. Rain intensity measurements during 1980-2006 in Riga have been aggregated. As acquired data shows, maximum rain intensity was observed on July 30 of 2005 when the rainfall was 49.4 mm during a 3-hour time, which caused overflowing of some streets, collectors, and pumping stations. Data on local and main pumping stations at the right bank of the river Daugava during various rainfalls suggest that pumping stations start to overflow during enduring rainfalls, 1-3 hours long and with average intensity of 0.1-0.4 mm min^{-1} (Ziemelnieks, Tilgalis, 2008). Data gathered indicate, that it is necessary to separate sewage systems for everyday necessities from those for rainwater.

Key words: rainfall, precipitation, rain intensity, sewage systems, pumping stations.

Introduction

The routine problem of Riga city in the 21st century is traffic jams that arise from several positive aspects: development of the state economy, welfare, development of technology, and its availability. The fact that precipitation is not duly collected causes additional traffic jams. It is delayed by outdated sewage collection systems, insufficient capacity of pumping stations and sewage purification plants (SPP), and insufficient rainwater management (Tilgalis, Siļķe, 2003). As a consequence, if pumping stations are not able to process sewage it is necessary to open overflows and unpurified sewage freely flows into the river Daugava. Usually precipitation problems of the sewage arise in summer months, however, recently it has been happening also in winter due to global warming.

It would be useful to reconstruct and separate rainwater sewage from the existing sewage co-system, but it cannot be accomplished rapidly because should be taken into account. Future development concept of the city, changes in the street width, and possibility of an underground construction. It is practically impossible to lay pipes in the largest part of the center of Riga and to accomplish development of the collection reservoir due to the high value of land.

In the accounting program of an automated pumping station of 'Rīgas Ūdens' Ltd, nondurable periodic strong rainfalls do not directly influence overflowing of the streets of Riga and do not cause problems with the pumping of sewage in the main pumping stations.

In Latvia, during summer, rainfalls with average intensity do not exceed 2 mm min^{-1} (Sarma, 1990). The average rainfall intensity in Riga according to calculations is:

0.7 mm min^{-1} on average in 20 minutes, 1.1 mm min^{-1} on average in 10 minutes, 3.4 mm min^{-1} during the first minute (Hydraulic model analysis for sewage network system of Riga, 1999).

Problems are caused by enduring rain that is

from 60 minutes to 2 or 3 hours long with average strong intensity, 0.1-0.4 mm min^{-1} provided the rain cloud is equally located over the entire city.

Materials and Methods

Publicly available data of the Latvian Environment, Geology, and Meteorology Agency for the period of 1980-2006, i.e., for 27 years, was used to perform the study.

Detailed data was analyzed from May 1 to October 1 when the strongest and largest precipitation take place that are manifested as liquid precipitation, rain, rain storm, and thunderstorm.

Hourly precipitation data was acquired in the center district of Riga by applying measuring method of Tretyakov gauge (Sarma, 1990). Minute data of precipitation was acquired from a pluviograph type P-2 for instruction reports TM-14. Average intensity was determined by analyzing minute, 3-hour, 9-hour, and 24-hour precipitation data in a time period in a set average intensity, which was then compared to the productivity of the main pumping station of Riga during rain.

According to the acquired data and by applying software Excel, data is classified and arranged in tables for calculations precipitation values and to draw diagrams.

Data available in the automated sewage pumping station accounting program was used for the period starting from 2000 on the operation of pumping stations in emergency mode and during drought.

Results and Discussion

It was observed that in the territory of Riga during strong rain it was raining with various intensities but the rain cloud had not affected the entire city. In these occasions only some local pumping stations were endangered as well as collectors and streets aligning to these stations. But it did not cause inability to pump the sewage in the main pumping stations. Temporary rainfalls with average strong intensity are accepted well by the co-system sewage system by gradually filling in the collector with no overload that operates as a collection reservoir.

From the data of 1980 - 2006 it was observed that precipitation had reached the maximum on June 1 of 1985 when during rainstorm in a 3-hour period rainfall was 47.9 mm and on July 30 of 2005 in a 3-hour period rainfall was 49.6 mm and in a 9-hour period 47.2 mm. The average intensity at 49.4 mm per 3h was 0.3 mm min^{-1}. By observing average intensity in a 3-hour period within 27 year period during moderate rain intensity, it was observed 0.07 mm min^{-1}, but on average during 9-hour period 0.02 mm min^{-1}.

Figure 1 shows average rainfall in Riga in the month of July during the period of 1980 to 2006.

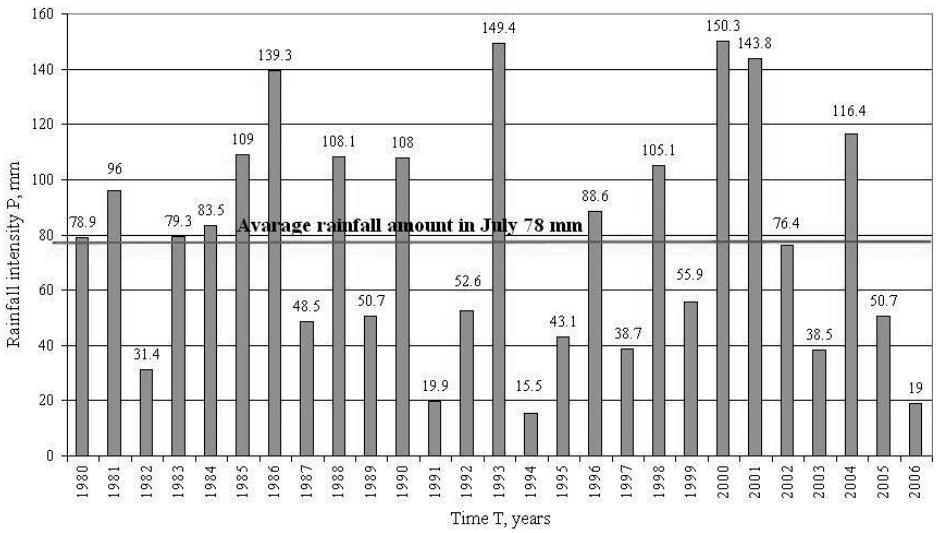

Figure 1.
Average rainfall amount in July in Riga for the Period from 1980 to 2006.

Strong and enduring precipitation reflecs on the operation of sewage pumping stations and may cause floods on the driving section of the streets. Floods caused in the center streets of Riga signify that the sewage system is too full and pumps are not able to process sudden rainwater runoff and sewage. Almost every time, when rainwater had overflooded sewage collectors, an emergency release of the main over-pumping station located on the right side of the river Daugava was used (Tilgalis, Juhna, Ziemelnieks, 2006). Sewage of the central district is collected in the pumping stations located in 7 Hanzas Street, 16a Eksporta Street, 28 Eksporta Street, 3 Grostonas Street, and 16 Elizabetes Street where they come together in the main pumping station of the right side of the river Daugava in 2 Ilzenes Street (Tilgalis, Siļķe, 2000). Some data is inaccurate, especially during strong rain storms when waving of water is observed in the collector of network pumping stations. This is regularly taking place in the pumping station in 7a Hanzas Street therefore measuring units there show inaccurate data. Exception is the pumping station in 16 Eksporta Street which even during the smallest rain storms (approximately 0.4 mm min^{-1}) is overflowed constantly because unfortunately the calculated pump of 120 l s^{-1} has been selected with too low productivity.

Rain intensity during an hour can change considerably as can be seen from the example of rainfall data measurements on 13 August 2001 (see Fig. 2).

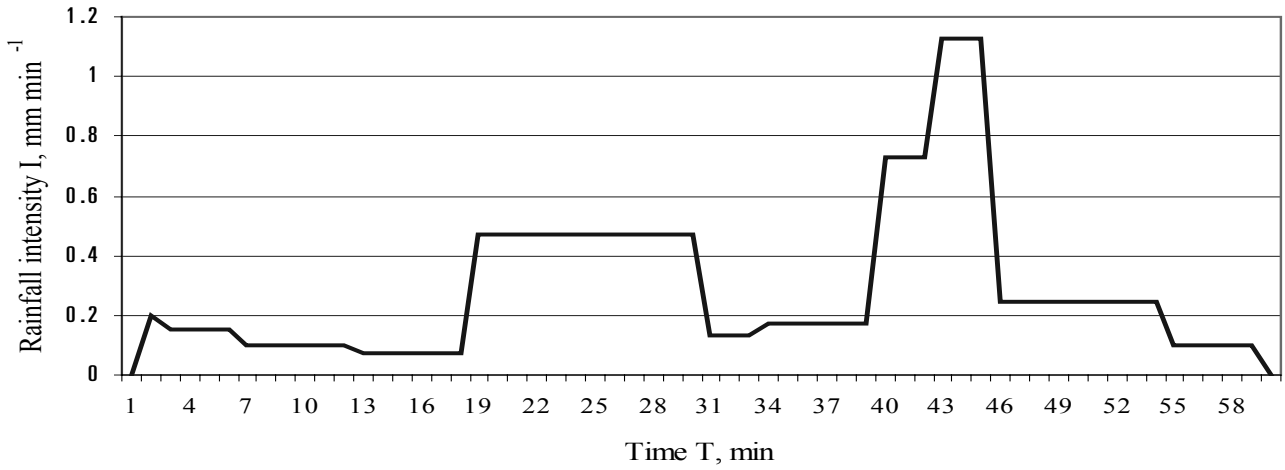

Figure 2.
Precipitation on 13 August 2001 (from 4:05 p.m.- to 5:05 p.m.).

Up to now it has not been precisely calculated how much time is necessary for rainwater to reach a pumping station and it depends on a flow amount, speed, pipeline decline and level of silting and it will be researched.

Problems for pumping stations arise if rain pours in the entire territory of Riga evenly for at least 1-3 hours (Ziemelnieks, Tilgalis 2007). As can be seen from the Figure 2 above, after short, sudden rain storms with average intensity during the time observed (0.3 mm $min^{-1}$and maximum intensity 1.13 mm min^{-1}) do not cause problems in pumping stations but cause them locally on streets because water is unable to flow away rapidly from the driving section to gullies or to be absorbed by any surface that is permeable to water.

Table 1 shows data on the operation of these pumping stations during rainstorm in comparison to dry period showing over-pumped amount of sewage that was observed on June 28 of 2007 in Riga during the time period from 3:00 p.m. to 6:00 p.m. and rainfall was 17.2 mm (average strong rain storm).

Table 1

Working regime of pumping stations

Pumping station	Productivity drought period, m^3 dnn^{-1}	During rain, m^3 dnn^{-1}	Notes
2 Ilzenes Street (the main pumping station on the right side of the river Daugava)	40 000-50 000	117 020	Pumping station operated with maximum productivity of ~14 800 m^3 h^{-1}
2b Eksporta Street	1870	9520	Pumping station operated with max productivity of ~1480 m^3 h^{-1}
7 Hanzas Street	8920	20 880	Pumping station operated with max productivity of ~2800 m^3 h^{-1}

Figure 3 shows operation of the main pumping station in 2 Ilzenes Street during and after the rain. The rain was recorded on June 11 of 2005 in 9-hour measurement interval: from 3:00 p.m. to 6:00 p.m. the rainwater was in total 22.4 mm, and from 6:00 p.m. to 03:00 a.m. 27 mm. Rain intensity decreased to 1.8 mm within the interval from 03:00 a.m. to 06:00 a.m. Emergency release of the pumping station opened at 6:00 p.m. and closed at 04:00 a.m.

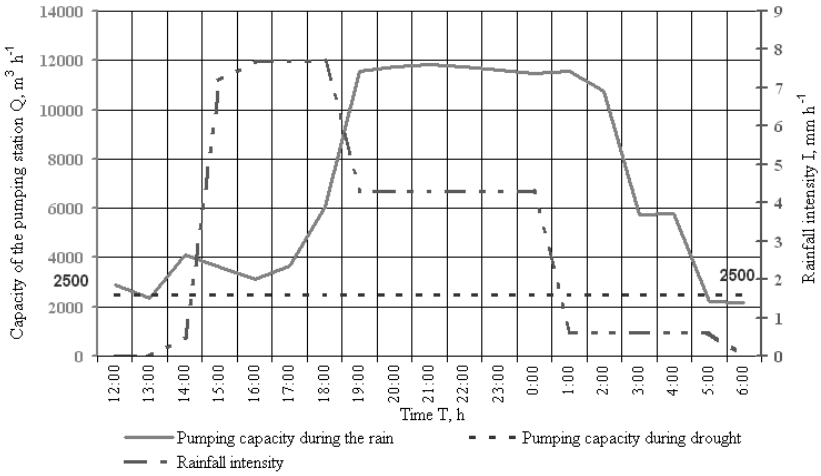

Figure 3.
Operation of the Main Pumping Station in 2 Ilzenes Street during the Rain from June 11 to June 12, 2005.

Strong rainstorm with hail (size of grains 5-8 mm in diameter) was observed in the center and some parts of Riga on May 25 of 2007 from 14:25 to 14:35. Active rain intensity was 3-5 minutes long. The rain cloud moved from Bauska Street district to the center of the city and soon reached Sarkandaugava, and later decreased in the area of Teika and Jugla. On that day in Pārdaugava area there was almost no rain and there was not a significant amount of sewage in the pumping stations. According to observations of the Latvian Environment, Geology, and Meteorology Agency, rain intensity reached maximum in the center of Riga at 14:20 to 14:21 with rainfall of 0.8 mm min^{-1}. According to the measure method by Tretyakov gauge rainfall was 7.7 mm in the center of Riga during the period of 06:00-15:00 I assume that at other time there was no precipitation because automatic rain intensity measuring unit showed no results. The recorded amount of 7.7 mm is not large. As observed on May 25 of 2007 in the center part of Riga after rain 2b Eksporta Street pumping station worked with all 3 pumps full capacity 450-500 l s^{-1}. At 14:36 and 14:42 pumping station suddenly worked with full capacity and it has to be concluded that water of rain precipitation reached the pumping station in approximately 15 minutes from the beginning of rain (see Fig. 4).

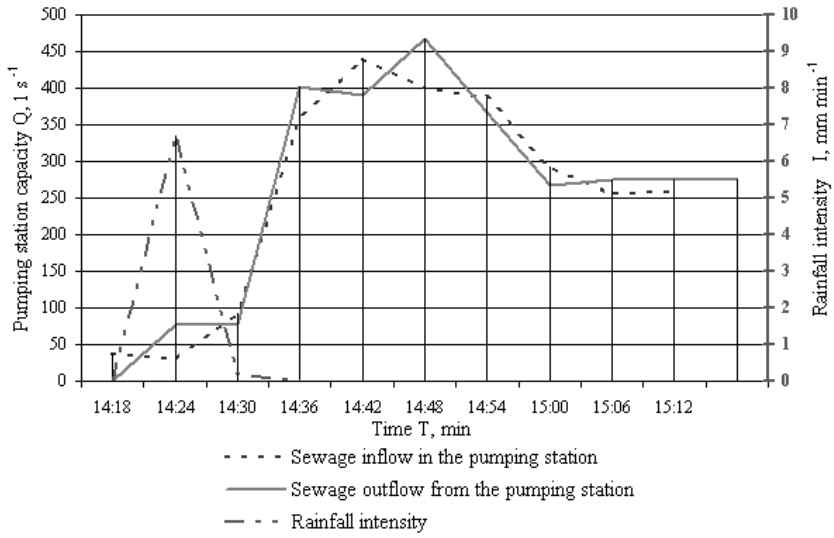

Figure 4.
Operation of Network Pumping Stations in 2b Eksporta Street during Rain, May 25, 2007.

On May 27 of 2007 the main pumping station of the right side of the river Daugava in 2 Ilzenes Street at the rain with started to work with additional capacity at 14:44, i.e., approximately 17-20 minutes after it rained. Maximum amount of the sewage pumping (12000 m^3h^{-1}) was reached at around 15:00 p.m. and continued till around 18:30. In this case approximately 20 minutes long strong rain with maximum intensity in one minute of 6.7 mm min^{-1} also affects operation of the main pumping station. Significantly, at this time streets were not overflowed because rain water was received by the collector at sufficient speed. According to analysis of the pumping station, the rain cloud moved towards Jugla, therefore the sewage was evenly pumped from collected center collectors and later they flowed from direction of Jugla direction and thereby letting the pumping station to work stably with almost full capacity of 12 000 m^3 h^{-1}. Also in this case it was necessary to open the emergency release. The pumped amount of sewage on May 29 of 2007 in the pumping station of Ilzenes Street was 110 889.7 m^3 dnn^{-1}.

Conclusions

1) Maximum rain intensity in Riga in the time period from 1980 to 2006 was observed on June 29 of 1999 and was 4.87 mm min^{-1}. Rainstorm in 3 hours reached 47.9 mm on June 1 of 1985, and 49.4 mm on July 30 of 2005, but 47.2 mm in a 9-hour period. Maximum rainfall was observed in 2000 when it was 837 mm $year^{-1}$.
2) Nondurable rainstorm with an average intensity of 1-2(3) mm min^{-1} does not significantly affect the operation of the main pumping station.
3) Streets are overflowed less often because during this period sewage collectors do not get full. Usually nondurable precipitation (approximately 5-20 minutes) that occur in summer at rapid vaporization can be easily envisaged and dark skies are also easy to notice by a pumping station dispatcher and he/she duly gets ready and pumps out reservoirs of the main pumping station Ilzenes street 2.
4) Overflowing of streets and pumping stations occurs if rain is pouring in the entire territory of Riga, at least for 1-3 hours, periodically becoming stronger with impulsive strength maintaining for several minutes at 1-2mm min^{-1} , which is more characteristic of Latvia's summer months June, July and August. By reviewing data of a 27-year period, the average

intensity in 3 hours at moderate rain intensity was observed to be 0.07 mm min^{-1}, but in 9 hours on average 0.02 mm min^{-1}.

5) In the future when electricity will become more expensive it would be useful to invest assets for a construction of a separation system for the sewage system to avoid necessity for several pumping stations to overpump inflowing water when, as the result, part of it gets in the river Daugava without being purified.

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IMPACT OF THE ROUGHNESS COEFFICIENT FOR THE HYDRAULIC CONDUCTIVITY OF REGULATED RIVES

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Abstract

The article presents hydraulic conductivity modelling results of the some regulated Southeast Lithuanian streams overgrown with woody vegetation. Possibilities to plan naturalization of the regulated streams are also presented in the article. The research of woody vegetation was carried out in the Neris river basin within the period of 2006 to 2007. Having evaluated the influence of hydraulic roughness (Manning coefficient of roughness) on hydraulic conductivity of the rivers Nemėža and Ž-2 streams it was established that the density of woody vegetation in the investigated section varied from 0.01 to 0.68 units m^{-2} in Nemėza stream and from 0.17 to 3.12 units m^{-2} in Ž-2 stream. At the existing density of woody vegetation the hydraulic roughness coefficient *n* established by hydraulic calculations reached in 0.025–0.045 in Nemėža stream and 0.033–0.053 in Ž-2 stream. Under present hydraulic roughness coefficient assessed by natural investigations in all investigated streams sections, when spring flood discharge probability is 10%, water overflow indicator is positive; the water depth in the bed (z_v) of the natural reaches was lower than the depth of a regulated stream (h_G). The reserve of hydraulic conductivity in the investigated Nemėža stream section is lost when roughness coefficient reaches the limit of 0.080, in Ž-2 stream 0.060. When roughness coefficient reaches 0.170, water overflowing indicator is negative in all investigated sections of the streams.

Keywords: regulated streams, hydraulic conductivity, woody vegetation.

Introduction

An intensive growth of grass vegetation in drainage trenches and regulated streams, especially in their beds, is one of the natural processes influencing the state of these trenches. According to the researches Poškus V., (2003), the growth of grass in the beds of regulated streams increases their roughness, decreases water velocities and stimulates sediment deposition.

Trees and bushes on the slopes naturally decrease their hydraulic conductivity as hydraulic roughness *n* is increased up to 0.030 – 0.147 (Melioracijos..., 2006).

Thorough researches of trench bottoms and slopes covered with woody vegetation, carried out in the Mid Plain (Lamsodis, 1999; Lamsodis et. al., 2006), showed that the probability of finding overgrown slopes of trenches which would decrease hydraulic conductivity by 1.5 - 2 times, is very small – about 0.01%; even in the forests, where the trenches are most overgrown, it is up to 3%. It has been observed that woody vegetation throughout the slopes is gradually thinning, which is why the hydraulic conductivity of the overgrown regulated streams may increase with time. Rimkus and Vaikasas (1997) states that trunks under the trees become thinner and bed conductivity increases. At this phase tree foliage merges and any bushes underneath become entirely thin. The bedding conductivity sets, and usually remains sufficient, even when the slopes are fully overgrown. It may be insufficient only in the streams having a very small slope.

It has been established (Rimkus et al., 1998) that a large number of trees in the streams with a small slope (0.2 - 0.5%) and a big watershed (15 – 30 km^2), is not allowed, although at least one row of trees is useful. In the regulated streams with a small catchments basin, when a slope is not very small (0.5% and bigger), the overgrowth of thick stem grass and young trees does not influence the functions of water recipients, which is why there is no rush to destroy them. It is better to pay more attention to bed mowing a small slope, covered with quickly sprouted and augmented water grass, which does not suit a described state. Young trees

stabilize the state of small slope channels and conductivity. During their growth, it is possible to form a central strip which is not overgrown, will not pullulate in the shade of the trees, and will remain clear. The channels of a small slope where trees do not grow need to be mown regularly.

The smallest hydraulic conductivity of the channels Dolgopolovienė (2003) is typical to the Baltic hills (Biržai, Joniškis, Pasvalys, Šiauliai districts) and the Mid Lithuania lowland (Radviliškis, Kėdainiai, Kaunas districts). These zones are in areas where the disturbances dominate which reduce the hydraulic conductivity (i.e. the beds and slopes are overgrown with grass and the channels are silted and sunk).

The work objective is the investigation of quantitative and qualitative regularities of regulated streams overgrown with woody vegetation, evaluation of functionality (hydraulic conductivity) changes and possibilities to plan naturalization of the regulated streams in the region of southeast highlands.

Materials and Methods

Field measurements were carried out in the Neris river basin (Fig. 1), the Baltic upland in Lithuania's South and East, in the sections of the regulated streams Bezdonė, Dūkšta, Gnesvianka, G-1, Nemėža, Riešė, Rudamina, Vaisvilė, Vilnoja, Girija, Ž-2, Ž-3, R–5 and Žalesa. In total the length of the observed stream sections amounts to 23 km and 210 slope sections. The average selected section length is 10 m. We identified an analysed profile in the most representative place of the section, in which we carried out morphometric measurements of the bed.

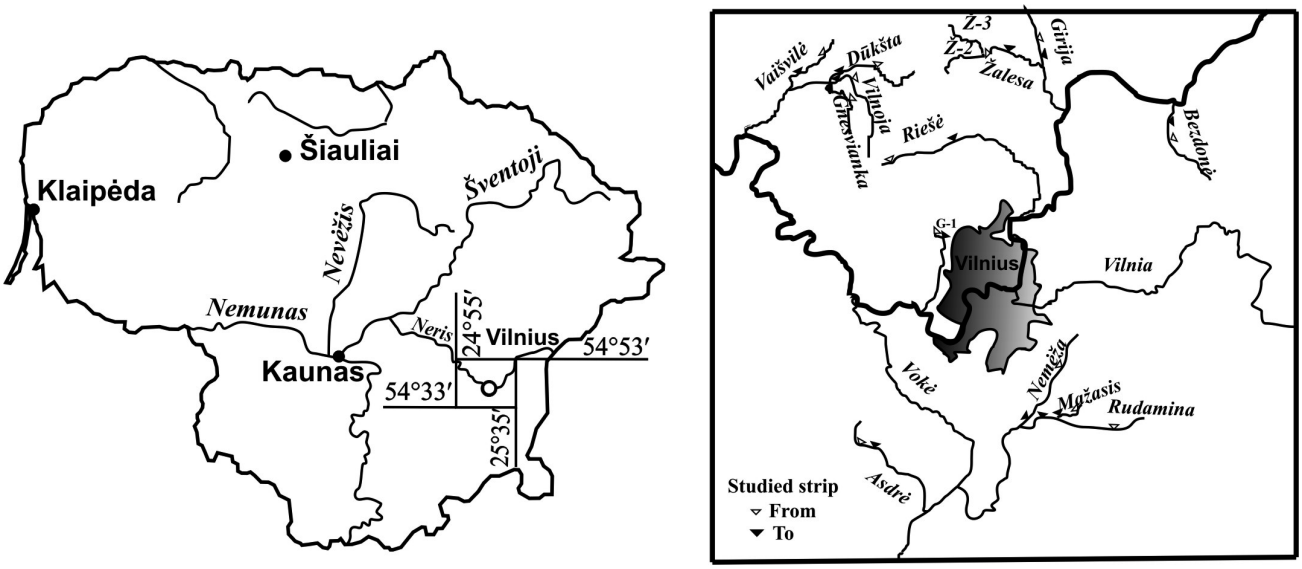

Fig. 1 Research location.

In each slope part of the regulated streams (place of dwelling) we identified distribution of the woody vegetation.

Density (T) – quantity of stems per 1 m^2 of slope area. A stream bed profile, in which specimens or communities of species are found, is regarded as a habitat of woody vegetation.

In establishing the suitability of regulated streams to perform the functions of main canals the main evaluation criterion of their condition is theirs hydraulic conductivity. It is reduced by vegetation – small trees, bushes and grasses growing on the slopes of regulated streams. In order to establish the impact of trees, dense low bushes (willows) and coarse-stem grasses growing on the slopes of regulated streams on hydraulic conditions a methodology of hydraulic calculations (Rimkus and Vaikasas, 1998) was used allowing calculation of emerging hydraulic resistances, water flow speeds and coefficients of hydraulic roughness.

The methodology of hydraulic calculations was made using a formula of hydraulic resistance force of cylindrical stem:

$$T = \gamma C_f K_T H_d \frac{\alpha v^2}{2g} \quad (1)$$

when γ – liquid volumetric weight;
C_f – stem shape estimation coefficient;
K_T – stem density estimation coefficient;
H – height of submerged stem part;
d – stem diameter;
α – Corioli's coefficient;
v – flow speed;
g – gravitational acceleration.

Having changed this force with an equivalent pressure flow pressure losses, hydraulic resistance coefficients and hydraulic gradient formed due to these resistances are achieved. Then, the average flow speed is calculated according to the following formula:

$$v = \sqrt{\frac{2gi}{\frac{\xi}{l} + \frac{\lambda}{4R}}} \quad (2)$$

when i – hydraulic gradient;
g – gravitational acceleration;
ξ – coefficient of hydraulic resistance of small tree stems;
l – average distance between tree stems;
λ – coefficient of hydraulic friction at canal bottom and on slopes;
R – hydraulic radius.

Having calculated the hydraulic roughness coefficients of the regulated streams we used HEC–RAS (River Analysis System) programme to evaluate the influence of woody vegetation on a stream's hydraulic conductivity. Software HEC–RAS created by the Hydrology Engineering Centre (HEC) is designed to carry out one-dimensional calculations of settled and unsettled flow and silt movement. The calculations of a stream hydraulic conductivity is made from a cross profile of one section to another by energy equilibrium equation:

$$h_1 + \frac{\alpha_1 v_1^2}{2g} = h_2 + \frac{\alpha_2 v_2^2}{2g} + h_w \quad (3)$$

When h_1 and h_2 – water depths in the first and second sections;
v_1 and v_2 – average water flow velocity in sections;
α_1 and α_1 – Corioli's coefficients in sections;
g – gravitational acceleration;
h_w – energy losses.

The programme can cover the entire network of beds, either a complicated branched system or a single arm of a river.

While hydraulic conductivity of the regulated streams varied, water levels in the bed were calculated at spring flood discharge with 10% probability (as it is required by standard documents of hydraulic calculations for drying systems) (Melioracijos..., 2006).

Results and Discussion

Different vegetation (woody vegetation – trees and bushes included) grows on the slopes of regulated stream beds. The density of average of woody vegetation forms in the investigated 17 regulated stream slope sections of total stem density T=1.259±0.202 units m^{-2}, trees T_M=0.225 ±0.037 units m^{-2}, bushes T_K=1.035 ±0.198 units m^{-2}.

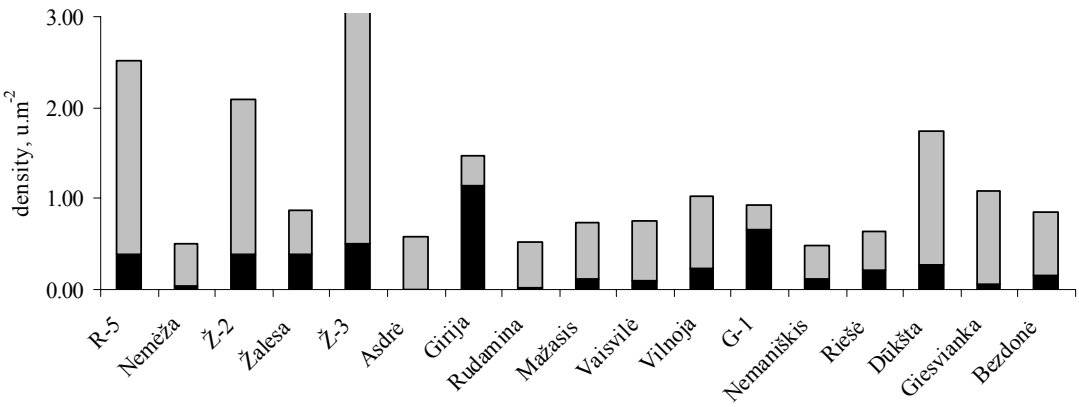

Fig. 2 Average density in the researched stream strips □Shrub ■ Tree

The least average density was found in the Nemaniškis, Nemėža and Rudamina regulated stream strips. The largest average density was calculated in Ž-3, R-5 and Ž-2 strips of regulated streams (Fig.2). Comparing the density of trees and bushes, we can see that the largest average bush density was found in Ž-3 and R-5 regulated streams. The largest average tree density was found in the Girija regulated stream (1.11 units m^2). The tree density in other researched streams did not achieve 1 units m^2.

After the calculation was made we find, that the majority of regulated streams have the reserve of conductivity and can pass floods under increased roughness (regulated stream slopes are overgrown with grassy and woody vegetation) without overflowing into the valley. However, under specific conditions (too small gradient or too high roughness coefficient) such reserve might be insufficient (Rimkus and Vaikasas, 1998). We chose for the model calibration 2 streams in the southeast of Lithuania: Nemėža and Ž-2. In the Nemėža stream the average density of woody vegetation was 0.50 units m^{-2}; in Ž-2 it is 2.10 units m^{-2}.

The Nemėža is the Rudamina's tributary. The total length of the stream – 10.3 km – is regulated, basin area is 42.8 km^2 (Gailiušis et al., 2001).The middle part of the stream from measurement point 22 to point 29 was chosen for research. The gradient in the upper part of the investigated section from point 29 to 27 is 4.5 ‰; in the lower part from point 27 to 22 – 0.6 ‰. According to the data of the National Water Management Planning Institute the average discharge with 10 % probability during vegetation period in the investigate section of this rives was 0.333–0.365 $m^3 s^{-1}$ and the discharge of spring flood with 10 % probability was 5.11–5.50 $m^3 s^{-1}$. In the summer of 2006–2007 field measurements of woody vegetation and hydraulic calculations in the Nemėža stream established that the hydraulic roughness coefficient n varied from 0.025 to 0.045.

The Ž-2 – is regulated, the total length of the stream 4.5 km, basin area is 10.5 km^2 Gailiušis et al. (2001). The middle part of the stream from measurement point 2 to point 17 was chosen for research. The gradient of the investigated section was from 0.5 to 8 ‰. In the summer of 2006–2007 field measurements of woody vegetation and hydraulic calculations in the Ž-2 stream established that the hydraulic roughness coefficient *n* varied from 0.033 to 0.053.

The dependence of the coefficient of roughness from the woody vegetation was estimated in a few other regulated streams in the southeast of Lithuania. The density of woody vegetation in the Vilnoja stream was 1.66 units m^{-2}, the roughness coefficient reached 0.057; in regulated Girija stream, when the density of woody vegetation was 2.29 units m^{-2} – 0.053. In the Vaišvilė stream overgrown with reeds the roughness coefficient was 0.094.

As the stream overgrows with woody vegetation, roughness coefficient n increases. By mathematical modelling roughness was changed from 0.025 (bed clean, straight, with no shoals or pits) to 0.290 (slopes overgrown with woody vegetation, bottom and slopes overgrown with reeds and other coarse-stem grasses).

Table 1

Values of roughness coefficient n and water overflowing indicator in the Nemėža and Ž–2 streams, when spring flood discharge is of 10% probability

Roughness coefficient n	Investigated stream sections	Quantity of sections	Water overflowing indicator
0.025-0.034	Ž17,Ž16 NE3, NE4, NE2, NE5,NŽ1, NE1, NE7, NE6, NŽ8	11	positive, $z_V \leq h_G$
0.035-0.044	Ž05, Ž12, Ž08, Ž15, Ž06, Ž10 NŽ14, NŽ16, NŽ12, NŽ15, NŽ13, NŽ5, NŽ3, NŽ4, NŽ10, NŽ11, NŽ7, NŽ6, NŽ9	13	positive, $z_V \leq h_G$
0.045-0.054	Ž14,Ž03,Ž04,Ž07,Ž01,Ž09,Ž13,Ž11 NŽ2	9	positive, $z_V \leq h_G$

Note. z_V – water level in bed; h_G – regulated stream depth.

The carried out modelling established that under present streams roughness spring flood water contained itself in the streams and did not overflow (Table 1) and water level in the bed (h_V) was in all cases lower that the depth of the regulated stream (h_G) and still had reserve.

The carried out field measurements showed that the density of woody vegetation in the Nemėža stream varies from 0.01 to 0.68 units m^{-2}, the density of woody vegetation in the Ž-2 stream varies from 0.17 to 5.42 units m^{-2}. When the density of woody vegetation (Nemėža stream) is 0.16 units m^{-2}, roughness coefficient varies at about 0.035. The increased density of woody vegetation on the slopes up to 0.24–0.68 units m^{-2} resulted in the roughness coefficient in the Nemėža stream up to 0.040. When the density of woody vegetation (Ž-2 stream) is 0.63-1.37 units m^{-2}, roughness coefficient varies at about 0.040. The increased density of woody vegetation on the slopes up to 3.86 units m^{-2} resulted in the roughness coefficient in the Nemėža stream up to 0.050. Besides, the regulated Nemėža stream is overgrown with coarse-stem grassy vegetation. Its impact on the roughness coefficient was measured as well.

Having increased the coefficient of the stream roughness up to 0.06, the rate of water overflow in the two strips of Ž-2 regulated streams became negative. When the coefficient of roughness reached 0.080, the overflow rate became negative in 6 out of 14 strips.

Having increased roughness coefficient in the stream sections (0.081–0.135), when spring flood discharge was with 10 % probability, overflowing indicator in 8 sectors out of 23 was negative and the discharge of the mentioned probability did not contain itself in the bed. Having increased roughness coefficient up to 0.140, water overflows in 10 sections, having increased it up to 0.160 – in 19 sections and when roughness coefficient was 0.170 water overflowing indicator was negative in all investigated sections of the stream.

Table 2

Water overflowing indicator in the Nemėza and Ž-2 streams when spring flood discharge is with 10% probability

Roughness coefficient n	Stream	Quantity of sections	Water overflowing indicator
0.025–0.080	Nemėža	23	positive, $h_V \le h_G$
	Ž-2	8	positive, $h_V \le h_G$
		6	negative, $h_V > h_G$
0.081–0.135	Nemėža	15	positive, $h_V \le h_G$
		8	negative, $h_V > h_G$
	Ž-2	4	positive, $h_V \le h_G$
		10	negative, $h_V > h_G$
0.136–0.145	Nemėža	13	positive, $h_V \le h_G$
		10	negative, $h_V > h_G$
	Ž-2	2	positive, $h_V \le h_G$
		12	negative, $h_V > h_G$
0.146–0.155	Nemėža	6	positive, $h_V \le h_G$
		17	negative, $h_V > h_G$
	Ž-2	1	positive, $h_V \le h_G$
		11	negative, $h_V > h_G$
0.156–0.165	Nemėža	4	positive, $h_V \le h_G$
		19	negative, $h_V > h_G$
	Ž-2	14	negative, $h_V > h_G$
> 0.166	Nemėža	23	negative, $h_V > h_G$

Modelling results show that, if the slopes of the streams bed overgrew with woody and grassy vegetation and roughness coefficient was higher than 0.060–0.080, a strip clear from trees at the foot of the slope must be arranged; or trees should be thinned on the entire slope; or one slope should be cleared of all vegetation and thus bed roughness coefficient reduced to an accepted value according to the requirements of bed hydraulic conductivity. In the case when about 0.40 m depth is lacking in the bed, woody vegetation should be thinned from 10–11 units m^{-2} to 6–7 units m^{-2} (the values submitted are approximate as while carrying out thinning grassy vegetation, the width of the strip overgrown with woody vegetation and bed gradient should be taken into account). When cutting small trees and bushes it is recommended Lamsodis (1999) to leave the overgrown southern slope because, as it was mentioned above, the woody vegetation growing on the southern slope will shade the bed, subdue overgrowing of the northern slope or the bottom with grassy and aquatic vegetation and reduce bed silting at the same time.

The Nemėža stream runs from the North-East to the South-West, therefore, in future the woody vegetation should be left on the south-eastern slope of the regulated stream. The Ž-2 stream runs from the West to the East therefore, in future the woody vegetation should be left on the south slope of the regulated stream. At the moment the stream roughness coefficient has not reached the critical limit. Water overflowing indicator is positive in the entire section of the investigated stream; therefore, small trees and bushes should be removed with consideration. From the hydraulic point of view they should not be removed yet.

When the regulated stream is overgrown with dense grassy vegetation (spring flood discharge) roughness coefficient might not reach the critical limit in the case, if spring flood discharge with 10% probability would not contain itself in the bed of the regulated stream (water overflowing indicator would be negative) as the snow in winter flattens course-stem vegetation and thus its resistance to the flow is reduced.

Moreover, the summertime water overflow into the floodplain in natural unregulated beds happens periodically and is very useful as the water purifies Meddelkoop (1999). Therefore, it might be even useful and tolerated when restoring (renaturalizing) regulated streams. All this shows that the issues of bed hydraulic conductivity, their maintenance and restoring have to be solved in an integrated manner, evaluating both economic and environmental needs.

Conclusions

1. The research established that the density of woody vegetation in the investigated Nemėža stream varied from 0.01 to 0.68 units m^{-2}, in Ž-2 stream varied from 0.17 to 5.42 units m^{-2}. Now field measurements have established roughness coefficient of 0.030–0.053. In all investigated streams sections, when spring flood discharge is with 10 % probability, water overflowing indicator is positive and water level in the bed (z_V) is lower than the regulated stream depth (h_G) in all cases.
2. Hydraulic conductivity reserve is lost in the investigated section of the streams, when roughness coefficient reaches 0.060–0.080. If the slopes of the streams bed overgrew with woody and grassy vegetation and roughness coefficient exceeded 0.060–0.080, according to the requirements of bed hydraulic conductivity calculations a strip devoid of trees at the bottom of the slope should be made or trees should be thinned out on the entire slope, or all vegetation should be removed on one slope and thus the bed roughness coefficient would be reduced to an acceptable value.

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PHOSPHORUS REMOVAL IN CONSTRUCTED WETLANDS OF SUBSURFACE AND SURFACE FLOW

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Abstract

Constructed wetland (CW) treatment systems are engineered systems designed to treat wastewater with the usage of the same processes that occur in natural wetlands. The full-scale investigations of free water flow surface filters (FWF), subsurface flow filters, including filters of vertical flow (SVF) and horizontal flow (SHF) were carried out in Lithuania. The investigations' database collected within the study period of 1995-2007 was used for the estimation of phosphorus removal efficiency of different constructed wetlands.

It was established that phosphorus removal efficiency depends on construction of filters and the load according to total phosphorus for the area unit of filter surface. Subsurface flow filters are distinguished by better phosphorus removal. At the same load of all filters, i.e., total phosphorus of 0.3 g m^{-2} d^{-1}, the removal efficiency of subsurface flow horizontal, vertical, and free water flow filters reaches 53.0, 46.5 and 28.0%, respectively.

The wastewater contains phosphorus in mineral and organic forms. Due to the aerobic conditions in filters of vertical flow, the amount of organic phosphorus removed by SVF is 3 times greater than in horizontal filters. Organic phosphorus in wastewater before the treatment by vertical filters constituted 27% of total P, and after the treatment 21%. In wastewater treated by horizontal filters this ratio was 21% and 31%, respectively.

Key words: constructed wetlands, phosphorus removal.

Introduction

Constructed wetland (CW) treatment systems are engineered systems designed to treat wastewater with the usage of the same processes that occur in natural wetlands. However, it is done within a more controlled environment.

Constructed wetlands may be divided into two types: subsurface and surface flow. These two types of CW may be of different constructions. They may be designed as free-water surface wetlands, further in the text called as free water flow filters (FWF). Another type of constructed wetlands is subsurface flow filters, including filters of vertical flow (SVF) and horizontal flow (SHF). All those systems have one common element – plants. Principal filter schemes of common construction are presented in Figure 1.

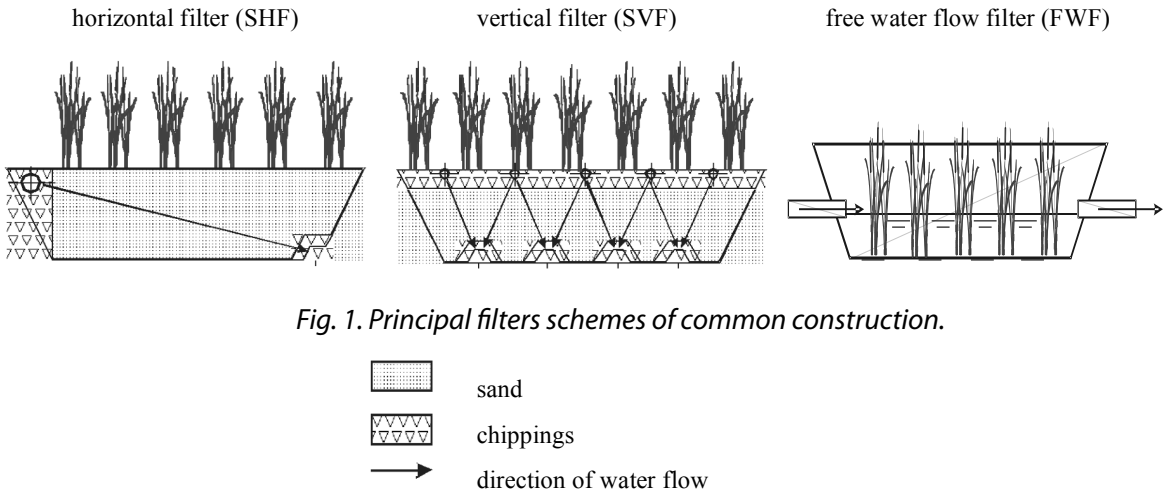

Fig. 1. Principal filters schemes of common construction.

In free water flow filters, the wastewater is related to atmosphere. Such kind of filter contains a filtration body (plant roots + soil) with an isolated bottom for the protection of subsurface water from pollution. Free water filters often include a pre-settling basin and several 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 filters of subsurface flow, the wastewater is flowing under the ground surface. The filters consist of excavated beds filled with soil in which marshy plants are growing; water level is below the ground surface in such filters. In filters of horizontal flow, the wastewater flows horizontally from the inflow zone through the body of the filter (i.e., roots of marshy plants, rhizomes and soil), where it is purified. The functioning principle of vertical filters is similar, only here the wastewater is spread on the surface of the filter; then it flows vertically through a 0.6-1.0-m deep sand layer into the collection pipes.

Phosphorus (P) within constructed wetlands is removed from wastewater via physical, chemical and biological processes occurring between the wetland substratum, vegetation and wastewater stream (Kim and Geary, 2000). Biological oxidation of phosphorus within CW converts most phosphorus species to an orthophosphate (soluble) form (Cooper et al., 1996; Kadlec and Knight, 1996). Phosphate can also precipitate with iron and aluminium oxides to form new mineral compounds (Fe- and Al-phosphates). These compounds allow the removal of phosphorus from a wastewater via sedimentation and filtration (Richardson and Craft, 1993; DeBusk and Dierberg, 1999).

Based on experience in the USA, it has been established that the purification efficiency of surface-flow wetlands is high for chemical oxygen demand (COD) and biochemical oxygen demand (BOD) - (90%), but substantially lower for nitrogen (N) and P (10–15%) (Kadlec and Knight, 1996). 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. P removal varied between 10 and 41 kg ha^{-1} yr^{-1}, and was related to differences in loads (Andersson et al., 2005).

In subsurface flow wetlands, P removal is greatly influenced by physico-chemical characteristics of used sand (Brix et al., 2001). However, other researchers indicate that only some physico-chemical characteristics are influential. The P-adsorption capacities of 13 Danish sands were studied by short-term isotherm batch experiments and related to the physico-chemical characteristics of the sands. If the most efficient sand for P-adsorption was used, the adsorption capacity would be used up after about 1 year, while, for the less efficient sands, the P-retention would go on for about 2 months. P-binding energy constants were not significantly related to the physico-chemical properties of the sands, except the Ca content, which showed, however, a low correlation coefficient (Del Bubba et al., 2003). Arias et al. (2001) data show that the content of calcium is particularly important, whereas iron and aluminium contents are of less importance. According to the data of Verhoeven and Meuleman (1999), in most filters phosphorus removal efficiency does not exceed 50%.

The objectives of the article are to summarize the data collected within the period of 1995-2007 and evaluate the phosphorus removal efficiency in constructed wetlands of different construction.

Materials and Methods

The full-scale investigations of free water flow surface filters (FWF), subsurface flow filters, including filters of vertical flow (SVF) and horizontal flow (SHF), were carried out in Lithuania. Due to construction differences, wastewater treatment conditions in filters are not identical, which has the influence upon the pollutant removal efficiency. The investigations database of different constructed wetlands collected within the study period of 1995-2007 was used for the estimation of phosphorus removal efficiency.

For horizontal filters, the studies were carried out in 6 wastewater treatment facilities where wastewater of different chemical composition was treated. All objects under investigation contain filters of common construction. After the primary treatment, wastewater is distributed into the filter via a distribution manhole. Chippings prisms arranged in filters contain distribution pipes. Here water is distributed evenly within the whole filter. Then, wastewater is filtered horizontally through a semi-coarse sand medium with the filtration coefficient of 5-8 m d^{-1}. Size of sand particles d_{10} is fluctuating between 0.15 and 0.17 mm, the ratio d_{60}/d_{10} is 2-5. The depth of filters is 0.8 m, filtration distance 4.5-

5.5 m. Filters are planted up with common reed (*Phragmites australis*).

The investigations of vertical filters systems were carried out in wastewater treatment facilities arranged in motels 'Nikola', 'Pastoge', and village Aristava, Kėdainiai district within the period of 2003-2007. After the purification in septic tanks, wastewater is directed into vertical filters for secondary (biological) treatment. Surface areas of filters are 300, 250, and 950 m^2 in motels 'Nikola', 'Pastoge', and Aristava, respectively. With the help of a pump, wastewater from septic tanks is distributed into a distribution manhole. Further wastewater is directed into distribution pipes, and finally it is sprayed into a layer of chippings arranged on the surface of the filter. Vertical filters contain a 20-cm thick layer of fine chippings with distribution pipes arranged at the spacing of 1 m. With the help of a pump, wastewater is distributed from the pump shaft into the distribution pipes. Further wastewater is spread throughout the chippings layer and is filtered downwards in a vertical direction via a 0.8-m deep sand layer into the collecting pipes arranged on the bottom of the filter. Sand filtration coefficient is 35.5 ± 5.9 m d^{-1}, the ratio of sand particles d_{60}/d_{10} is 5-6. Filters are planted up with common reed (*Phragmites australis*).

For free water filter, the investigation object included the Babenai wastewater treatment facilities (Kedainiai town) that have been re-constructed from an aeration wastewater treatment plant into a natural one. A free water filter has been arranged for additional wastewater treatment. The filter was set up in 2003. Currently it is completely overgrown with reed and cat's tail (*Typhaceae)*. The area of the filter is 675 m^2. 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 10-20 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 data of measurements taken in different study periods (2003-2006) was used for the analysis. Another examined free water filter set in village Aristava was used for the secondary wastewater treatment after the wastewater treatment in the vertical filter. The filter was set up in 2004. The area of the filter comprises 130 m^2. The amount of wastewater varies from 10 to 30 m^3 d^{-1}. Water levels are the same as in the Babenai examined object. The free water filter is completely overgrown with cat's tail (*Typhaceae)*.

Further analysis of wastewater treatment efficiency is performed only from the beginning of influent into the filters. To evaluate phosphorus removal efficiency, for statistical data analysis 182 measurement data of different periods for SHF, 90 for SVF and 55 for FWF were taken. Regression and analysis of variance were used for the mathematical processing of data.

Results and discussion

To estimate total phosphorus (TP) removal efficiency of filters with different construction, the load for filter surface area and removed TP amount for one area unit were calculated. The calculation results are presented in Fig. 2. The average load of studied SHF according to TP was 0.29±0.27, of SVF – 0.32±0.25, and of FWF – 0.25±0.23 g m^{-2} d^{-1}.

To compare the treatment efficiency, the calculations of pollutants removal efficiency have been made at the same load of all filters, i.e., TP 0.3 g m^{-2} d^{-1}. To make the calculations, the results of relationships presented in Fig. 2 have been used. In this case the treatment efficiency of horizontal, vertical, and free water flow filters reached 53.0, 46.5, and 28.0%, respectively.

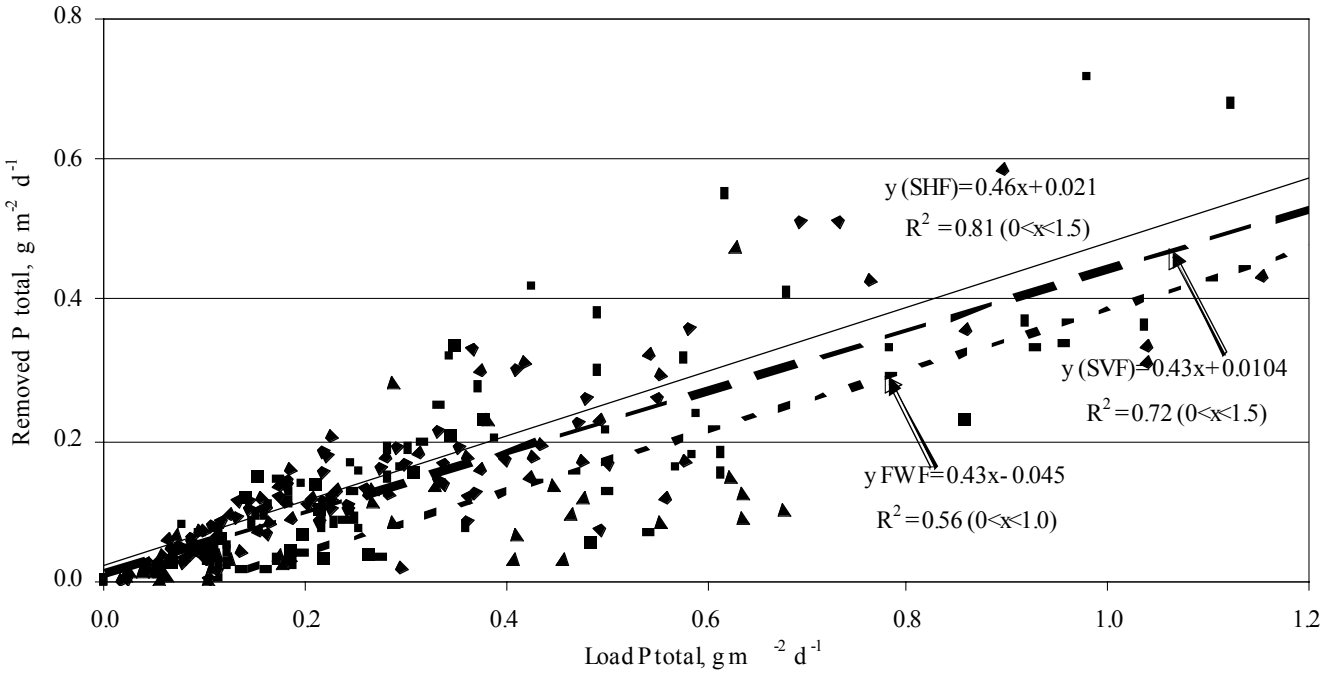

Fig. 2. Removal rate of total phosphorus (TP) in different filters with respect to the load

SHF SVF FWF SVF SHF FWF

Under aerobic conditions with the variation from neutral to acid reaction, trivalent iron joins phosphates into stable complexes. Due to the change of conditions into the anaerobic ones when sand is flooded, trivalent iron is reduced into bivalent thus causing less adsorbtion and release of phosphates (Faulkner and Richardsson, 1989). This may explain rather little phosphorus removal efficiency in free water flow filters, because wastewater treatment processes take place under anaerobic conditions. Filters of horizontal flow are more efficient for phosphorus removal than the vertical ones because of the longer residence time of wastewater in the filter and because of the greater volume of sand used for the same amount of wastewater treatment.

Ciupa (1996) has found that, at first, with the operation of plant filters phosphorus removal efficiency is quite high, then it decreases to the minimum. According to the data of our research, phosphorus treatment efficiency in vertical filters during the first two months exceeded 90.0%. Then it started decreasing and in 4-6 months set at the level of 40-60%.

According to the Lithuanian regulations, when wastewater treatment level according to P is not regulate, the concentration of total P in wastewater released into surface water should not exceed 4.0 mg l^{-1} (Nuotekų...2007). In order to estimate the possible filter load not exceeding the allowable concentration, a regressive analysis on the dependence of total P concentration in filters of effluent wastewater with respect to its load was carried out. The results of the analysis are presented in Figure 3. According to the dependencies presented in the figure, it is possible to calculate the possible filter load not exceeding 4.0 mg l^{-1} of total P concentration in the filters after the treatment. In this case, it comes out that filter load according to P total in filters of horizontal flow (SHF) cannot exceed 0.38 g m^{-2} d^{-1}, and in filters of free water flow (FWF) 0.26 g m^{-2} d^{-1}. Whereas filters of vertical flow (SVF) failed to reach the wastewater treatment level according to total P lower than concentration of 4.0 mg l^{-1}, because the initial wastewater pollution with phosphorus was twice bigger than in other filters.

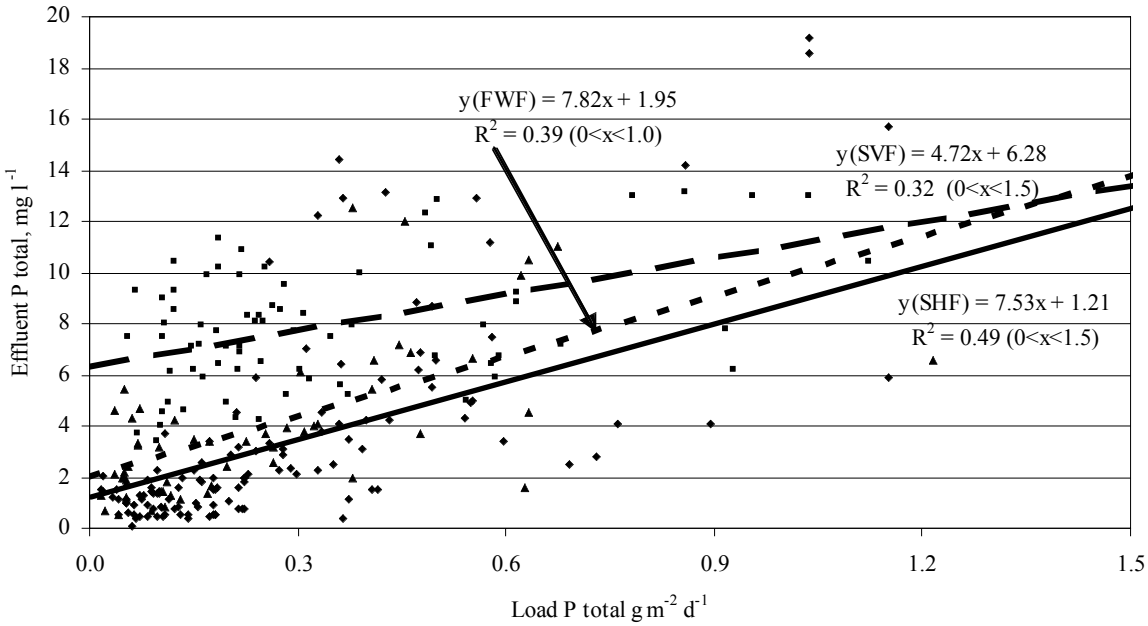

Fig. 3. Concentration of total P in effluent with respect to the load of filters.

◆ SHF ▪ SVF ▲ FWF —— SHF ▬ SVF - - FWF

Total P in wastewater occur in mineral and organic forms. Phosphorus of the organic form before treatment in filters constituted 21-27% from total P. Organic phosphorus in filters of horizontal flow constituted 21% before and 31% after the treatment from total P. It reveals that filters withheld more phosphorus of mineral form. Organic phosphorus in vertical filters constituted 27% before and 21% after the treatment. In free water flow filters, it constituted respectively 24 and 19%.

Water treatment processes in filters of different construction take place under unequal conditions thus influencing phosphorus removal efficiency according the given phosphorus forms. Average values of total phosphorus and its forms in influent and effluent wastewater are presented in Table 1. The analysis of the research data shows that phosphorus removal in subsurface flow filters is influenced by conditions caused by filter construction for wastewater treatment. Removal efficiency of phosphorus of mineral form in filters of vertical and horizontal flow varied slightly, whereas phosphorus of organic form in vertical filters was removed by 3 times more, which was mostly influenced by the factor that wastewater treatment processes take place under aerobic conditions providing better decomposition of organic substances.

Table 1

Phosphorus removal efficiency in filters with respect to its form

		P total	$P\text{-}PO_4$	P org.
SVF	Influent, mg l^{-1}	13.93	10.24	3.81
	Effluent, mg l^{-1}	7.18	5.73	1.51
	Removal efficiency, %	48.49	44.01	60.38
SHF	Influent, mg l^{-1}	6.62	5.25	1.37
	Effluent, mg l^{-1}	3.62	2.52	1.11
	Removal efficiency, %	45.29	52.11	19.15
FWF	Influent, mg l^{-1}	5.40	4.13	1.27
	Effluent, mg l^{-1}	4.38	3.55	0.84
	Removal efficiency, %	18.91	14.20	34.23

Conclusions

Phosphorus removal efficiency depends on the construction and load of constructed wetlands according to total phosphorus for area unit of filter surface. Subsurface filters are distinguished by better phosphorus removal efficiency. It was determined that at the same load of all filters, i.e., TP 0.3 g m^{-2} d^{-1}, the treatment efficiency of subsurface flow horizontal, vertical, and free water flow filters reaches 53.0, 46.5, and 28.0%, respectively.

Aerobic wastewater treatment conditions, caused by the construction of filters vertical flow, result in a three times greater removal of organic phosphorus compared to horizontal filters.

In order not to exceed the allowable concentration of 4.0 mg $l^{-1}$of total P in effluent, the load of horizontal flow filters (SHF) cannot exceed 0.38 and free water flow filters (FWF) 0.26 g m^{-2} d^{-1}. Filters of vertical flow (SVF) failed to reach the wastewater treatment level according to total P which has to be lower than concentration of 4.0 mg l^{-1}, because the initial wastewater pollution with phosphorus was twice bigger than in other filters. In order to improve phosphorus removal efficiency, it is necessary to apply additional means.

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INVESTIGATIONS ON GROUND WATER IN THE SWINE-BREEDING COMPLEX

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Abstract

The data on chemical composition of groundwater in the boreholes installed in the fields of a swine-breeding complex JSC "Kontvainiai" irrigated by liquid manure and in the production territory are presented in the article. This complex is situated on the Lithuanian coast, southeast of Klaipeda district. The data covers the period 2001-2005.

It was established that the chemical composition of groundwater depends mainly on the soil. Ion sum was 2 times higher in the water of the well which was installed in the soil having a peat layer.

The chemical composition of groundwater depended as well on its movement direction. As groundwater moves to the southeast, south and southwest from the fertilized area, the mineralization of water in wells 1 and 4 was the highest – 699 and 728 mg l^{-1}, respectively.

Keywords: swine-breeding complex, groundwater quality, boreholes, mineral and organic materials.

Introduction

Almost all drinking water used by citizens in Lithuania is groundwater; therefore, its quality is very important. When chemical composition of water changes due to natural reasons independent of the man's activities, usually, water quality corresponds to the requirements raised for drinking water. However, quite often drinking water quality worsens due to farming. Installed rubbish dumps, sewerage, water reservoirs, sites for washing pesticide spraying machinery, etc. are detrimental to water qualities. Large and small scale animal husbandry enterprises are considered pollution sources as they accumulate lots of manure (Tumas, 2003). Especially huge amounts of manure are accumulated in large animal husbandry complexes.

Swine breeding has always been a very important branch of animal husbandry in Lithuania. According to the Strategy for Animal Husbandry Development up to 2015 approved by the Ministry of Agriculture it is planned to raise 2.7 million pigs. According to the data of the Department of Statistics there were 955.8 thou pigs on 1 June 2007, of which 335.9 thou were bred by farmers and family farms, and 619.9 thou – by agricultural companies and enterprises. Compared with the data of 1 June 2005, the number of pigs in 2007 in farmers' and family farms decreased by 50% and that in agricultural companies and enterprises increased by 14.4% (Žemės…, 2007). This means, that swine-breeding farms are increasing. The concentration of a huge number of animals in one location increases environmental pollution highly.

By spraying liquid manure from animal husbandry enterprises in the fields, groundwater is polluted unevenly: a solid area of polluted groundwater in loamy formations of such fields does not establish. However, it does establish in sandy formations. It covers both the source itself and a section of about 100-150 m in length in the direction of groundwater flow (Žemaitis, 1993).

According to the Law on Environmental Monitoring of the Republic of Lithuania (Lietuvos..., 1997), economic entities creating materials dangerous to natural environment in their activities must perform monitoring of natural environment state.

JSC 'Kontvainiai' is attributable to the group of economic entities that increase technogenic environmental load but do not cause direct danger to environmental objects. The work objective is to establish the influence of a swine-breeding enterprise on the quality of groundwater.

Materials and Methods

The investigations were carried out in the swine-breeding enterprise JSC 'Kontvainiai' which is established on the southeast part of Klaipėda district, to the west from Agluonėnai township in 2001-2005. Production activities are carried out on a 23.96 ha production territory (10.0 ha are built with production buildings, and liquid manure collectors are erected on 12.96 ha area). This compact territory can be divided into 3 parts: the northern, central, and southeastern. There are an administration building, barns and other buildings in the southeastern part, and slurry collectors (liquid manure reservoirs) and fields for spraying in the northern part (140 ha) in which a functioning spraying system is installed. Perennial grasses grow in sprayed areas. The structure of JSC 'Kontvainiai' territory is showen in Figure 1.

Judging by the local hydrographical network, groundwater horizon takes in quite a large area located in the valley between the Minija and its tributaries-the Agluona and the Rokupis. JSC 'Kontvainiai' and the fields for spraying occupy the central and southeastern parts of this area, therefore, the groundwater in the discussed territory, which accumulates during the infiltration of rainfall and polluted water sprayed in the fields, flows to the southeast, south, and southwest. In the east, the polluted water comes into the Agluona and its tributaries and moves westwards and northwards to the Rokupis and its tributaries from the western part of the sprayed fields (Fig. 1). Therefore, the economic activities of the company JSC 'Kontvainiai' in the territories to the southeast, south, west, and northwest can just affect groundwater (UAB 'Kontvainiai' …, 2000).

Figure 1. Situation scheme of JSC 'Kontvainiai' M 1:50000:
1...4 – groundwater monitoring boreholes;
→ – flowing direction of groundwater.

To establish groundwater quality, 4 boreholes were installed in moraine sandy loams, loamy sands, and sands. Observations in borehole 1 (depth h=4 m) allow monitoring of groundwater in the western part, in borehole 2 (h=4.5 m) – in the central part of the fields for spraying, and observations in borehole 3 (h=6 m) enable achieving information on the groundwater in the eastern edge of the spraying for fields. A similar function is performed by borehole 4 (h=6 m), only regarding the information on hydrochemical state of the water flowing out of the fields for spraying and moving below liquid manure reservoirs (Fig. 2).

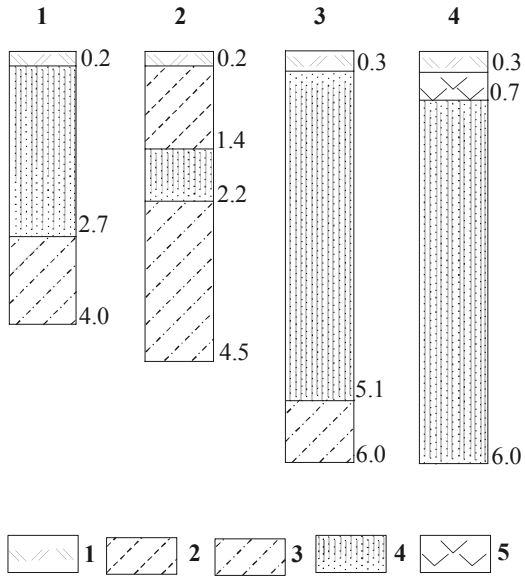

Figure 2. Ground profiles of boreholes: 1 – humus soil layer; 2 – sandy loam; 3 – loam; 4 – sand; 5 – peat.

The complex breeds 1600 units of sows and 7900 units of fattening pigs, which results in 42 187 m^3 of slurry per year. Manure fractioning gives 4200 m^3 of solid fraction and 37 987 m^3 of liquid manure. A totally of 48 000 m^3 of household waste are accumulated from Agluonėnai settlement, where the overall amount of accumulated slurry makes 85 987 m^3 and 4 200 t of filtered manure of solid fraction. The amount of nitrogen in the slurry was established to be 0.87 kg t^{-1}, and of phosphorus – 0.05 kg t^{-1}, but in solid manure – 4.35 and 2.4 kg t^{-1}, respectively.

The slurry diluted with the household waste from Agluonėnai settlement was sprayed in the area of 140 ha. The annual rate of spraying is 125 m^3 ha^{-1}.

The samples of groundwater were taken from monitoring wells 2 times per year: in spring before starting fertilization, and in autumn at the end of fertilization period after the last spraying of slurry. The following indicators were established in water samples: NH_4^+, NO_3^-, NO_2^-, N_{total}, P_{total}, total oxygen demand (TOD), and chemical oxygen demand (COD). Additionally, once a year during spring sampling, groundwater samples were taken to establish macrocomponent composition.

Chemical analyses of water samples were made in the Chemical Analysis Laboratory of the Water Management Institute of the Lithuanian University of Agriculture by applying unified methods (Unifikuoti nuotekų…, 1994).

Mathematical and statistical analysis of the test study was performed with the help of standard computer program 'Excel'. There were calculated the means and medians of the chemical elements group, minimal, maximum values and coefficient of variation were established.

Results and Discussion

There are mineral and organic materials dissolved in groundwater. They pass into water with run-off and precipitation and form in the water due to the living activities of water organisms and products of decomposition. Slurry and household waste from Agluonėnai settlement are sprayed in the fields of JSC 'Kontvainiai' swine-breeding complex. This run-off is the source or organic materials.

Mathematical statistical analysis was made on the basis of five-year research data. The indicators describing pollution of water with organic materials are presented in Table 1. The group mean defines the research data in the best way. It is statistically the closed point to all the variants of the statistical line. The group mean is calculated as the sum of all the feature values divided by the number of the data. Median was used to define the mean values.

Table 1

Statistics of groundwater hydrochemical parameters

Indices	COD	TOD	N_{total}	P_{total}
Maximum	342.00	96.0	44.40	0.90
Minimum	4.56	2.4	0.25	0.01
Mean	28.70	10.8	7.10	0.14
Median	15.85	6.5	5.81	0.06

Hydrochemical data varied a lot during the research period (e.g., the minimum and maximum values of COD differ 75 times, the total oxygen demand 40 times, N_{total} -178 times, and P_{total} -90 times). The highest variation is observed in the range of maximum values; therefore, the arithmetic averages are much higher than their median values. In mathematical statistics, median is a value when the number of higher and lower values than the median is equal. Conditionally, it can be stated that the values lower than the median reflect a normal state of pollution, and the higher values – the state of increased pollution. Thus, on the basis of the available data, COD values lower than 15.85, TOD lower than 6.5 mg O_2 l^{-1}, N_{total} lower than 5.81 mg l^{-1}, and P_{total} lower than 0.06 mg l^{-1} are counted as normal. But the higher values are considered to belong to the category of increased values (Figs. 3, 4).

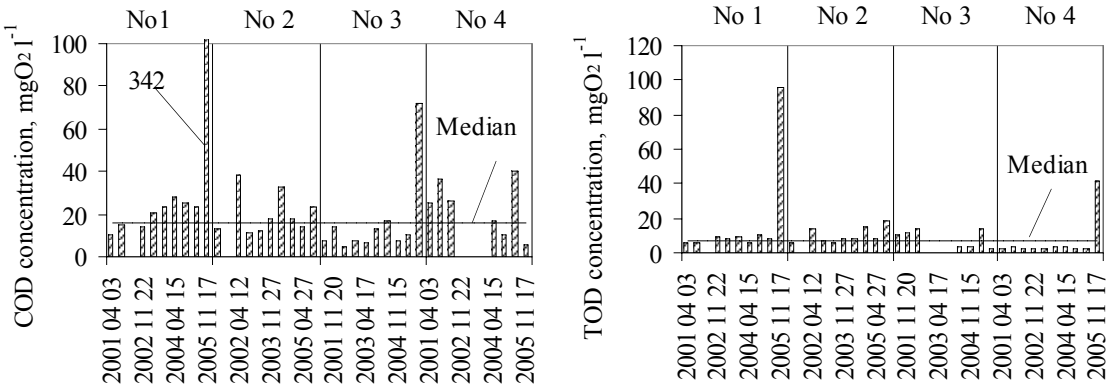

Figure 3. Values of COD and TOD in groundwater.

If assessing by COD, which shows the shortage of oxygen for the oxidation of chemical materials, the highest pollution was observed in the western part of the spraying fields where borehole 1 was situated. As this value most often was higher than a median – 1.3 times in April 2003, 1.4 times in November, in April 2004 it was higher 1.8 times, in November - 1.8 times, and in April 2005 it was higher 1,5 times, in November – even 21.5 times. The cleanest water was in borehole 3, except in one case when COD of a sample taken on November 15, 2005 was 4.5 times higher than the median.

The cleanest water, judging by permanganate oxidation, during five-year investigations was in borehole 3 compared with the median (Fig. 3). However, the index of permanganate in the samples taken in the autumn of 2005 was much higher than the median (13.9 times) in boreholes 1 and 3 (6.1 times).

The investigation results show that the trace of organic matter presence was prime in borehole 1 as the values of COD and permanganate number were the highest. The irregularity of the relief of spraying area had the effect on that – there is a depression in the place of the borehole installation which accumulates the runoff that failes to sink into the soil. A larger amount of runoff accumulates in this place, which has an impact on the quality of groundwater.

Concentration values of N_{total} higher than the median were observed in boreholes 3 and 4. These boreholes are located near the slurry reservoirs. The cleanest is well 2 as the only sample showed the concentration of N_{total} higher than the median. On November 15, 2004, N_{total} concentration was 7.6 times higher than the median (Fig. 4).

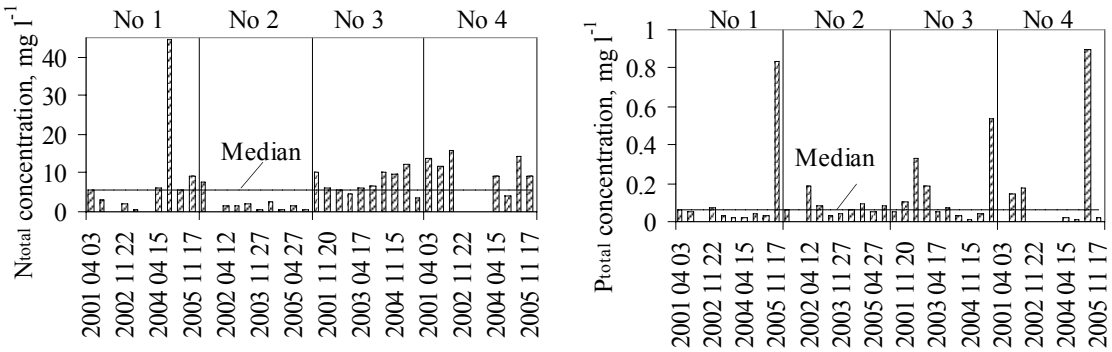

Figure 4. Contentrations of N_{total} and P_{total} in groundwater.

P_{total} concentrations in groundwater varied least in boreholes 1 and 2, except on November 17, 2005 when P_{total} concentration in well 1 was 43 times higher than the median. Whereas P_{total} concentrations in wells 3 and 4 often were higher than the median value; the highest value (0.9 mg l^{-1}) on November 17, 2005 was observed in well 4 with one soil layer of peat during five years of the research period. In the northern part of Lithuania it was established that P_{total} concentrations were higher in the wells installed in peat reaching 0.56 mg l^{-1} (Rudzianskaitė and Sukys, 2002), because peat increases migratory features of phosphoric compounds (Narbutas et al., 2001).

The analysis of the chemical composition of groundwater showed that the highest amount of dissolved mineral materials was observed in borehole 4 (Table 2). The total dissolved solids there made 728 mg l^{-1}. Bicarbonates in the borehole water made from 43 to 58%, and calcium ions – from 12 to 18 % of the total dissolved solids.

Table 2

Groundwater chemical composition, mg l^{-1}

Borehole	NH_4^+	K^+	Na^+	Ca^{2+}	Mg^{2+}	HCO_3^-	SO_4^{2-}	Cl^-	NO_3^-	NO_2^-	TDS
1	1.4/224	23/226	37/187	109/46	15/68	382/89	47/54	61/165	22/213	0.1/226	699
2	0.6/100	12/31	13/36	82/17	12/57	262/16	52/54	17/54	2/112	0.1/234	454
3	0.6/160	19/28	27/258	47/45	11/67	196/95	18/79	25/179	26/56	0.1/203	369
4	5.4/124	28/66	103/93	86/31	16/63	313/63	66/76	94/98	14/79	3.3/194	728

Note. The mean/coefficient of variation, %; TDS – total dissolved solids.

As it is stated in the literature (Rudzianskaite and Sukys, 2008), reduction environment of peat has the highest effect on nitrogen of all biogenic elements and converts the nitrate form (NO_3^-), which is not so harmful, into an especially harmful nitrous one (NO_2^-). The data in Table 2 shows that well 4, which is bored into a peaty soil layer, has 33 times more nitrites and 4 to 9 times more ammonium compared with the boreholes installed in sandy soils.

The concentrations of chlorides and sulphites in the groundwater of all boreholes were lower than maximum permissible concentration (MPC) (Lietuvos…, 2003). As the literature states (Никаноров, 1989), with the increase of water mineralization, the concentrations of chlorides and sulphates increase as well. As the highest mineralization was observed in the water of borehole 4, the highest concentration of chlorides and sulphates (241 and 110 mg l^{-1}, on April 03, 2001 and November 17, 2005, respectively) was observed there as well (Fig. 5).

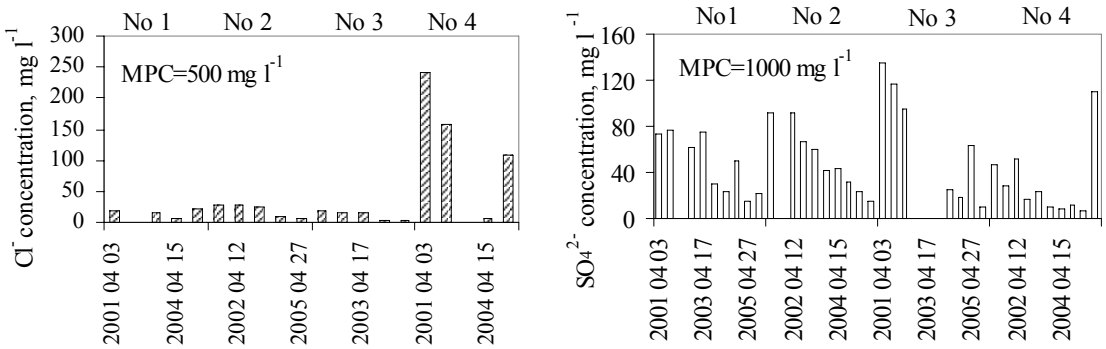

Figure 5. Chlorides and sulphates in groundwater.

The most important elements having the greatest influence on groundwater quality in the fertilized areas of swine-breeding enterprises and production territories are biogenic elements – nitrogen and phosphorus.

Nitrogen concentration fully depends on the intensity of biochemical and biological processes that take place in water. Nitrogen in natural environment can be found in different inorganic and organic compounds. Inorganic compounds include the ions of ammonium NH_4^+, nitrite NO_2^-, and nitrate NO_3^-. These compounds show whether the water is polluted and toxic.

The concentrations of ammonium nitrogen were also 2 times higher than MPC in borehole 4 (11.2 and 11,7 mg l^{-1}, on April 12, 2002 and April 27, 2005, respectively). That was determined by nitrification and denitrification conditions as the water in peat has more organic matter which requires quite a large amount of oxygen to be dissociated. Therefore, microorganisms use not only free oxygen but also nitrate and nitrite oxygen for oxidation (Никаноров, 1989) (Fig. 6). In other boreholes the concentrations of this element were lower than MPC; therefore, it can be stated that in those wells the water was clean.

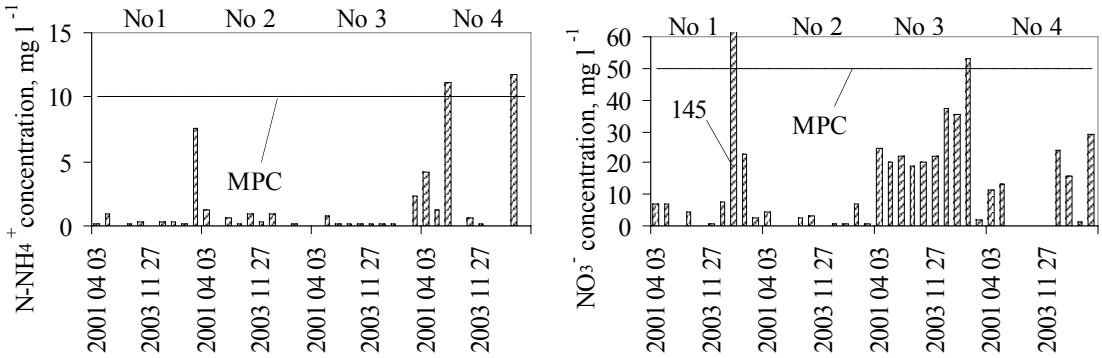

Figure 6. Variation in the concentrations of ammonium nitrogen and nitrates in groundwater.

During the five-year research period, nitrate concentrations in the boreholes were only 2 times (wells 1 and 3) higher than MPC (Fig. 6). This chemical compound varied most in borehole 3; however, the concentrations were not higher than MPC, except in two cases, when the concentration was 1.1 times higher on April 27, 2005, and in borehole 1 where NO_3^- concentration was 2.9 times higher than MPC on November 15, 2004.

Figure 7 shows that nitrites varied most in well 4, in which the concentrations were 2 times higher than MPC during the research period (3.65 and 17,4 mg l^{-1}, on April 03, 2001 and November 20, 2001, respectively). Water was clean in other boreholes where the concentrations were not higher than MPC.

There is very little phosphorus in natural water. When the concentration of phosphorus in water increases, the water is polluted – phosphorus compounds show that dissolution of complex organic materials takes place in the water.

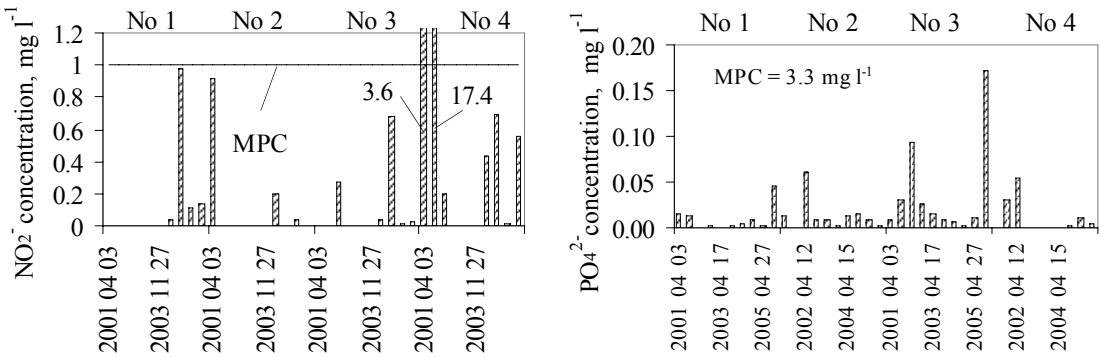

Figure 7. Variation in the concentrations of nitrite and phosphate in groundwater.

During the five year research period, the amount of phosphates in all boreholes was very small (Fig. 7), therefore even the highest phosphate value (0.53 mg l^{-1}) actually was 6.2 times lower than MPC. According to the amount of phosphates in groundwater, the water in all observed boreholes was clean.

V. Žemaitis, who had been investigating migration of moisture and pollution in the aeration zone, established that there is danger of polluting groundwater horizon of larger areas in sandy cross-sections, as the lateral runoff prevails there and transports pollutants in horizontal direction. In places where non-permeable moraine loams prevail, distribution of pollutants in horizontal direction is not high. It is concentrated locally in the source of pollution and most often spreads in vertical direction. Thus, in such situation, pollution is especially dangerous for the water horizons that are situated lower (Žemaitis, 1993).

Also the chemical composition of groundwater in JSC 'Kontvainiai' depended on the direction of groundwater movement. As groundwater is moving to the southeast, south, and southwest from the area fertilized with slurry, mineralization of the water in boreholes 1 and 4 is the greatest – 699 and 728 mg l^{-1}, accordingly.

Conclusions

1. The water quality found in the boreholes under study corresponded to groundwater requirements, with the exception of some instances where the ammonium nitrogen, nitrite and nitrate concentrations exceeded the highest permitted levels. These were isolated instances from different boreholes, making it impossible to define a distinct trend in groundwater pollution.
2. Variations of organic compounds in all boreholes were not high, except the case in well 1 where the concentrations of COD, TOD, N_{total}, and P_{total} were significantly higher. COD, N_{total}, and P_{total} concentrations varied more in borehole 4 compared with other boreholes.
3. The chemical composition of groundwater depended mainly on the soil. Total dissolved solids were up to 2 times more in the water of borehole 4 which was installed in the soil having a peat layer.
4. The chemical composition of groundwater depended on its movement direction as well. As groundwater moves to the southeast, south, and southwest from the fertilized area, the amount of total dissolved solids of the water in boreholes 1 and 4 is the highest – 699 and 728 mg l^{-1}, respectively.

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RESEARCH OF TREATMENT OF WASTEWATER FROM MILK COLLECTION STATIONS IN SAND FILTER

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Abstract

Highly polluted wastewater accumulates in milk collection stations. Its biochemical oxygen demand (BOD_5) ranges from 369 to 1388 mg O_2 l^{-1}. The average contamination was 600 mg O_2 l^{-1}. There was a comparatively small amount of biogenic materials in it: total nitrogen – 27.3, total phosphorus – 5.0 mg l^{-1}. When variations of wastewater amounts are high, sand filters of vertical filtration are successfully used for the treatment of household wastewater. Model investigations were carried out to establish the possibilities of using these filters in treating wastewater in milk collection stations. The efficiency of wastewater treatment with these filters was 99.3% by BOD_5, 99.1% – by suspended solids, 91.2% – by total nitrogen and 98.8% – by total phosphorus.

According to the research results dependency equations were made; they were used to calculate the amount of main contaminants in milk collection stations that infiltrated through a layer of silt of different thickness. The calculations showed that wastewater treatment to permissible limits is ensured by filtration through 0.6 m thick layer of sand. The average treatment level by BOD_5 in such a filter of vertical filtration would be 20 mg O_2 l^{-1} and the treatment efficiency – 95.9%. Treatment efficiency of total nitrogen would be 88.1%, total phosphorus – 96.9, suspended solids – 95.5%.

Preliminary research in the model showed that sand filters of vertical filtration can be used to treat wastewater from milk collection stations.

Keywords: wastewater treatment, vertical filtration, filtration path, treatment efficiency.

Introduction

Lately sand and plant filters of vertical filtration (VF) have become popular; to install them a smaller area of land is needed compared with filters of horizontal filtration (HF). They remove suspended solids from wastewater more efficiently per surface area unit of the filter compared with horizontal filters, biochemical oxygen demand (BOD_5) are reduced. When filter load by BOD_5 is equal – 4 g m^{-2} d^{-1}, the efficiency of removing organic contaminants VF reaches 97.0, and HF – 77.5%. In order to achieve standard purification level by BOD_5 – 25 mg O_2 l^{-1}, probable VF load has to be 19.0, HF – 6 g m^{-2} d^{-1}. Given the same filter load by suspended solids, their treatment efficiency in vertical filter is 87.3, in horizontal one – 67.5% (Gasiūnas and Strusevičius, 2006). However, biogenic materials are better removed in horizontal filters. When filter load is 1.5 g $m^{-2}d^{-1}$ by total nitrogen, the efficiency of removing this element in horizontal filters reaches 39.6, in vertical filters – 24.0%, hence it is 1.6 times higher. Ammonia nitrogen prevails in the wastewater treated in horizontal filters and nitrate nitrogen – in wastewater treated in vertical filters (Gasiūnas and Strusevičius, 2005).

Milky wastewater is highly contaminated with organic contaminants – BOD_5 reaches up to 6000 mg O_2 l^{-1}. Such wastewater needs primary treatment. 98.6% of organic contaminants are removed from it in aeration installations. After deep treatment has been carried out in sand-plant filter its contamination is reduced by 75.1% and is 21 mg O_2 l^{-1} (Wood et al., 2007).

A great advantage of vertical filters is that 1.6 times less area is needed to install them compared with horizontal ones.

The main objective of the work is to analyse in model the possibilities of using sand filters of vertical filtration for treating wastewater from milk collection stations.

Materials and Methods

Model research was carried out in the Water Management Institute of LUA in 2007. The trial scheme is presented in Figure 1. The wastewater from Padargupiai (Ariogala municipality, Raseiniai district) milk collection station was used for the investigations; primary treatment had been carried out in an experimental wastewater treatment plant.

The area of the vertical filter model is 0.2 m^2. According to the experience of other authors (Gasiūnas and Strusevičius, 2004) the selected filtration path length was 0.8 m. One more vertical filter model of the same diameter was installed as well (filtration path – 0.4 m). The same wastewater was applied to both filters. On the basis of the achieved research data equations of dependencies of the main contaminant treatment on the filtration path were made.

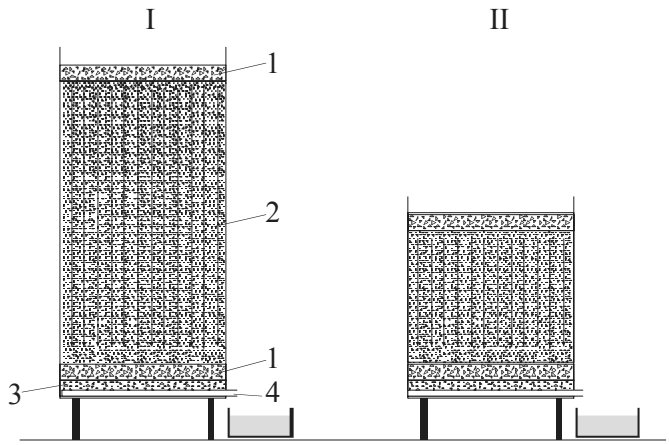

Figure 1. Models of vertical filters: I – filtration path length 0.8 m; II – filtration path length 0.4 m; 1 – chippings; 2 – fractional sand; 3 – fractional gravel; 4 – outlet pipe.

A required area need for sand and plant filters in treating household wastewater by BOD_5 is calculated using the following formula (Gasiūnas and Strusevičius,2007; Cooper, 1999):

$$A=, \quad A=\frac{Q(\ln C_0 - \ln C_v)}{K_r}, \qquad (1)$$

A – necessary surface area of the filter, m^2;
Q – wastewater discharge, $m^3 d^{-1}$;
C_0 – BOD_5 of wastewater inflow, mg l^{-1};
C_v – normative BOD_5 after the treatment, mg l^{-1};
K_r – reaction constant, m d^{-1}.

In calculations of horizontal filter area K_r is equal to 0.056 m d^{-1}, vertical filter – 0.09 m d^{-1}. During the analysis the average wastewater contamination by BOD_5 indicator was 600 mg O_2 l^{-1}. To treat 1 m^3 of wastewater of such contamination filters with the following areas are needed: horizontal filtration filters – 57 m^2, vertical filtration filters – 35 m^2. The load on the vertical filter will be 0.03 m^3 of wastewater on 1 m^2 per day. According to these calculations we established the load rate on model filters. As model areas are 0.2 m^2 each, we applied wastewater 2 times per day 3 litres every time.

To install the vertical filter model coarse sand with filtration coefficient 39.5 m d^{-1} was used. Quarry sand was used for investigations. It was mixed well before filling the models. The investigations continued for 3 months. Wastewater from the milk collection station was brought 3 times per week. Production conditions were imitated, so wastewater was poured into the models 2 times each day. The samples for laboratory analyses were taken 2 times per month. Wastewater analyses were made in the certified Chemical Analysis Laboratory of the Water Management Institute of LUA by applying unified methods (Unifikuoti ..., 1994). The following indicators were established: BOD_5, pH, $N\text{-}NO_2$, $N\text{-}NO_3$, $N\text{-}NH_4$, N_{total}, P_{total} and suspended solids.

Results and Discussion

Wastewater from the milk collection station of different contamination rate was used for investigations. Its contamination with easily dissolvable organic contaminants by BOD_5 indicator ranged from 332 to 860 depending on the amount of water used for cleaning containers and the average contamination was 600 mg O_2 l^{-1} (Table 1).

Table 1

Main chemical indicators of investigated wastewater from milk collection station

Index mg l^{-1}	BOD_5	pH	N_{total}	P_{total}	SS	Cl	SO_4
Before treatment min – max	332 – 860	6.2 – 7.2	14.8 – 43.2	7.9 – 2.0	184 – 492	195 – 329	223 – 644
average	600	6.7	27.3	5.0	270	246	449

Filter load with organic contaminants ranged from 10 to 26 g m^{-2} d^{-1} BOD_5. 99.3% of organic contaminants are stopped when wastewater flows through a vertical 0.8 m thick sand layer. Even in the cases when wastewater contamination was 3 times higher than that of household wastewater – 860 mg O_2 l^{-1}, the contamination of wastewater coming out of the filter was 12.4 mg O_2 l^{-1} (Figure 2). As long-term analyses of Padargupiai milk collection station suggest the highest contamination with organic contaminants reaches 1388 and the average contamination is – 821 mg O_2 l^{-1}. Therefore, wastewater contamination has to be reduced by using coagulant 'ZETAG 8660'. Having poured 4 g of this coagulant into 1 m^3 wastewater contamination with organic contaminants is reduced down to 68% within 6 hours and does not exceed the contamination of household wastewater on average. In such a case filter load with organic contaminants would be reduced 1.5 times.

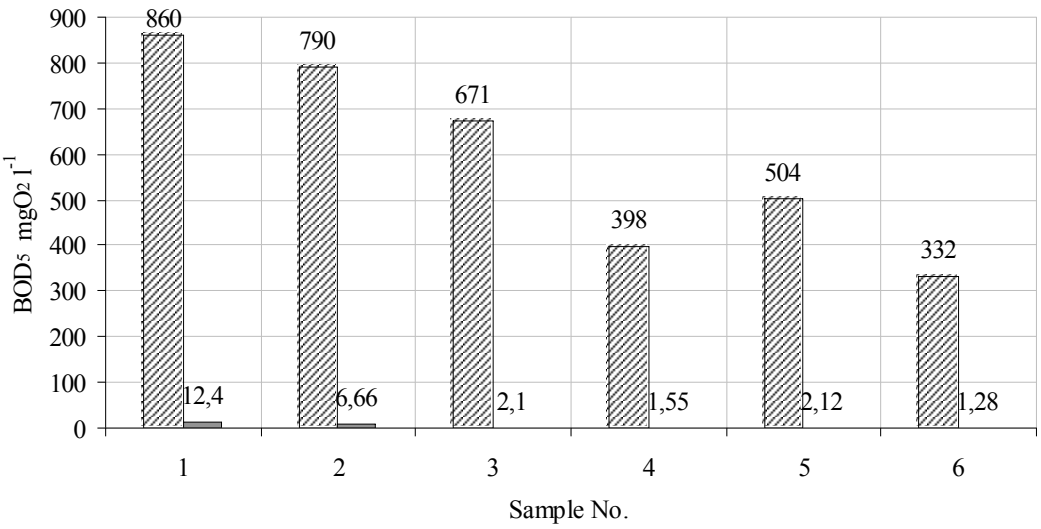

Figure 2. Contamination of wastewater entering and leaving vertical sand filter model by BOD_5.

Before treatment ▪ After treatment

At the moment strict requirements are raised for all wastewater treatment plants: wastewater released to open water courses cannot have concentrations higher than: 30.0 – for total nitrogen, 5.0 – for ammonium nitrogen, 0.3 mg l^{-1} – for nitrite nitrogen (Nuotekų ..., 2006). The amount of biogenic materials in wastewater from the milk collection station is doubly smaller than in household wastewater. The average amount of total nitrogen is lower than permissible even in untreated

wastewater. When primary wastewater treatment is performed applying coagulant 'ZETAG 8660' the amount of total nitrogen is additionally reduced by 2.2. The investigations showed that only after wastewater has been treated in two stage septic system, it can be purified in the vertical filter model up to 91.2%, from 22.7 to 2.0 mg l^{-1} on average. The highest contamination of treated wastewater was 4.2 and the least was 0.08 mg l^{-1} (Figure 3). Treatment in vertical filters is taking place under aerobic conditions. Besides, 90% of wastewater is accumulated within 5 hours in the milk collection station. Therefore, the wastewater was poured into filter only 2 times per day, thus the filter was not functioning for the better part of a day. Under such conditions the efficiency of filter function increases even more.

Before treatment wastewater had 0.2% nitrates and 29.2% ammonia nitrogen. As nitrogen comes into treatment installations mainly in the form of ammonia, due to contact with oxygen, it first of all turns into nitrate nitrogen and due to the effect of oxygen – gaseous nitrogen, and then it is removed from wastewater. The investigations were made when air temperature was 18–20 °C, therefore, nitrate nitrogen prevails in treated wastewater – 84.2% and ammonium nitrogen makes only 2.8%. As other authors indicate (Gasiūnas and Strusevičius, 2004), during cold season ammonium nitrogen prevails in the wastewater coming out of the filter and after air temperature rises up to 8.4 °C the amounts of nitrate and ammonium nitrogen become equal. There is not much nitrite nitrogen in the wastewater: before treatment it accounts for 0.04, after treatment – 0.02 mg l^{-1}.

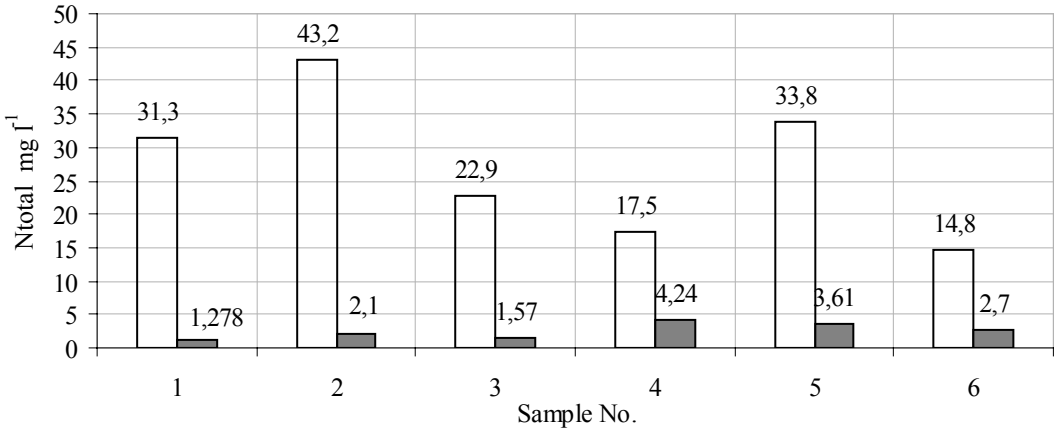

Figure 3. Contamination of wastewater entering and leaving vertical sand filter model by total nitrogen.

□ Before treatment ■ After treatment

Small amount of total phosphorus can be explained by the fact, that detergents are used to wash containers and they have little phosphorus. The largest amount of phosphorus in the wastewater used for research was 7.9 and the smallest – 2 mg l^{-1} (Figure 4). The investigations showed that total phosphorus is removed more efficiently than total nitrogen in the vertical filter by 98.8% on average. However, as the majority of authors indicate (Ciupa, 1996; Kadlec, 1985), the efficiency of air removal is rather high only in the beginning of filter action, but later, after the ground is saturated with phosphates it decreases to the minimum. In the majority of filters the efficiency of phosphorus removal is not higher than 50% (Verhoeven and Meuleman 1999). The efficiency of phosphorus removal in the vertical filter of the inn 'Pastogė' decreased from 60 to 20% during a year (Gasiūnas and Strusevičius, 2004).

The milk collection wastewater is little polluted with total phosphorus – 5 mg l^{-1} (Table 1) on average. After the primary treatment with coagulant 'ZETAG 8660' wastewater contamination would decrease 2.6 times (down to 1.9 mg l^{-1}) on average and 20% of phosphorus would be needed to remove in the vertical filter down to permissible 1.5 mg l^{-1} limit.

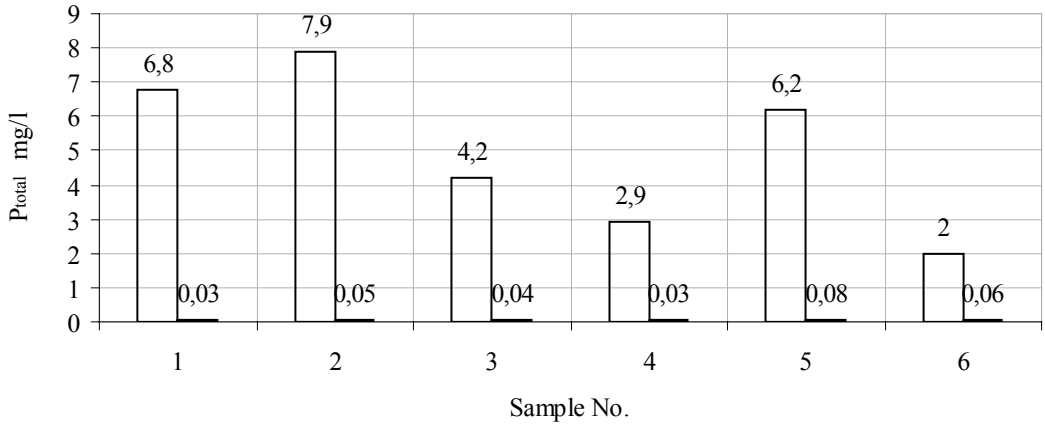

Figure 4. Contamination of wastewater entering and leaving vertical sand filter model by total phosphorus

□ Before treatment ■ After treatment

When chemically untreated wastewater is used, there is a risk of filter clogging as the amount of suspended solids is large, 270 mg l^{-1} on average. Suspended solids from wastewater are treated with 99.1% efficiency in the vertical filter model. The largest amount in the treated wastewater was 5.8 mg l^{-1} – 5.2 times smaller than the permissible rate.

To have wastewater treated appropriately its active reaction in sand filters is of key importance. The optimum medium for biological processes to take place is wastewater pH equal to 7–8. The average pH of the wastewater used for investigations was 6.7 and ranged from 6.2 to 7.2. After the infiltration of wastewater both through 0.4 and 0.8 m thick sand layer in the vertical sand filter model pH was the same – 8.

Recently, if there is no collector of treated wastewater nearby and the groundwater horizon in high, at first, household wastewater is treated in the vertical filter and later they are released to the field of undergroundfiltration. The same pattern could be applied in treating wastewater from milk collection stations. Economically, it is important to find such thickness of the sand layer which would ensure wastewater treatment to permissible limits. In order to calculate wastewater contamination in any point of filtration route the dependencies of main pollutant treatment on the path length was made (Figure 5, 6, 7 and 8).

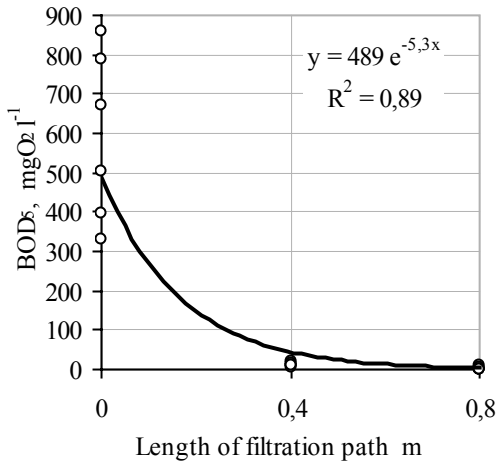

Figure 5. Dependency of treatment of organic pollutants on filtration route length.

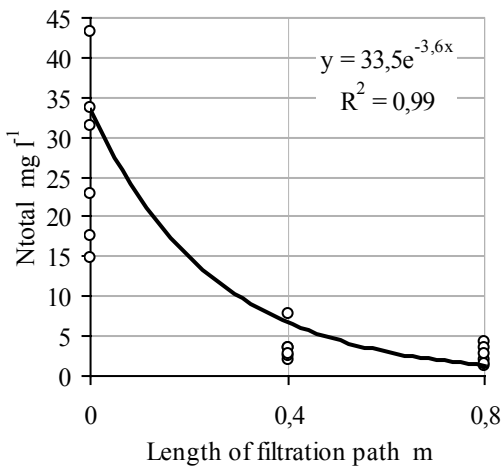

Figure 6. Dependency of treatment of total nitrogen on filtration route length.

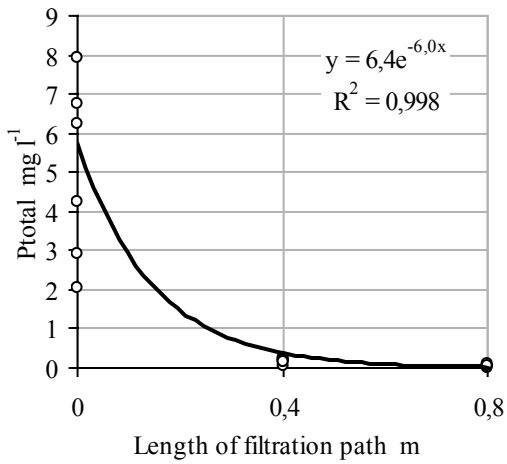

Figure 7. Dependency of treatment of total phosphorus on filtration route length.

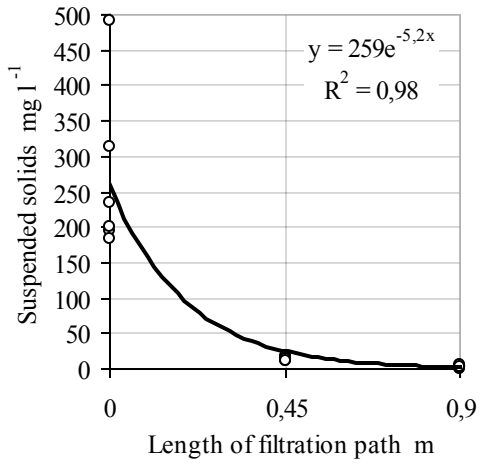

Figure 8. Dependency of suspended solids decrease on filtration route length.

By using the achieved dependency equations the amounts of the main pollutants in the wastewater from milk collection stations that infiltrated though sand layers of different thickness were calculated. Calculation data is given in Table 2.

Table 2.

Purification of wastewater from milk collection stations depending on filtration path length

Index	Length of filtration path m									
mg l^{-1}	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
BOD_5	489	288	171	100	60	35	20	12	7	4
N_{total}	33.5	23.5	16.8	11.6	8.2	5.7	4.0	2.8	2.0	1.4
P_{total}	6.4	3.5	1.9	1.1	0.6	0.3	0.2	0.1	0.05	0.03
SS	286	171	102	61	36	22	13	8	5	3

It can be seen from the table that 0.6 m thick sand layer is sufficient to purify wastewater to permissible limits. The average treatment level by BOD_5 in such a vertical filtration filter would be 20 mg O_2 l^{-1} and treatment efficiency – 95.9%. The treatment efficiency of total nitrogen would be 88.1%, total phosphorus – 96.9% and suspended solids – 95.5%.

Preliminary investigations carried out in the model showed that the vertical sand filter would be an optimal alternative for the treatment of wastewater from milk collection stations. Whereas such stations are mainly situated in rural areas, where the primary wastewater treatment with coagulants is not always carried out as it is provided for in the project, high efficiency of removing organic contaminants and suspended solids would prevent pollution of surface waters. Biogenic materials are treated less efficiently in the filters of vertical filtration compare with those of horizontal filtration, however, as the contamination of wastewater from milk collection stations with them is less than that in household wastewater, they will be purified until permissible limits.

The research was made only of the treatment of wastewater from milk collection stations by filtrating them through sand. Filter action is improved by marshy plants. In wastewater treatment plants have more of an indirect role: their roots and rhizomes are needed for the ground and oxygen to maintain the growth of aerobic organisms; these microorganisms stimulate decomposition of wastewater, increase and maintain hydraulic permeability of the ground. Plants act as catalysts giving away oxygen and other substances to other living organisms participating in the removal of biogenic materials. Therefore, it is necessary to have a vertical filter used for treating wastewater from milk collection stations overgrown with reeds.

Conclusions

1. Preliminary research in the model showed that vertical filters can be used to treat wastewater from milk collection stations. The efficiency of wastewater treatment was 99.3% by BOD_5, 99.1% – by suspended solids, 91.2% – by total nitrogen and 98.8% – by total phosphorus.
2. Treatment to permissible limits is ensured by filtration through 0.6 m thick layer of sand. The average treatment level by BOD_5 in such a filter of vertical filtration would be 20 mg O_2 l^{-1} and the treatment efficiency – 95.9%. Purification efficiency of total nitrogen would be 88.1%, total phosphorus – 96.9, suspended solids – 95.5%.

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MODERNISATION OF MANURE MANAGEMENT TECHNOLOGIES IN LARGE PIG COMPLEXES OF LITHUANIA

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Abstract

Technologies of keeping livestock and management of manure pig complexes holdings built in the country under the Soviet regime no longer satisfy modern veterinary and environmental requirements. Conditions for the modernisation of such complexes were created as from 2000, when agricultural aid programmes (funds) appeared in Lithuania. Information about old and newly implemented manure management technologies, fertilisation value of manure, and quality of the drainage runoff from manure-fertilised fields has been collected in six large livestock companies. Analysis of collected data revealed that new livestock keeping, feeding and manure management technologies are more cost-effective in using energy and mineral resources and conform to the animal welfare, environmental protection and hygiene requirements that are becoming more and more stringent. As the traditional manure management in economic terms is quite expensive and has a significant impact on the environmental quality, academic community is looking for new manure processing methods. The global development of manure management technologies focuses on the manure processing in biogas plants. Biogas generated from liquid manure and animal waste in such plants is an alternative source of energy.

Key words: manure, fertilising value, spreader, pollutants.

Introduction

Currently, the modernization and development of large pig complexes is a top issue in the livestock sector. Due to high amounts of animal units in one place, large livestock holdings are more dangerous to the environment than the small ones. In spite of this, currently the development of livestock holdings is orientated to the increase of capacity all over the world, because in such enterprises it is much easier to implement more productive and more economical equipment, to automatize technological processes and in such way to reduce the cost price of production. Moreover, in large livestock holdings it is possible to implement advanced systems of work organization, work control, work security, and environment protection management. Therefore, the most urgent projects are those aimed at the implementation of modern cattle breeding, feeding and manure handling technologies saving energy, nature resources, and satisfying all requirements of animal welfare, environment protection and hygiene.

Since 2000, agricultural support programs (funds) have been established, which ensured perfect conditions for the modernization of livestock farms. In large pig complexes the systems of cattle breeding and shed ventilation were changed, new manure sites were constructed. No water was used to remove manure from sheds.

In 2006, in Lithuania there were 0.8 million cattle units, 1.1 million pigs, 9.4 million poultry units, and 0.2 million units of other animals (goats, sheep, horses) (Statistikos…, 2006). According to the calculations, about 560 thousand ha are needed in this country in order to spread the manure produced by animals and poultry considering all environment protection requirements. This makes up about 16% of all agricultural land use of Lithuania (3.487 mln ha) (Statistikos…, 2006). Such area of land with manure applied is not very large, therefore the country has resources for the expansion of cattle breeding in order to develop a well-balanced agricultural system. Manure is described as a product maintaining the humification process of the soil. When developing the plant growing based on mineral fertilizers it is rather difficult to maintain

the humus of the soil. When there are no animals, fields are not fertilized with organic fertilizers, which results in reduced amounts of humus in the soil. When the same crops are grown in crop rotations, more mineral fertilizers and crop protection means are needed in order to maintain crop productivity. After some time the soil becomes exhausted, plant uptake of nutrients worsens, production is getting more expensive, and the environment pollution is increasing (Pažangaus..., 2000). As the scientist Tripolskaja L. refers in her monograph, when no organic fertilizers are applied, the amount of humus contained in the soil decreases by 19.5% within the period of 11 years (Tripolskaja, 2005). Therefore it is very important to modernize old livestock holdings, construct new ones, and encourage their vital capacity. In livestock holdings constructed during the Soviet period, cattle breeding and manure handling technologies do not meet the veterinary and environment protection requirements anymore. Only the construction of manure sites meeting the requirements of environment protection will demand about 785.3 million Lt of investments (Šileika, 2001).

The objective of the work is to analyze the tendencies of the new manure handling technologies in large pig complexes, as well as to estimate their perspectives.

Materials and methods

To carry out the study, the works of scientists from foreign countries and from Water Management Institute of Lithuanian University of Agriculture dealing with manure handling technologies were used; also the information about the new realized projects when modernizing large livestock holdings (more than 3000 pig units) was considered. The material about the implemented projects of new technologies was collected in four pig breeding companies: 'Gražionių bekonas' (Radviliškis district), 'Girkalnio kiaulių kompleksas' (Raseiniai district), 'Sajas' and 'Berka' (Kelmė district). The information for the comparison was collected from large pig-breeding complexes where old pig breeding and manure handling technologies are used, i.e., when water is used for manure removal from sheds 'Krekenavos agrofirma' (Panevėžys district), and 'Litpirma' (Radviliškis distric). In those objects the technological solutions were analyzed, the comparison of data about manure composition, data about manure spreading rates during field fertilization was made, as well as pollution dynamics of drainage water released from fields with manure applied. Mathematical and statistical analysis of test study results was used for mathematical processing of data.

Results and discussion

Manure handling technologies applied in large pig complexes. During the Soviet period, in Lithuania, 33 large pig complexes were built, where the same manure removal technology – hydraulic removal of manure – was applied. In 1995, having evaluated the ecological conditions in those complexes, the Government of Lithuania prepared a program for their modernization (LR Žemės..., 1995). In all complexes, manure from sheds was removed in a hydraulic way – i.e., using subsurface or surface water. Fertilization value of manure was low due to its dilution with water. Moreover, accumulation of such diluted manure (slurry) requires very large reservoirs. In agricultural company 'Girkalnio kiaulių kompleksas', reservoirs of 160 thousand m^3 capacity were arranged. After modernization of the complex, when no more hydraulic manure was applied, the sufficient capacity of reservoirs was reduced to 8.6 thousand m^3. 'Sajas' had slurry reservoirs with the capacity of 140 thousand m^3, but after modernization the capacity of 30 thousand m^3 was enough. Figure 1 presents the dependence of manure quantity produced from one place of weight of a 20-100-kg pig on the manure moisture (dilution).

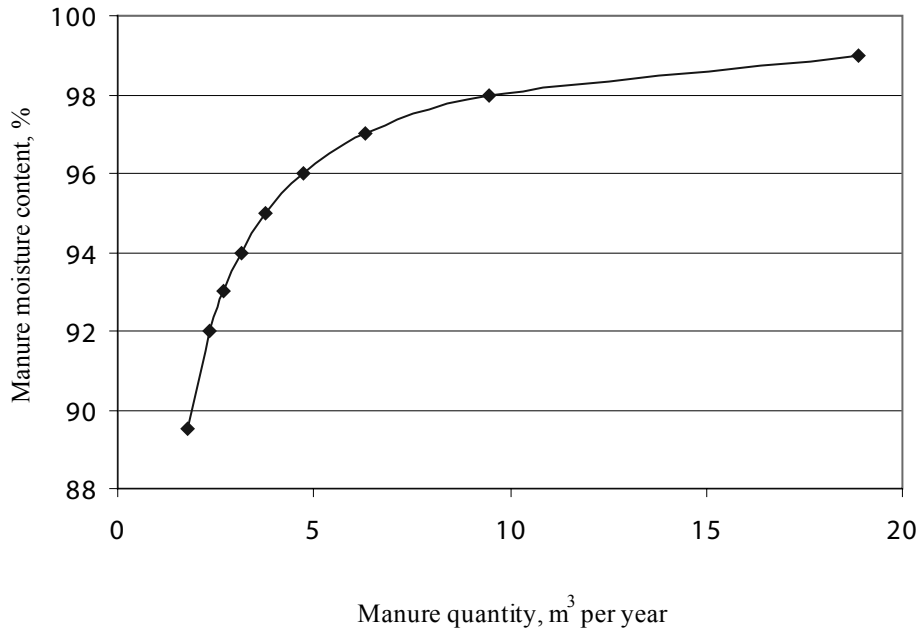

Fig. 2. Dependence of manure quantity produced from one place of weight of a 20-100 kg pig on manure moisture (dilution).

During the reconstruction of old sheds, their old floor is removed, and manure baths with self-flow collectors are arranged. The baths are covered with grating. Liquid manure from the baths is removed with the help of self-flow pipe collectors. On the bottom of the bath, a pipe for the release of manure is arranged, which is closed with a cork. The cork is taken out only when the bath is fully filled with manure. Such system is simple and comfortable to use. It is particularly efficient when manure contains about 8-12% of dry matter. Self-flow manure collectors are directed from sheds into the pumping-house. Liquid manure is accumulated in manure reservoirs of a new type – i.e., in reservoirs of cylindrical shape with metal or reinforced walls with reinforced bottom, or in lagoon-type reservoirs with two-level geomembranes (1.5 and 2.0 mm thick). In the reservoir, manure splits up into three layers: upper layer (manure crust), middle layer (slurry), and lower layer (sediment). Those layers make up 10-15%, 20-30%, and 55-70% of the capacity of the reservoir, respectively. The crust partially reduces nitrogen evaporation losses. Before starting the fertilization of fields, manure is accurately mixed in the reservoir with the help of special mixers in order nutrients (nitrogen, phosphorus, potassium, and microelements) would distribute evenly (Strusevičius, 1996).

Liquid manure has many advantages. Due to its compactness it can be properly rated, evenly spread, and can ensure better plant uptake of nutrients (~ 50% of nitrogen per year). Liquid manure can also be used during the whole vegetation season of plants, it can reduce nitrogen losses during the fertilization period to a maximum, because liquid manure can be inserted into the soil. The main advantage of liquid manure is that its handling can be fully mechanized and automatized.

Liquid manure is spread with the help of a spreading plate, hoses, or it is inserted into the soil.

Liquid manure spreading with the help of spreading plates is one of the simplest means. However, during the irrigation, about 20-30% of ammonia nitrogen evaporate into the environment, therefore this way of manure spreading is least suitable from the environmental point of view. Such kind of manure spreader should be used in calm, cool weather, when the soil is not sown up and is immediately ploughed up.

Surface irrigation with the help of hoses has more advantages, because nitrogen losses make up only 10-20%. According to the studies of water Management Institute of Lithuanian University of Agriculture, spreading unevenness is only 3-5%. When using the dragging hoses, liquid manure does not splash over plants, which means this way

of manure spreading is hygienic and can be applied in the sown up soil.

Compared to other liquid manure spreading ways, manure introduction into the soil significantly reduces ammonia losses (LR Žemės…, 2000). Other advantages include less dispersion of odors, and dependence on the wind. However, the main disadvantages include small spreading area, strong tractive force, and low labour productivity.

As liquid manure can be pumped with special pumps, it can be provided to the spreader through flexible pipelines. The use of pipelines for the transportation of manure (especially when the distance to fertilization fields is rather long) may reduce work expenses much better than slurry transportation with tractor spreaders. Z.Strusevičius, a scientist of Water Management Institute of Lithuanian University of Agriculture, after technological measurements has determined that transporting manure in a tank of 8.0 m^3 capacity, the transportation of 100.0 m^3 of manure at the distance of 3 km will require 37.3 l of diesel fuel, whereas pumping of the same amount of manure with diesel engine will require only 9.6 l of diesel fuel (Strusevičius, 1996).

Before spreading manure on fields, the farms investigate the composition of manure produced in their enterprises in special certified laboratories. Table 1 presents the average data of long-term research of Water Management Institute of Lithuanian University of Agriculture: the composition of manure produced on modern pig complexes and the composition of slurry produced on farms using old hydraulic manure removal system.

Table 1

Average data about composition of the liquid manure and slurry (mg l^{-1})

Manure management technology	Organic manure	N_{total}*	P_{total}**	K***
Self-driven liquid manure removal system with covered livestock manure storage facility	Liquid manure	4025**** 3415-4500	784 450-1000	1732 1620-1800
Hydraulic manure removal system, fractioning into slurry and thick fraction, open slurry storage tanks	Slurry	635 548-713	335 277-459	610 522-686

Notes:
** - total nitrogen;*
*** - total phosphorus;*
**** - kalium;*
***** - numerator represents the average value, and denominator – min...maximum values.*

As Table 1 shows, fertilization value of slurry is 6.3 times lower than that of liquid manure. When making up plans about manure usage for field fertilization, farms are orientated towards spreading rates that would ensure nitrogen input amounts with manure no higher than 170 kg per 1 ha (LR Aplinkos…, 2005). Thus, when fertilizing fields with slurry, annual spreading rate is up to 300 m^3 ha^{-1} and when fertilizing with liquid manure, annual spreading rate is up to 38 m^3 ha^{-1}. This means that hydraulic load of fields fertilized with slurry is much higher than that of fields fertilized with liquid manure. Table 2 presents the data of environment monitoring (drainage water outlets) collected at modern agricultural company 'Gražionių bekonas', and at 'Krekenavos agrofirma' using old manure handling technology.

As it is seen from the data in Table 2, applying slurry on fields, nutrient leaching is more intensive a applying liquid manure (according to N_{total}-3.1 times, according to P_{total}-2 times). This is due to more intensive hydraulic load of the fields.

Table 2

Quality of the drainage runoff from manure-fertilised fields (environmental monitoring data, 2006)

Company	Composition of the drainage runoff from organic manure-fertilised areas, mg l^{-1}				
	BOD_7*	N_{total}	$N\text{-}NO_2$	$N\text{-}NH_4$	P_{total}
'Gražionių bekonas'	1.0	10.4	0.01	0.06	0.05
'Krekenavos agrofirma'	1.8	31.3	0.1	0.6	0.10
MPC** for drainage outlets	23.0	15.0	0.3	5.0	2.00

Notes:
** - biochemical oxygen demand;*
*** - maximum permissible concentration.*

Perspectives of the development of manure handling technologies. Traditional manure handling activities (accumulation transportation, spreading on fields) are successfully applied today. However, from the economical point of view, traditional manure handling is rather expensive. Besides, it results in dissatisfaction of inhabitants due to bad odor produced by manure gas (indol, mercaptan, sulphur hydrogen, ammonis). Scientists keep looking for manure handling ways seeking to deodorize it as well as reduce its amount by separating water from manure. German scientist J. Beck and British scientist C. Burton have analyzed the following manure processing and handling technologies used in European Union: mechanical separation, centrifuging, aeration, thermophylic aeration, anaerobic mesophylic fermentation, anaerobic thermophylic fermentation, treatment with acid, drying-evaporation, and osmosis (Beck and Burton, 1998). All those technologies differ in respect of their efficiency and cost price. In 2006, scientists of Water Management Institute of Lithuanian University of Agriculture started implementing the program of searching technological studies aimed at the decomposition of slurry, produced on industrial pig complexes, into solid matter and wastewater. According to this program, manure will be processed with strong acid, alkaline solutions in whirling-inductive equipment. In such way, all viruses and microbes will be destroyed, and ammonia will be bound up. As the obtained dry organic product will be used as a fertilizer, scientists suggest using sulphur acid which is rather cheap; besides, its the amount is usually insufficient in the soils of Lithuania. Heavily polluted wastewater produced after the processing of manure will be biologically treated and released into open water bodies.

Currently, the technology of manure processing in biogas reactors is being used all over the world. Biogas can be produced from animal manure in a fermentation way. Biogas has about 50% of the energetic value of natural gas (Šileika, 2001). Manure processing in biogas reactors improves the hygienic characteristics of manure; besides, a contiguous product – flammable biogas – is obtained. However, in such manure nearly all nitrogen is turned into ammonia nitrogen. In order to reduce ammonia nitrogen losses (due to evaporation) in the next stages (accumulation and fertilization), additional means are to be used. On the other hand, the arrangement of biogas power station requires particularly large investments. During the last decade, in foreign countries, biogas power stations are constructed in places with stable users of thermal energy, and with sufficient resources of grease wastes from food production and animal slaughterhouses. Such resources should make up 50% of biomass produced in the reactor; the rest 50% goes to manure. With such composition of biomass, 1 m^3 of biomass may produce up to 100 m^3 of biogas. If the biomass is composed only of manure, 1 m^3 of biomass would produce only about 20-25 m^3 of biogas.

Biogas obtained in countries of European Union makes up only 2-5% of all energy demand. According to the data of scientific researches, in Lithuania biogas could meet up to 3% of all energy demand. According to the study data of all Lithuanian Energy Institute, the estimated expenses of the construction of biogas power stations with different capacity (volume of bio-reactor from 10 to 200 m^3) would make up from 45 to 627 million Lt respectively. The expenses of the technologies would be covered after 10 or more years depending

on the purpose for which where biogas will be used (for greenhouses, for house heating, etc.). Therefore, state financial support is necessary in this field. On the basis of legal, organizational and economical means, the state should support the production of alternative energy by giving preferential credits to the projects of implementation of alternative energy sources (i.e., biogas production) (Šileika, 2001).

Conclusions

1. When producing liquid manure, small spreading loads (up to 38 m^3 ha^{-1}) are used due to its high fertilization value (1 m^3 of liquid manure contains up to 4.5 kg of nitrogen). In farms where water is used for hydraulic removal of manure, liquid manure is diluted. This results in lower fertilization value of manure, therefore high spreading loads (up to 300 m^3 ha^{-1}) are used for the fertilization of fields.
2. In agricultural company 'Gražionių bekonas', where are newly implemented manure management technologies, the quality of drainage water released from fertilized fields satisfies the environment protection requirements. In 'Krekenavos agrofirma', where fields are fertilized with the rates up to 300 m^3 ha^{-1}, drainage water pollution according to nitrogen is 2.1 times higher than MPC.
3. The development of manure handling technologies in the world is orientated to manure processing in biogas power stations and the use of biomass for the fertilization of fields. 1 m^3 of liquid manure mixed up with wastes from foodstuff production may produce about 100 m^3 of biogas. Having expanded the network of biogas power stations in Lithuania, we could satisfy up to 3 % of energy demand of the country.

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INFLUENCE OF PIG COMPLEX ACTIVITIES ON THE ŠUŠVĖ RIVER POLLUTION WITH NITROGEN COMPOUNDS

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Abstract

The research was made in the Šušvė river basin fertilized with organic fertilizer in the vicinity of a pig complex 'Litpirma' Ltd (25.0 thousand fattening pigs per year), Šiaulėnai local administration, Radviliškis district, in 2001-2006. This article presents total nitrogen concentrations and its amounts leaching from the complex to the basin, in the field drainage water and the Šušvė river (at a distance of 11.6 km from the pig complex).

In the investigated Šušvė section, biologically treated wastewater from Šiaulėnai township and the areas fertilized with organic fertilizers come into the river. In total, 11.8 t of nitrogen come into the river, of which 4% (0.49 t) come from the township's wastewater, and the rest major part (96% or 11.3 t) is the drainage water coming from fertilized agricultural fields. The dynamics of nitrogen concentrations both in the river and in the drainage outlet is of a seasonal nature: in winter (January – March) concentrations were higher, and in warm season (April – November) – lower. The Šušvė pollution by total nitrogen, both above and below the pig complex activities range, almost all the research period was exceeding the limit (2 mg l^{-1}). Due to the pig complex activities and intensive agriculture, the runoff of nitrogen pollutants increases from 14.9 to 29.3% in the Šušvė river. This proves that the processes of spontaneous purification are not intensive enough to neutralize completely the pollution from a such size pig complex in this particular section of the river.

Key words: manure, fertilization rate, total nitrogen, runoff.

Introduction

In Lithuania, about 30 out of 34 large pig complexes built during the Soviet period are still functioning. Since 2002, with the support from structural funds of EU, those complexes apply advanced animal breeding technologies, because the previous ones do not satisfy modern environmental protection and animal welfare requirements.

The main environment protection related problems in large pig complexes built during the Soviet period are as follows:

- hydraulic system of manure removal from pigsties, as pig excrements are diluted with water 3-5 times. Large open reservoirs of liquid manure arranged nearby the complexes are real ammonia evaporators exuding about 30% of nitrogen compounds into the environment during the period of 8 months;
- to sprinkle the liquid manure, overhead irrigation systems are used (during the irrigation process about 20% of nitrogen evaporates into the environment). Such spreading of liquid manure cannot be applied due to the intensive spread of manure aerosols and odours;
- fertilization value of diluted liquid manure used for overhead irrigation is not high – only 0.6-0.7 kg of nitrogen for 1 m^3 of liquid manure. Therefore when fertilizing the soil at the rate of 170 kg ha^{-1} of nitrogen, spreading rates are to be increased up to 260-300 m^3 ha^{-1}. This may increase the danger for the drainage water and ground water to be polluted during rainy periods of the year.

Having estimated environment protection problems related with keeping animals in old pig complexes, there were suggestions to reconstruct them using water-free manure removal technologies.

Due to large amount of animals, large animal husbandry enterprises are more dangerous to the environment than the small enterprises. Despite of this, recent development of animal husbandry enterprises is orientated to the increase of capacity all over the world.

Having evaluated the market prices of mineral fertilizers, we have calculated that a farmer who applies manure containing 170 kg of nitrogen, 25.56 kg of phosphorus and 68 kg of potassium on the soil, may save about 232.0 €. Those evaluations do not include the price of microelements.

The effect of the fields with applied manure on the surface water bodies is usually estimated as non-point source pollution. The amount of pollutants leached from a certain area during the calculation period is the best index of pollution: in spring the runoff of annual water usually makes 35-95%, in summer and autumn-4.5-43% (Vuoristo, 1998), and in winter it is up to 22% (Šileika et al., 1998). In spring, when the weather is warmer, nitrogen gets into streams as the product of mineralization of organic matter, as well as the mineral fertilizer non-uptaken by plants. In autumn, the amount of this element contained in water increases due to the soil fertilization in autumn as well as due to plant mineralization processes.

Lithuanian scientists Šileika S.A., Bučienė A., Gaigalis K., and Kutra G. have determined that during plant vegetation, when plant uptake of nutrients is highest, nitrogen amounts contained in the stream are lowest (Šileika et al., 2005; Bučienė et al., 1998; Kutra G. et al., 2002).

According to the Finnish scientist Vuorenmaa (Vuorenmaa et al., 2002), the state of surface water bodies gets worse due to the non-point source pollution, particularly because of the pollution from agricultural sources. Having investigated the pollution of small streams, he refers just to the weather conditions as the main reason of pollution and not to the effect of changes in agriculture.

The objective of the work is to determine the pollution of a large pig complex (LTD "Litpirma") with total nitrogen and purification possibilities of the river, on the basis of the observations of the quality of river water and drainage water within the period of 2001-2006.

Materials and Methods

The studies were carried out in the Šušvė river basin fertilized with organic fertilizers, in the vicinity of the pig complex 'Litpirma', in Šiaulėnai local administration (Radviliškis district) as well as in the river Šušvė. The pig complex is operating since 1978. Until the beginning of the reconstruction/ modernization (in 2000), the annual capacity of the enterprise was 12.0 thousand meaty pigs with the weight of 105-115 kg per year. In 2001-2006, the average annual capacity was 25 thousand meaty pigs per year. Complexes of such capacity may contain 1200 sows, 3200 little pigs up to 20 kg each, and 7600 fatling pigs with the weight from 20 to 115 kg. Total pollution of such amount of animals may correspond to the pollution produced by 1212 animal units.

Technological scheme of the activities of the enterprise is presented in Figure 1.

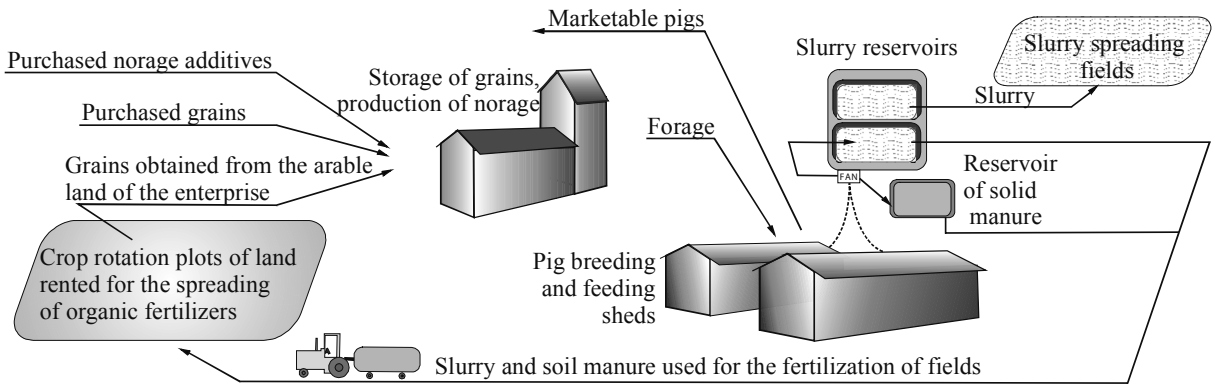

Fig. 1. Principal production scheme of 'Litpirma' Ltd pig complex.

The enterprise lends 572 ha of land where forage plants fertilized with organic fertilizers are cultivated (33 thousand m^3 m^{-1} of liquid manure, slurry, and solid manure fraction). Moreover, the enterprise is using the irrigation system of liquid manure arranged in the area of 156 ha. The irrigation system sprinkles out 25 thousand m^3 of liquid manure every year. Figure 2 presents the plan of the vicinity with indicated fertilization areas and water sampling posts.

Organic fertilizers are applied on fields according to the strict requirements of the fertilization program. Liquid manure is applied on a 156 ha area twice a year – in spring and before sowing in autumn – at the rates of 100 m^3 ha^{-1}. Slurry is also spread twice a year, at the rates of 50 m^3 ha^{-1}, and solid manure is used only for autumn fertilization of fields (spreading rate – up to 18 t ha^{-1}).

The whole area is drained. Water from this area is drained through 2 water outlets (D1 and D2, Fig. 2). Water from the 102 ha land plot is drained through the water outlet D1, water from the 54 ha field is drained through the water outlet D2.

During the study period 2001-2006, water samples were taken from two spots of the river Šušvė (ŠA and ŠŽ) for the laboratory analysis. Data of the river Šušvė hydrological regime was collected from the annual reports of Šiaulėnai hydrometric station of Lithuanian hydrometeorological station. Water samples were taken 4 times a year. Water sampling places in the Šušvė correspond to the discharge measurement place, therefore water discharge in water sampling places were calculated after evaluating the difference in the area. The size of rive catchment near ŠA is 147.8 km^2, near Šiaulėnai hydrometric station it is 162.4 km^2 and near ŠŽ 255.2 km^2

(Gailiušis et al., 2001). The river Šušvė above Šiaulėnai is polluted only with the runoff of pollutants from agricultural fields. In Šiaulėnai,

Fig. 2. Location of land plots with applied organic fertilizers in the territory of 'Litpirma' Ltd:

1 2 3 DA 4 D1 5

1 – production territory of 'Litpirma' Ltd; 2 – fertilized area; 3 – forest;
4 – sampling place of surface water in the river; 5 – drainage water outlet.

the river receives biologically treated domestic wastewater from the town (on the average 130 m^3 d^{-1}). Discharges in drainage outlet were measured in volumetric way during the water sampling. Changes in nitrogen pollutants amount were estimated according to the average weighted concentration (Helsinki…, 1996).

Total nitrogen contained in water was determined in the Chemical Analysis Laboratory of Water Management Institute of Lithuanian University of Agriculture, certified by the Environment Ministry of the Republic of Lithuania. Also the main forms of total nitrogen ($N\text{-}NO_3$, $N\text{-}NH_4$, and $N\text{-}NO_2$) were determined:

- N_{total} – by a titrometric way, having burnt the material (Kjeldal method);
- $N\text{-}NH_4$ – by a spectrometric method;
- $N\text{-}NO_2$ – by a spectrometric method;
- $N\text{-}NO_3$ - by a spectrometric method.

Currently, maximum allowable concentration of ammonia nitrogen in surface waters of Lithuania is 0.39 mg l^{-1}; maximum allowable concentrations of

total nitrogen, total phosphorus, and phosphate phosphorus are 2 mg l^{-1}, 0.2 mg l^{-1}, and 0.08 mg l^{-1}, respectively. According to the present rates, in animal wastewater released into surface water bodies, BOD_7 concentration should not exceed 20 mg l^{-1}, and concentrations of total nitrogen, total phosphorus, ammonia nitrogen, and nitrite nitrogen should not exceed 15 mg l^{-1}, 2 mg l^{-1}, 5 mg l^{-1}, and 0.3 mg l^{-1}, respectively (Aplinkosaugos…, 2007).

The quality of river water and drainage water is analyzed twice a year: in summer (04-11 months, during the vegetation period of plants when soil is fertilized with organic fertilizers) and in winter (12-03 months).

Results and discussion

The resources of organic fertilizers of the investigated pig complex accumulate on the average 80.2 t of nitrogen, 9.0 t of phosphorus, and 47.2 t of potassium every year. 1 m^3 of liquid manure, slurry and solid manure contains on the average 0.82 kg, 1.6 kg, and 4.4 kg of total nitrogen. A 156 ha field irrigated with liquid manure receives on the average 131.4 kg ha^{-1} of total nitrogen every year; whereas a 572.0 ha field fertilized with slurry and solid manure receives on the average 105.2 kg ha^{-1} of total nitrogen every year. The leaching of nitrogen and other nutrients from the river basin is related to meteorological conditions.

According to the data collected at Šiauliai Meteorological Station, the most humid study period was June and July of 2001, when the territory experienced 132-147 mm of precipitation. According to the annual sum of precipitation, the years 2002, 2004, and 2006 were close to the perennial rate; however, they were also distinct for wet months of the warm period. The year 2005 was driest, when the territory received only 69% of perennial precipitation rate. The average annual air temperature in different years was either equal to the rate (+6.0 °C) or exceeded the rate up to 1.5 °C (Table 1).

Table 1

Meteorological conditions of the study period 2001-2006 (data collected at Šiauliai meteorological stations)

Year	Annual precipitation		Air temperature	
	amount, mm	% from the rate	average annual, t °C	deviation from the rate, t °C
2001	704	121	6.0	+0.0
2002	581	100	7.5	+1.5
2003	527	91	6.8	+0.8
2004	597	103	6.7	+0.7
2005	401	69	6.8	+0.8
2006	606	104	7.3	+1.3

The upper reaches of the Šušvė (up to Šiaulėnai) with the basin area of 162.4 km^2, is distinct for marshland and woods. The area of arable land covers only 26% here. Moreover, there are no large industrial objects or towns that may influence the river water quality. This is a place for sampling water quality (ŠA), according to which water quality data obtained at the same place below the pig complex (ŠŽ) were compared (Fig. 3). Total nitrogen concentration contained in the river Šušvė below the pig complex (ŠŽ) increased by 0.58 mg l^{-1}. During the whole study period only four times nitrogen concentration in ŠŽ was either the same as in ŠA or lower.

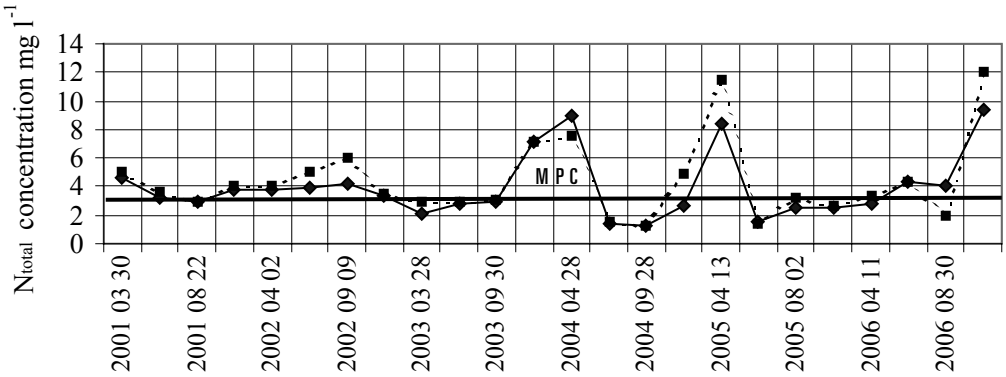

Fig. 3. Changes in total nitrogen concentrations in the river Šušve above (ŠA) and below (ŠŽ) the pig complex.

MPC - maximum permissible concentration —◆— (ŠA) - - -■- - - (ŠŽ)

Those periods make up 11.8% of the whole study period. The most significant changes in total nitrogen concentrations due to intensive farming in the basin reached up to 2.6 mg l^{-1}. This was because nitrogen compounds of high concentration are released from the basin where slurry from the pig complex are accumulated (Table 2). Dynamics of nitrogen concentrations in the river as well as in drainage outlets is of seasonal nature: in winter (December till March) concentration values were higher, but in the warm period (04-11)-lower.

Table 2

Total nitrogen concentrations in drainage water and in the river Šušvė

Measurement place	Concentration, mg l^{-1}			
	MAC*	Average	Maximum	Lowest
D(1)	15.0	8.18	17.3	1.73
D(2)	15.0	15.54	24.0	9.9
Average	**15.0**	**11.86**	**18.5**	**6.75**
Š(A)	2.5	3.94	9.4	1.22
Š(Ž)	2.5	4.42	12.0	1.31
Average	**2.5**	**3.46**	**8.2**	**0.96**

**Maximum allowable concentration*

The river Šušvė received from 2.73 to 15.8 t of nitrogen through drainage from the whole fertilized area of 728 ha. In the section between the measurement points ŠA and ŠŽ, biologically treated wastewater from Šiaulėnai town is canalized into the river Šušvė. Wastewater treatment efficiency satisfies the environment protection rates. Together with biologically treated wastewater, the river Šušvė received from 0.25 to 0.99 t of nitrogen pollutants every year. Besides, this section has two more tributaries: the Upytė (13.7 km^2) and the Beržutė (14.8 km^2). Considering the amounts (t per year), on the average 11.8 t per year of total nitrogen were released from the pig complex and the town into the Šušvė basin during the study period. The main part of pollution was from the pig complex (96% or 11.3 t per year), whereas the amount of total nitrogen from the town made up only 0.5 t per year. The runoff of pollutants differed significantly in different study years (Fig. 4). The smallest amount of total nitrogen was observed in 2006 (3 t per year) and 2006 (7 t per year). The largest amounts of nitrogen reached 16 t per year and even more (in 2004 and 2005).

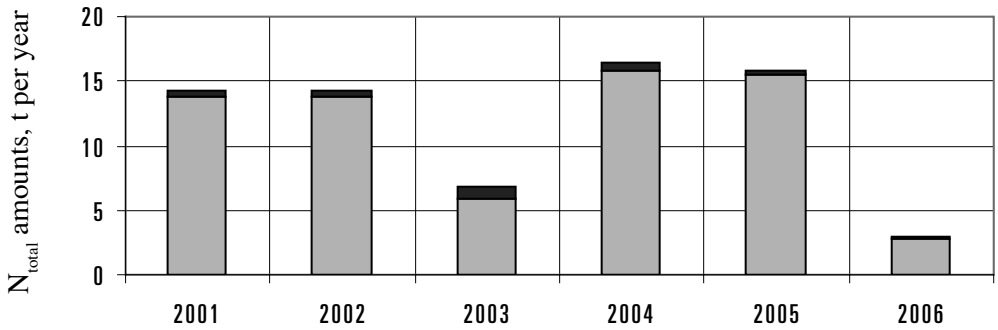

Fig. 4. N_{total} amounts received from the pig complex and Šiaulėnai town
from the pig complex from Šiaulėnai

Leaching of total nitrogen through drainage from fields with applied organic fertilizers was significantly different in separate years: in 2006 (when runoff head was lowest) only 3.75 kg of nitrogen leached from 1 ha, but in 2004 (when runoff head was highest) even 21.75 kg of nitrogen from 1 ha (Fig. 5). Annual leached nitrogen amounts made up accordingly 2.8 and 16.6% of nitrogen amount introduced with organic fertilizers per year.

S. Misevičienė has studied the emission of pollutants from areas with manure application. She determined that, every year depending on precipitation amount, from 4.1 to 32.3 kg ha^{-1} of nitrogen get into the environment through drainage (Misevičienė, 2002). Figure 6 presents annual total nitrogen runoff in the river Šušvė above Šiaulėnai (ŠA) and below the pig complex. The least significant differences (24-33 t) were observed in 2003 and 2006, when the annual precipitation amount was close to the rate. The most significant differences (141-158 t) in total nitrogen runoff were observed in 2004 and 2005, when the year 2005 was driest of all the study years. Additionally, on the average 92 t of total nitrogen per year flows through the river Šušvė below the pig complex.

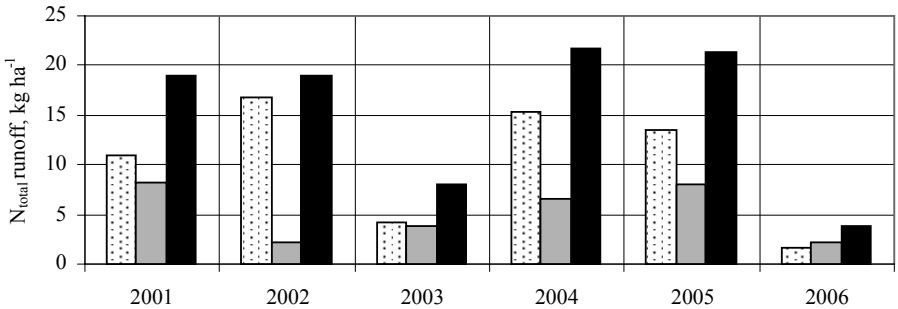

Fig. 5. N_{total} runoff throught drainage from areas with organic fertilizer application
12-03 months 04-11 months 01-12 months

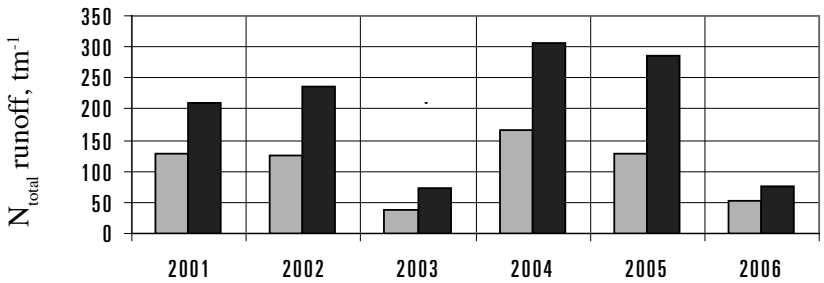

Fig. 6. N_{total} runoff in the river Šušve above Šiaulėnai (ŠA) and below the pig complex (ŠŽ)
(ŠA) (ŠŽ)

Although annual differences in nitrogen runoff are rather high, they do not fully reflect the changes in pollution in the Šušvė in the studied section between ŠA and ŠŽ. After calculating nitrogen pollutants runoff in the river for the area unit of the basin (kg ha^{-1} per year), it is possible to evaluate the changes in pollution more exactly. Calculation results are given in Table 3.

Table 3

Comparative indices of nitrogen runoff in the river Šušvė in the section between ŠA and ŠŽ

Year	Total nitrogen runoff, kg ha^{-1} per year		
	Šušvė above Šiaulėnai (ŠA)	Šušvė below the pig complex	Increase (+) and decrease (-) of pollution
2001	8.7	8.21	-0.49
2002	8.19	9.25	+1.06
2003	2.61	2.82	+0.21
2004	11.26	12.05	+0.79
2005	8.69	11.24	+2.55
2006	3.56	3.00	-0.56
Average	**7.2**	**7.8**	**+0.59**

Due to the activities of the pig complex, total nitrogen amount increased in the Šušvė on the average by 0.59 kg ha^{-1} per year during the study period. As it was observed in 2001 and 2006, the river was able to remove all the pollutants flowing from fertilized fields and the town. However, in most cases the pollution of the river increased from 14.9 to 29.3%. The 11.6 km long section of the Šušvė is too short to ensure a spontaneous purification and neutralization of the pollution.

Conclusions

1. Every year from 2.73 to 15.8 t of nitrogen (from 3.75 to 21.75 kg ha^{-1}), which accounts for 2.9–16.6% of the amount imported into fields, come to the Šušvė by drainage from the areas fertilized with organic fertilizers. The main polluter is the pig complex (96% or 11.3 t per year); the rest amount of total nitrogen (0.5 t per year) gets from wastewater from the town.
2. According to the data of 2001-2006, in the Šušvė, total nitrogen concentration below the pig complex increases on the average by 0.58 mg l^{-1}. The most significant differences reached 2.6 mg l^{-1}. However, there were years when nitrogen concentration in the Šušvė below the pig complex was either the same or lower than that above Šiaulėnai. Water flowing from the river basin by drainage contains 4 times higher nitrogen concentration than water in the river.
3. During a year additional 92 t of total nitrogen flow through the river Šušvė below the pig complex. The smallest amounts of pollutants (24-33 t) were observed in 2003 and 2006, when the amount of annual precipitation was close to the rate. The highest amounts of pollutants (141-158 t) occurred in 2004 and 2005, when the year 2005 was driest of all the study years. This shows that the change in river pollution depends on such factors as fertilization regime of fields and nitrogen amount taken with the harvest, but it almost does not depend on meteorological conditions.
4. Due to the activities of the pig complex and intensive farming, total nitrogen runoff increased from 14.9 to 29.3% during the study period. The 11.6 km long section of the Šušvė is too short to ensure a spontaneous purification and neutralization of the pollution.

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VISIBLE AND INFRARED ABSORPTION SPECTRA OF COVERING MATERIALS FOR SOLAR COLLECTORS

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Abstract

Use of solar energy increases every year. In Latvia, solar energy is used mainly by solar collectors.

The main part of the solar collector is the absorber, but not less important is the covering material which protects the absorber from the cooling impact of the wind. This cover must be transparent for solar radiation, but opaque for thermal radiation of the absorber, which is at greater wavelengths. Therefore it is important to measure absorption spectra of possible covering materials at visible and infrared wavelength ranges.

Absorption spectra have been measured for several materials: glass, polythene, Plexiglas, and cells Plexiglas.

Absorption spectra for all these materials are measured in three ranges:

ultraviolet – visible (UV – VIS): 250 – 1000 nm;

near infrared (NIR): 700 – 110 nm;

infrared (IR): 1200 – 8000 nm.

UV-VIS spectra with the 'Ocean Optics' device HR-4000 have been measured, but NIR and IR – with 'Bruker' Furje spectrometer EQUINOX 55.

Evaluation of absorption spectra showed that the most suitable material (from the considered) for covering of solar collectors is Plexiglas.

Key words: solar collector, thermal radiation, absorption spectra.

Introduction

Besides other environment-friendly renewable energy sources, solar energy is widely used in the world. Also in Latvia solar collectors are used (Ziemelis et al., 2004; Kancevica et al., 2006).

The energy received of the solar collector can be calculated (Pelece et al., 2007). However, important is also energy loss because of re-radiation.

The main part of the solar collector is the absorber, but not less important is the covering material which protects the absorber from the cooling impact of the wind. This cover must be transparent for solar radiation, but opaque for thermal radiation of the absorber, which is at greater wavelengths. Some authors (Muresan et al., 2006; Maatouk Khoukhi et al., 2006) speak about absorption of solar radiation at the cover, but not any was found paying attention to thermal radiation of the absorber.

Therefore it is important to measure absorption spectra of possible covering materials at visible and infrared wavelength ranges. Such spectra have not been found in the literature.

Materials and methods

Solar energy can be used in two ways: solar cells, which transform solar energy into electrical energy, and solar collectors, where solar energy is used for heating of water. In Latvia, solar collectors are more popular because of their superior efficiency compared to solar cells (BSI, 2005).

A traditional flat-plate solar collector (Fig. 1) consists of absorber (black, well absorbing material), heat carrier (usually pipes in which water circulates), heat insulation, and cover (Ziemelis et al., 2004; Kancevica et al., 2006).

Main function of the cover is to protect the absorber from the cooling impact of the wind. This cover must be, of course, transparent for solar radiation. But the absorber same, as a warm body, irradiates thermal radiation.

Thermal radiation can be described by such well-known formulae: radiation power of a black body per unit of area, unit of solid angle, and unit of frequency is given by

$$u(\nu, T) = \frac{2h\nu^3}{c^2} \cdot \frac{1}{\exp\left(\frac{h\nu}{k_B T}\right) - 1}, \quad (1)$$

where ν – frequency, Hz;
T – temperature, K;
h – Plank's constant, J s;
c – speed of light, m s^{-1};
k_B – Boltzmann constant, J K^{-1}.

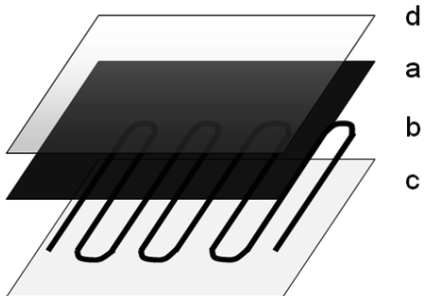

Fig. 1. Structure of the solar collector:
a – absorber, b – heat carrier, c – insulation, d – cover.

Integrating the above equation over ν the power output given by the Stefan–Boltzmann law is obtained

$$W = \sigma A T^4, \quad (2)$$

where σ – Stefan-Boltzmann constant, W m^{-2} K^{-4};
A – area of the radiating surface, m^{-2};
T – temperature, K.

The wavelength λ, for which the emission intensity is highest, is given by Wien's Law:

$$\lambda_{max} = \frac{b}{T}, \quad (3)$$

where b – Wien's displacement constant, m K;
T – temperature, K.

Solar radiation spectrum is shown in Fig. 2 (Rottman, 2006).

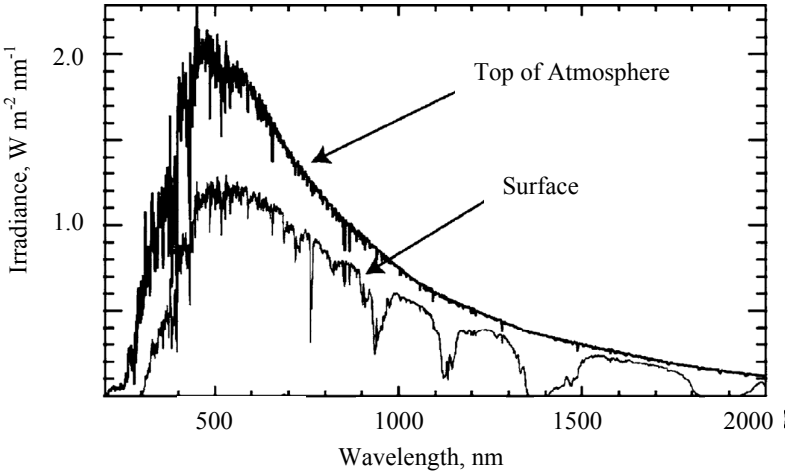

Fig. 2. Solar radiation spectrum at the top of the atmosphere and at the sea level.

Maximal irradiance is at 550 nm. Integral power at the top of the atmosphere is equal to the solar constant $S_0 = 1367$ W m^{-2}.

Mean temperature of the absorber of the solar collector usually is approximately 60 °C. The spectrum of the thermal radiation of a black body with such temperature is shown in Fig. 3.

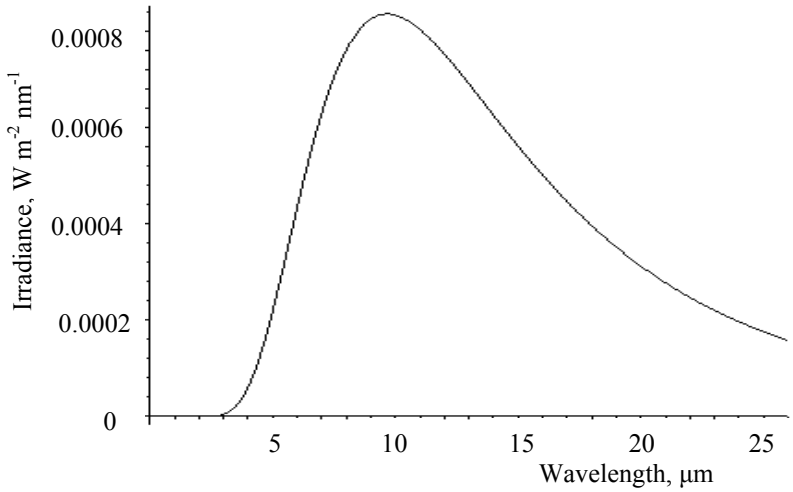

Fig. 3. Thermal radiation of a black body at the temperature of 60 °C.

Maximal irradiance is at wavelength of 10 µm. Integral irradiance is approximately 670 W m^{-2}. Since real objects, including black-coloured solar collector, are not absolutely black, the integral irradiance can be even half of that, but still is comparable with the incoming solar radiation.

The cover material of the solar collector must be transparent for the maximum radiation of the sun (at wavelengths smaller than 1 µm), but opaque for the maximum radiation of the absorber (at wavelengths greater than approximately 5 µm). Therefore it is important to know the absorption spectra of these materials.

Absorption spectra have been measured for several materials: glass, polythene, Plexiglas, and cells Plexiglas.

Absorption spectra for all these materials are measured in three ranges:

ultraviolet – visible (UV – VIS): 250 – 1000 nm;

near infrared (NIR): 700 – 110 nm;

infrared (IR): 1200 – 8000 nm.

UV-VIS spectra with the 'Ocean Optics' device HR-4000 have been measured, but NIR and IR – with 'Bruker' Furje spectrometer EQUINOX 55.

Results and discussion

At the visible range (400 to 700 nm), the most transparent is glass (Fig. 4 a), but, if also ultraviolet range is considered, in which the sun also irradiates, more transparent is Plexiglas (Fig. 4 b). Cells Plexiglas (Fig. 4 c) is less transparent at both visible and ultraviolet ranges. Polythene (Fig. 4 d) is more transparent than glass and Plexiglas at the ultraviolet range, but less transparent at the visible range.

At the near infrared range (700 to 1100 nm), more transparent is Plexiglas (Fig. 5 b). Values of absorption of glass and polythene (Fig. 5 a and d resp.) are similar to each other and greater than that of Plexiglas. Least transparent is cells Plexiglas (Fig. 5 c).

At the infrared range (1000 to 10000 nm), where solar radiation is weak, but thermal radiation of the absorber is considerable, better for covering is more opaque material.

Greatest absorption at this range is that of Plexiglas and cells Plexiglas (Fig. 6 b and c resp). For glass (Fig. 6 a) and polythene (Fig. 6 d), absorption at this wavelength range is weaker.

Evaluation of absorption spectra showed that the most suitable material (from the considered) for covering of solar collectors is Plexiglas.

Of course, in order to choose the material for covering of the solar collector, the absorption is not the only criteria. Important are also costs and, especially if the solar collector is not flat, possibility to shape it. Polythene and Plexiglas are more malleable than glass and cells Plexiglas. Important is also durability. Plexiglas and cells Plexiglas are more durable than glass and polythene.

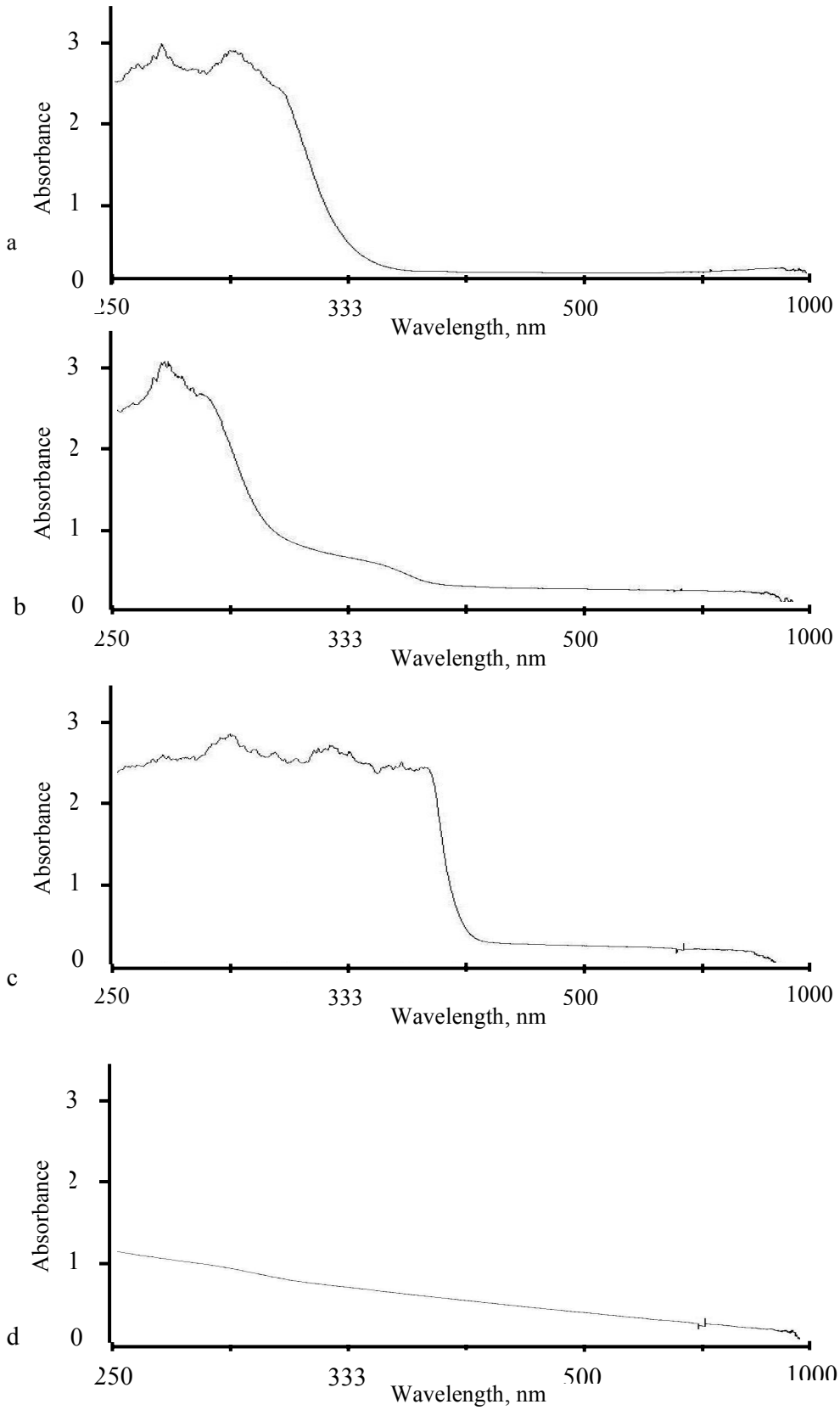

Fig. 4. Absorption spectrum of glass (a), Plexiglas (b), cells Plexiglas (c), and polythene (d) at visible and ultraviolet range.

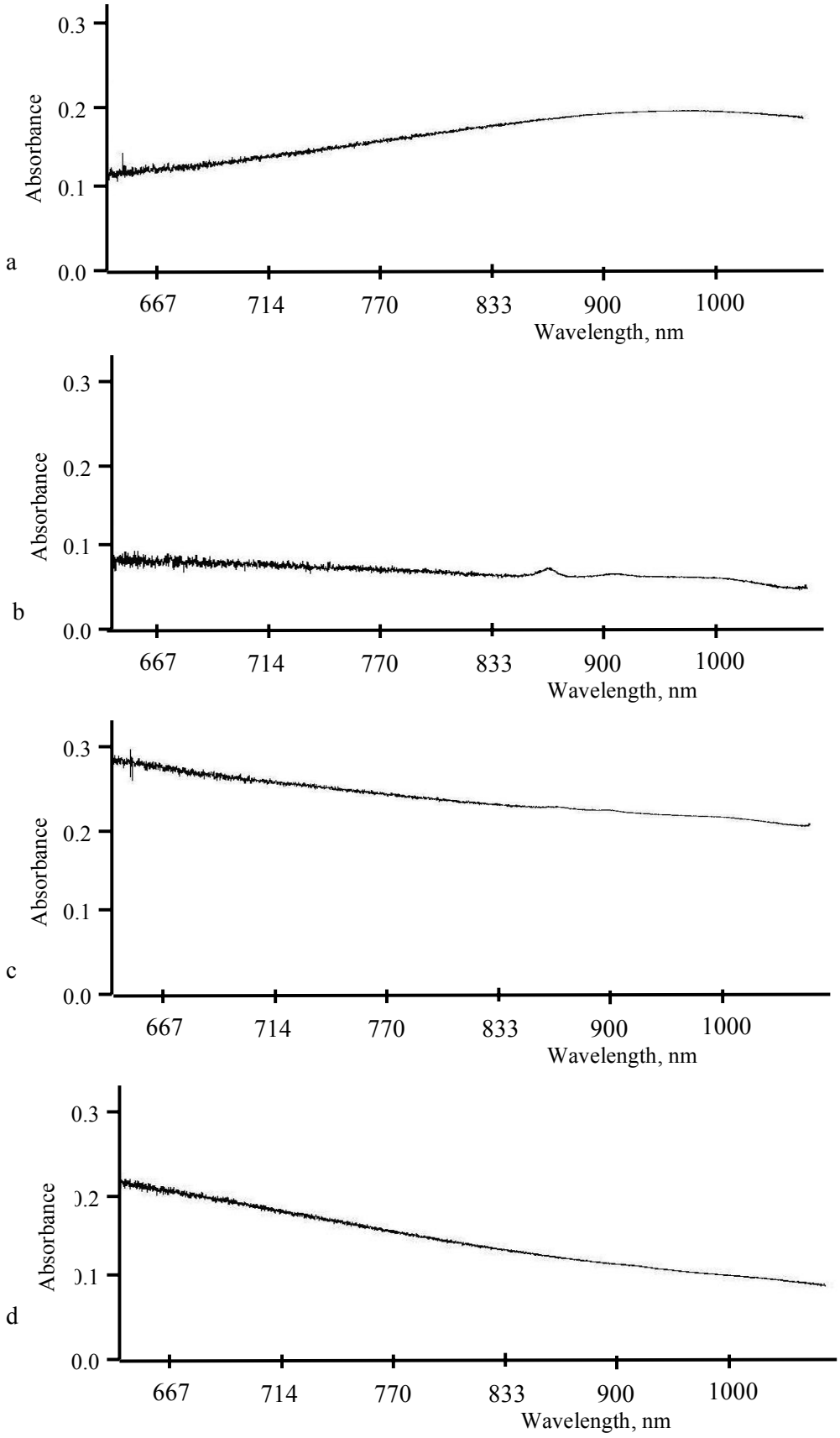

Fig. 5. Near infrared absorption spectra of glass (a), Plexiglas (b), cells Plexiglas (c), and polythene (d).

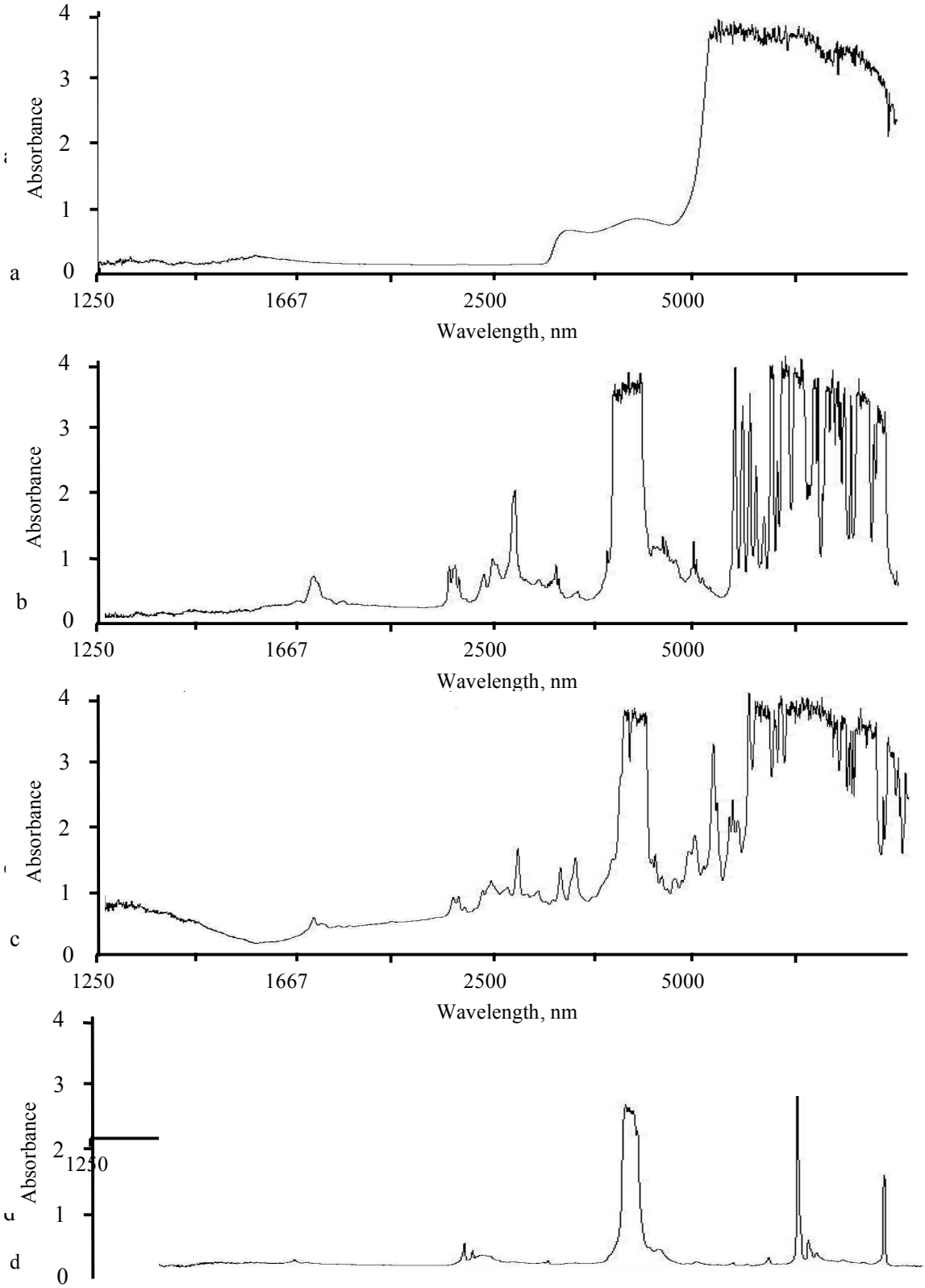

Fig. 6. Infrared absorption spectra of glass (a), Plexiglas (b), cells Plexiglas (c), and polythene (d).

Consequently, from all viewpoints together, the best material for covering of solar collectors is Plexiglas.

Investigations are also required on the stability of those optical characteristics in outdoor conditions.

Conclusions.

1. Energy loss of the solar collector via thermal radiation is considerable.
2. If only optical qualities of materials are considered, the best material for covering of solar collectors is Plexiglas.

Acknowledgement

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USING OF ANYLOGIC AND EXTENDSIM IN MODELLING OF BIOFUEL LOGISTIC SYSTEMS

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Abstract

Rising oil prices, national security concerns, the desire to increase farm incomes, and a host of new and improved technologies are propelling the European Union to set the directive for the year 2010 – each member state should achieve at least 5.75% biofuel usage of all used transport fuel. The report on the progress made in the use of renewable fuels shows that the average Member State of the EU has achieved only 52% of its target, and biofuels' share in 2010 will not raise much above 4%. The prices of different biofuels are still not able to compete with oil based fuel prices. One of the possible ways how to solve this problem is to optimize biofuel supply chains using different methods of systems engineering. The aims of this investigation were finding out appropriate simulation tools for biofuel supply chain modelling, development of rapeseed oil supply chains for different production types, and modelling the developed supply chains. As the result of software survey, two packages were chosen – *AnyLogic* and *ExtendSim Suite*. Modelling studies showed that rapeseed oil supply chain is very sensitive, because changing just single parameters in a short scale, the actual cost price of 1 litre of oil changes considerably. Comparing the fossil diesel fuel prices with rape oil actual cost from modelling studies, the use of oil as a fuel for farm machinery seems to be profitable. Analysis of costs distribution shows that the greatest part is composed by rapeseed growing expenses.

Key words: biofuel, rapeseed oil, logistic, supply chain, systems engineering, modelling.

Introduction

The term 'biofuel' applies to any solid, liquid, or gaseous fuel produced from organic matter. The various biomass feedstock used for producing biofuels can be grouped into two basic categories: the currently available 'first-generation' feedstock, which is harvested for its sugar, starch and oil content that can be converted into liquid fuels using conventional technology; and the 'next-generation' cellulosic biomass feedstock, which is harvested for its total biomass and whose fibres can be converted into liquid biofuels only by advanced technical processes. The two primary biofuels in use today are ethanol and biodiesel, which can both be used in existing vehicles. Ethanol is readily blended with gasoline, and biodiesel is blended with petroleum-based diesel for use in conventional diesel-fuelled vehicles. The use of pure vegetable oil and pure biodiesel in diesel engines as well as neat bioethanol in spark-ignition engines are other available alternatives nowadays, but they may require modification of engine or fuel system components.

The European Union in its biofuels directive has set the goal for the year 2010 – each member state should achieve at least 5.75% biofuel usage of all used transport fuel. Unfortunately, the report on the progress made in the use of biofuels and other renewable fuels in the Member States of the European Union shows that the average Member State achieved only 52% of its target (Biofuels Progress Report, 2007), and biofuel share in 2010 will not raise much above 4%.

Concerning Latvia, the great number of different regulations has been developed since 2003, for example, the programme 'Production and use of biofuels in Latvia (2003-2010)', the decree of the Cabinet of Ministers No. 511 on the implementation strategy of the mentioned programme, and the law on biofuels accepted by the Saeima on April 2005. Regardless of that, the real situation in this country is unsatisfactory – Latvian biofuel share changed from 0.07% in 2004 to 0.33% in 2005, but in the last two years it has stayed almost the same.

The main reason of this seems to be economical by nature – the prices of biofuels are not able

to be in competition with gasoline and diesel prices. If governments and others wish to expand production and use of biofuels significantly at the domestic and global levels, they will need to have an effective wide-ranging policy strategy. The most common policies supporting biofuels today are blending mandates and exemptions from fuel taxes. Other policy instruments are loan guarantees; tax incentives for agriculture and forestry, consumers and manufactures; preferential government purchasing policies; and research, development, and demonstration funding for current and next-generation biofuels and technologies (Biofuels for Transport …, 2007).

Another possible way to enlarge the production and use of biofuels is to optimize biofuel supply chains using different methods of systems engineering. Systems engineering can be defined as a structured process for arriving at a final design of a system. The final design is selected from a number of alternatives that would accomplish the same objectives and considers the total life-cycle of the project including not only the technical merits of potential solutions but also the costs and relative value of alternatives. The most common structure of the systems engineering process is shown in Figure 1 (Bahill and Gissing, 1998).

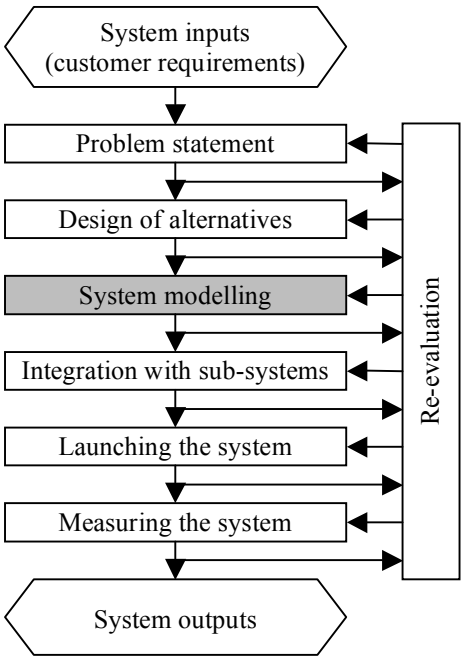

Figure 1. The systems engineering process structure.

Considering that system modelling plays a very important role in engineering process structure, it is chosen for this investigation. Before starting the modelling process, identification of the system is very important.

In this investigation the system is a biofuel logistic or supply chain. The different possible conversion routes for the production of different biofuel types play a central role in the model. These conversion routes are defined by interlinked subprocesses, which are defined by input and output. The simplified general outline of conversion route definition is shown in Figure 2 (Van Thuijl et al., 2003).

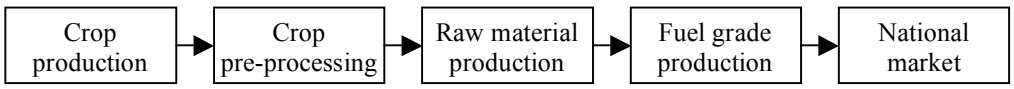

Figure 2. General outline of conversion route definition for the model.

Crop production denotes the production of biomass and biomass residues from agriculture, forestry, and industry. The pre-processing of the crop may consist of several pre-treatment steps. After pre-processing of the biomass it is converted into a raw material (for example, bio-crude or raw ethanol), which serves as an input for the production of fuel grade biofuels. Both raw material production and fuel grade produc-

tion may consist of several conversion processes. Finally, the produced biofuels are transported to the national market, where distribution to end-consumers takes place (in either pure form or blends with conventional automotive fuels).

Analysing the existing solutions in modelling of biofuel supply chains, the first ones were found relating biomass fuel supply and collection correspondingly in the Netherlands and the United Kingdom (Allen et al., 1998; De Mol et al., 1997). The most valuable information from these investigations was used input and output data for modelling, but researchers didn't specify the used modelling tools. Another problem to use these models as analogues for biofuel logistic chain modelling in Latvia is different modelling input parameters, for example, raw materials, distances between objects, network of roads, etc.

The most fundamental and recent investigations in the modelling of biofuel supply chains were carried out within the European Commission-supported project 'Clear Views on Clean Fuels' (Wakker et al., 2005). The objective of this research was to develop a cost efficient biofuel strategy for Europe in terms of biofuel production, cost and trade, and to assess its larger impact on bioenergy markets and trade up to 2030. Based on the biomass availability and associated costs within EU countries, scenarios for biofuels production and cost was constructed using quantitative modelling tools. Combining this with data on biofuel conversion technologies and transport of biomass and biofuels, the lowest cost biofuel supply chain given a certain demand predetermined by the biofuels directive was designed. Two complementary models were developed in this research, the BIOTRANS model and the ChalmersVIEWLS model.

The BIOTRANS model needs the following inputs: costs and potentials of biomass resources (including organic waste fractions and residues) in individual countries, data on the possible conversion routes containing different process steps, data on the national and international transportation and handling of the different products involved and data on policy incentives. The model has been formulated as a multi commodity network flow model connected by country nodes. The ChalmersVIEWLS is a regionalised energy system model. It has three end-use sectors: electricity, transportation fuels, and heat. Specific energy demand scenarios are developed for each of the three sectors. In addition to energy demand and costs, the supply potentials, energy conversion characteristics and expansion limitations, the initial capital stock and trade parameters are exogenously defined.

Unfortunately, reports on these modelling studies don't share with used modelling equations and used computer software also. Only results in graphical and numerical form are available. Another problem is that these models are too global. For example, if the distance from Gulbene to Ventspils in European model is inconsiderable, than in modelling of biofuel supply chain in Latvia scale it is very significant.

Regardless of this, analysis of these investigations were very useful, especially studies of background document for modelling using the BIOTRANS model (Van Thuijl et al., 2003). As an example conversion route for pure vegetable oil from this document is shown in Figure 3.

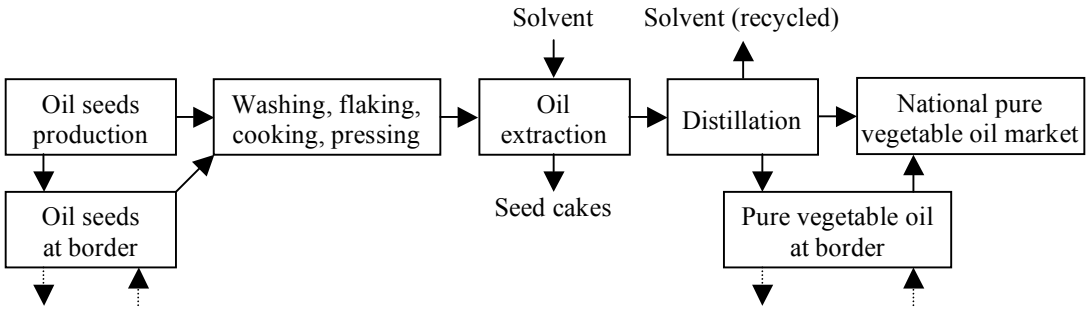

Figure 3. Conversion route for pure vegetable oil.

Since the pure vegetable oil chain is the simplest from all others and it is also the part of the biodiesel production, rapeseed oil supply chain was chosen for the modelling studies.

The choice of the most suitable modelling and simulation software is very important. Of course, for the simpliest modelling studies it's possible to use some of tools (for example, *Solver*) integrated in spreadsheet programs. The use of powerful common use modelling software, for example, *Powersim* or *Simulink* is also available, but probably other software which is specially designed for modelling of logistics would be more suitable.

Analysing existing surveys of simulation software tools as the most fundamental investigations made by Lionheart Publishing Company were found out. More than sixty different packages were compared (Simulation Software Survey, 2007; Swain, 2005; Samuelson and Macal, 2006). A lot of criteria were used, for example, typical applications of the software, primary markets for which the software is applied, system requirements, supported operating systems, model building characteristics, etc. Most of these packages can be used also for supply chain and logistic modelling, but which of them could be the most suitable for the modelling of biofuel logistic systems is not specified in these surveys.

Summarizing literature studies, the following tasks were set for this investigation:

- selection of criteria for simulation software comparison to find out the appropriate ones for biofuel supply chain modelling;
- adaptation of previously shown conversion route (Figure 3) to specific peculiarities of Latvia and development of rapeseed oil supply chains for decentralized and unitary production;
- modelling the developed rapeseed oil supply chains using selected simulation tools.

Materials and Methods

Basing on the typical applications of the software as well as on computer and operating systems requirements, eight different simulation packages were chosen for the final evaluation – *AnyLogic*, *Arena*, *ExtendSim Suite*, *Flexsim Simulation Software*, *ProModel Optimization Suite*, *ServiceModel Optimization Suite*, *ShowFlow*, and *Simul8*.

The main model building characteristics were set as the criteria for further comparison. All necessary information was obtained from vendor home pages and demo models. All of these programs include following features: graphical model construction (icon or drag-and-drop), access to programmed modules, run time debug, input distribution fitting, model optimization tools, animation, import CAD drawings, different templates, user support and discussion area, training courses, on-site training, and consulting. As the first discarded package was *ShowFlow*, because it doesn't support both modelling types (discrete event and continuous event) and real time viewing of model animation.

Seven programs satisfy other main criteria – output analysis support, presence of tools to run experimental design and to support model packaging (e.g., can completed model be shared with others who might lack the software to develop their own model?). Despite these features are included, they are different in particular programs. Not all programs are able to export animations (e.g., MPEG version that can run independent of simulation for presentation). Description of differing tools is summarized in Table 1.

Table 1

Simulation software survey

Software	Output Analysis	Batch run or experimental design	Tools to support packaging	Export animation
AnyLogic	Statistics tools, various charts, histograms, etc.	Simulation, optimization (including Monte Carlo and Sensitivity Analysis), and custom experiments	Generates Java applets and applications with full simulation-optimization functionality	+
Arena	Arena Output Analyzer for statistical analysis	Arena Process Analyzer	Seamless operation, no tools necessary	+
ExtendSim Suite	Confidence intervals are calculated at the click of a button	Automated execution of different scenarios	Free downloadable player from the web site runs the models	–

Software	Output Analysis	Batch run or experimental design	Tools to support packaging	Export animation
Flexsim Simulation Software	Flexsim Charts. Outputs to Excel and Access	Flexsim Experimenter	–	+
ProModel Optimization Suite	Output analysis reports and charts. Outputs to Excel and Access	Unlimited scenarios can be predefined to experiment on parameters	Models packaged within software; view using free ProModel Player	–
ServiceModel Optimization Suite	Output analysis reports and charts. Outputs to Excel and Access	Unlimited scenarios can be predefined to experiment on parameters	Models packaged within software; view using free ProModel Player	–
SIMUL8 Professional	Included in main product	Included in main product	Included in main product	+

To make the final decision, the pricing information and presence of academic/research versions were taken into account too because financial resources to purchase software were limited. As the result, two different packages were chosen – *AnyLogic* and *ExtendSim Suite*.

Adapting conversion route for pure vegetable oil (Figure 3) to specific peculiarities of Latvia, rapeseed oil supply chain was developed including decentralized and unitary production (Figure 4).

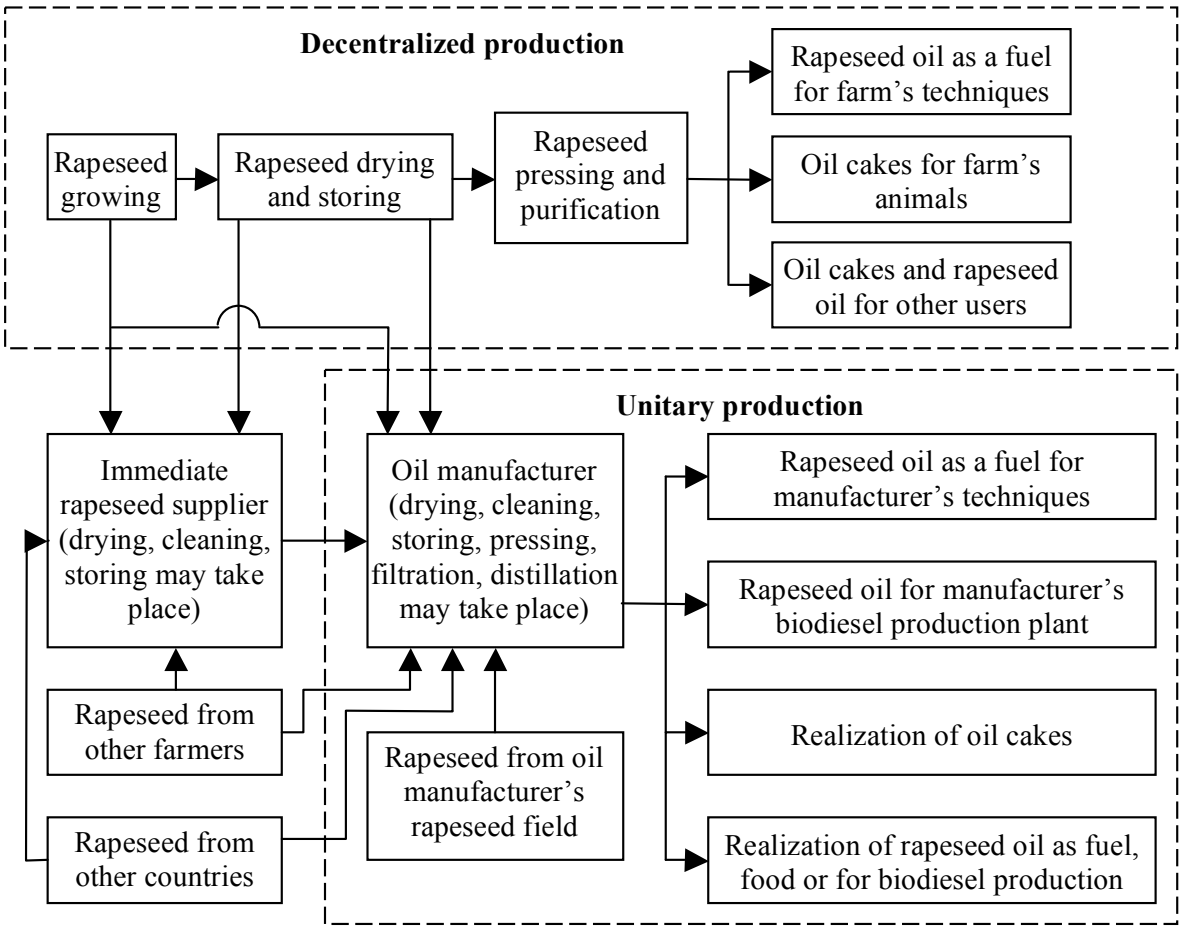

Figure 4. Rapeseed oil supply chain for decentralized and unitary production.

Transportation of intermediate products may take place between the most of two subprocesses. It can be realized by farmer, intermediate supplier or oil manufacturer transport. Biofuel or fossil fuel can be used in transportation and rapeseed growing.

A lot of different input parameters for modelling were used, for example, seed, fertilizer, herbicide and fungicide prices and norms; ploughing, cultivation, sowing, fertilizing, dusting, harvesting, transportation, cleaning and drying expenses; rapeseed yield capacities; state-aided payments; oil extraction expenses; possible oil cake sale price, average rapeseed transportation distances, etc. Besides, some of the parameters that initially seem to be constant, for example, seed price and sowing norm, are changing in practice. Thus, winter rapeseed price is 7.00 LVL kg^{-1} and 3 kg of seed is needed per 1 ha. For summer rape these numbers are correspondingly 5.00 LVL kg^{-1} and 4 kg ha^{-1}, but if only biological technologies are used on the farm ('biological rape'), 8 kg ha^{-1} of specially treated seed is needed.

Models were developed using both of previously chosen packages – *AnyLogic* and *ExtendSim Suite*.

Results and Discussion

The main questions to be answered from these modelling studies were:

- What is the actual cost of rapeseed oil for decentralized and unitary production?
- Is the price of rapeseed oil able to compete with fossil diesel fuel prices?
- What is the distribution of costs in rapeseed oil supply chain using different production technologies grouping expenses by categories – growing, transportation, cleaning/drying, and pressing/purification?

Performing system simulation different scenarios of supply chain were executed. For example, expenses for ploughing, cultivation, sowing, fertilizing, dusting, harvesting and transportation at farm (decentralized production) in the model can be assumed as external services or they can be performed by farmer's machinery. The same situation is with cleaning, drying and pressing. Oil cakes can be fed to farm animals or sold to other farmers. As an example, the results of simulation studies for decentralized production are summarized in Table 2. For technical services, neighbour machinery is used, seed pre-processing and oil extraction are done by the farmer himself, but rape cakes are sold.

Table 2

An example of the simulation results for decentralized production

Expense item	Summer rape	Winter rape	Summer rape ('biological')
Rapeseed growing, LVL ha^{-1}	-447.85	-511.52	-497.74
Transportation, LVL ha^{-1}	-8.80	-8.80	-8.80
Cleaning/drying, LVL ha^{-1}	-14.50	-21.75	-14.50
Total state-aided repayment, LVL ha^{-1}	86.01	86.01	161.61
Total expenses, LVL ha^{-1}	-385.14	-456.06	-359.43
Average rapeseed yield (8% moisture), t ha^{-1}	2.34	3.27	1.22
Total expenses, LVL t^{-1}	-164.80	-139.39	-295.77
Pressing, LVL ha^{-1}	-101.64	-142.29	-51.11
Rape cake realization, LVL ha^{-1}	334.96	468.95	174.18
Rape oil actual cost, LVL ha^{-1}	-151.82	-129.40	-236.36
Rape oil quantity, l ha^{-1}	851.35	1191.89	442.70
Rape oil actual cost, LVL l^{-1}	-0.18	-0.11	-0.53

If only a half of oil cakes is sold, but other is used for farm's animals, rape oil actual cost for winter rape, summer rape and 'biological' summer rape changes correspondingly to 0.38, 0.30 and 0.73 LVL l^{-1}. But, in this case, economy in forage purchase for animals has to be taken into account. If the farmer uses his own machinery for technical services in this scenario, values mentioned before decrease to 0.30,

0.24, and 0.56, respectively. Rapeseed oil supply chain model is very sensitive, because changing just single parameters (for example, yield capacity, rapeseed transportation distance, or rape cake sale price) in very short scale, the actual cost price of 1 litre of rapeseed oil changes very considerably.

How do these values look in comparison with fossil diesel fuel prices? Let's assume that the diesel fuel price in the fuel tank is 0.87 LVL l^{-1}. The farmer can receive the excise tax compensation (0.19 LVL l^{-1}) and value added tax repayment (18%). In this case, the final diesel fuel price for the farmer is 0.52 LVL l^{-1}. If we compare this value with rape oil actual cost for winter and summer rape, the use of oil as a fuel for farm machinery is profitable. If only biological technologies are used on the farm, economically the use of oil as a fuel seems not so beneficial but, as the quality of final products is very high, they can be used in food (oil) and for animals (cakes), which is also very important for the farmer.

Concerning unitary production, rape oil actual cost was approximately the same when rape was grown on oil manufacturer field. On the one hand, the actual cost of growing, transportation, cleaning, drying and pressing was less than at the farm, but, on the other hand, maintenance expenses of plant infrastructure raise the prime cost. If the rapeseed is bought from the immediate supplier, rape oil actual cost is approximately 20% lower. Unfortunately, if the farmer desires to buy oil for use as a fuel from this manufacturer, purchase costs are much higher (value added tax, profit percentage, etc.).

The distribution of costs in rapeseed oil supply chain grouping expenses by categories – growing, transportation, cleaning/drying, and pressing/purification – are shown in Figures 5 and 6 (for unitary production infrastructure maintenance and logistics expenses are assumed too).

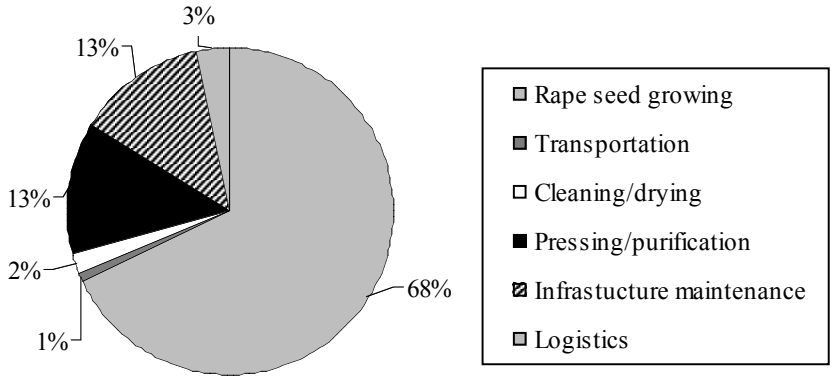

Figure 5. Distribution of costs in rapeseed oil supply chain for unitary production.

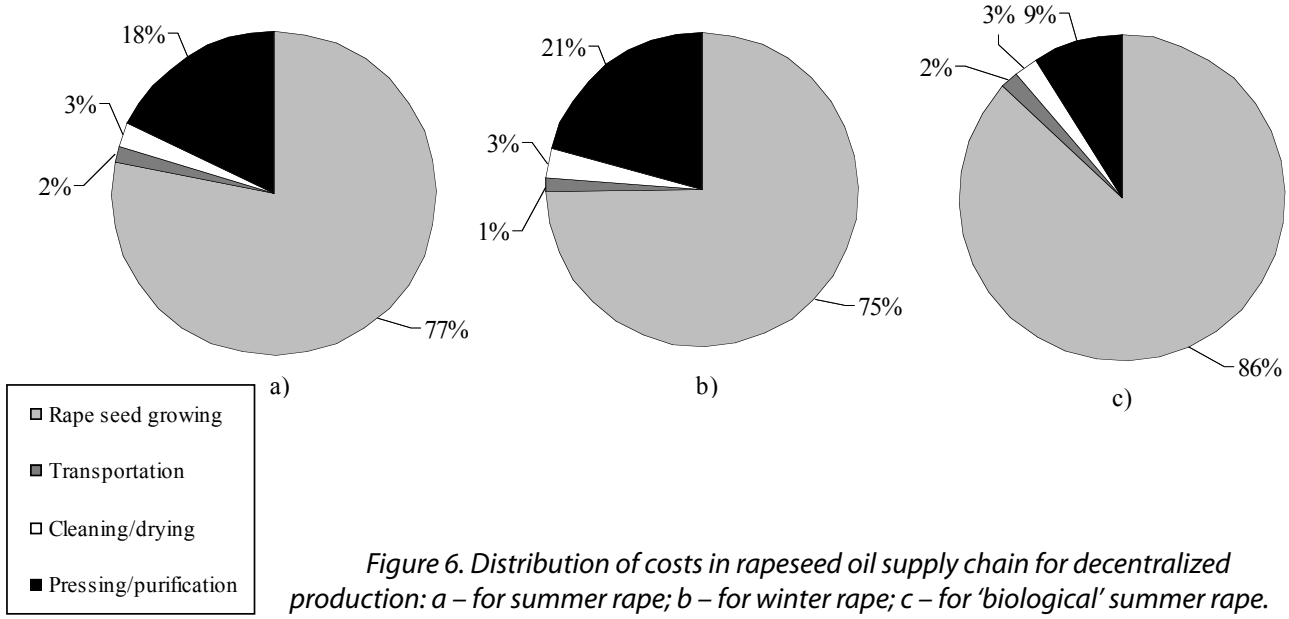

Figure 6. Distribution of costs in rapeseed oil supply chain for decentralized production: a – for summer rape; b – for winter rape; c – for 'biological' summer rape.

Distribution of costs shows that the greatest part is composed of rapeseed growing expenses. As it was mentioned before, for decentralized production this part could be reduced using own machinery with optimal productiveness characteristics as well as using rapeseed oil as a fuel for technical services as much as possible. For unitary production it's possible to buy rapeseed from the immediate suppliers or farmers.

Comparing models using *AnyLogic* and *ExtendSim Suite*, both of them showed similar results, but *AnyLogic* will be more useful from the viewpoint of sharing with others who might lack the software to develop their own model, because this software generates *Java* applets and applications with full simulation and optimization functionality.

Conclusions

1. Besides legislative initiatives, one of the possible ways how to enlarge the production and use of biofuels is to optimize biofuel supply chains using different methods of systems engineering.
2. Analysis of existing solutions in modelling of biofuel supply chains shows that existing solutions in this field are not usable for Latvia directly because this country's area, production capacities and other parameters are very different from other European countries.
3. Analysing available tools for the modelling of biofuel supply chains two different software were chosen – *AnyLogic* and *ExtendSim*. *AnyLogic* will be more useful from the viewpoint of sharing with others who might lack the software to develop their own model, because this software generates *Java* applets and applications with full simulation and optimization functionality.
4. Modelling studies showed that rapeseed oil supply chain model is very sensitive, because changing just single parameters (for example, yield capacity, rapeseed transportation distance, or rape cake sale price) in a short scale, the actual cost price of 1 litre of rapeseed oil changes considerably. That's why the future investigations in modelling of biofuel supply chains in Latvia have to be done very carefully, building models step by step and taking into account all parameters, which are affecting the final biofuel price most.
5. Comparing the fossil diesel fuel price (approximately 0.52 LVL l^{-1} after tax compensation) with rape oil actual cost from modelling studies, the use of oil as a fuel for farm machinery seems to be profitable.
6. Analysis of cost distribution shows that the greatest part (from 68% to 86% depending on production type) is composed of rapeseed growing expenses. This part could be reduced using own machinery with optimal productiveness characteristics as well as using rapeseed oil as a fuel for technical services as much as possible.

Acknowledgements

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DRAFT RESISTANCE OF THE PLOUGHS DEPENDING ON SOIL FRICTION

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Abstract

By using analytical correlations derived as a result of theoretical research, a computer algorithm has been worked out for simulating the functions of the plough body and the forces exerted by soil upon the operating parts, as well as its draft resistance. These correlations allow to determine the draft resistance of the plough depending on the parameters of its body, as well as to evaluate the impact of the physical and mechanical properties of soil, such as friction upon it. The greatest influence upon the draft resistance is exerted by soil hardness, density and slip resistance along the surfaces of the operating parts. The latter is also affected by soil adhesion, which particularly manifests itself in wet clay soils at lower temperatures. It has been clarified that the friction resistance constitutes 46 – 62% of the total draft resistance of the plough body. The main ways of lowering the friction resistance and the total draft resistance of the plough are the introduction of a more rational design of its body having optimum parameters, decreasing the resistance of the share-mouldboard surface and the values of reactions of the supporting surfaces, as well as the application of antifriction materials and better modes of joining with tractors.

Key words: plough draft resistance, friction resistance, analytic correlations, optimisation of parameters.

Introduction

It follows from our previous investigations (Vilde 1999, 2003, 2004; Rucins and Vilde 2003, 2004) that the draft resistance of ploughs depends on the body parameters, the physical and mechanical properties of soil, and the working modes. However, there were not enough investigations for analytic assessment of the impact of the body parameters and the variability of soil properties, such as friction, on the variations in the ploughing resistance. This encumbers the calculation of the proper solution of the plough body design and raising the ploughing efficiency.

The purpose of these investigations was analytical assessment of the impact of the variability of the plough body parameters and the soil friction properties on the variations in the ploughing resistance in order to determine the optimal body design under particular soil conditions to improve the ploughing efficiency.

Materials and Methods

The objects of the research are the forces acting on the plough body and its draft resistance depending on the body design parameters, as well as the physical and mechanical properties of soil and the working modes. On the basis of previous investigations, a computer algorithm has been worked out for the simulation of the forces exerted by soil upon the operating (lifting and supporting) surfaces of the plough body, and the draft resistance caused by these forces (Fig. 1).

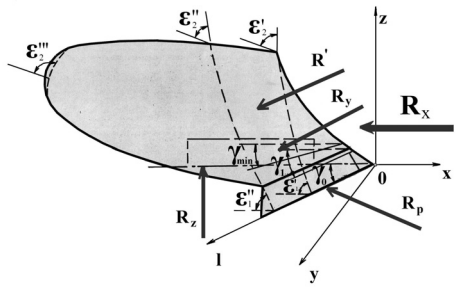


Fig. 1. Scheme of the plough body, its parameters and acting forces.

According to our previous investigations (Vilde, 1999), the draft resistance R_x of the plough body is determined by the share of the cutting resistance R_{Px}, the resistance caused by the gravity (weight) R_{Gx} of the soil slice lifted, by the inertia forces R_{Jx}, by soil adhesion R_{Ax}, and by weight R_{Qx} of the plough body itself (including a part of the weight of the plough):

$$R_x = \sum R_{ix} = R_{Px} + R_{Gx} + R_{Jx} + R_{Ax} + R_{Qx}. \quad (1)$$

The vertical reaction R_z and the lateral reaction R_y of the operating part are defined by corresponding partial reactions. The total draft resistance R_x of the operating part is composed of the resistance of the working surface R'_x and the resistance of the supporting (lower and lateral) surfaces R''_x:

$$R_z = \sum R_{iz}; \quad R_y = \sum R_{iy}; \quad R_x = R'_x + R''_x = \sum R'_{ix} + f_0 \left(\sum R_{iz} + \sum R_{iy} + p_{Axy} S_{xy} + p_{Axz} S_{xz}\right), \quad (2; 3; 4)$$

where: f_0 – the coefficient of the soil friction along the working and supporting surfaces of the plough body;
p_{Axy} and p_{Axz} – the specific adhesion force applied, respectively, to the lower and the lateral supporting surfaces of the body;
S_{xy} and S_{xz} – the surface area, respectively, of the lower and the lateral supporting surfaces of the body.

The friction resistance F_x is a constituent part of these reactions and their components (Rucins et al., 2003), and, by analogy, we can write that

$$F'_x = \sum F'_{ix} = F'_{Px} + F'_{Gx} + F'_{Jx} + F'_{Ax} + F'_{Qx} = R'_x - R'_{xo}; \quad (5)$$

$$F''_x = f_0 (R_z + R_y + p_{Axy} S_{xy} + p_{Axz} S_{xz}) = R''_x; \qquad F_x = F'_x + F''_x. \quad (6; 7)$$

The friction resistance of the share-mouldboard surface is defined as the difference between the total resistance (general value of the partial resistance) and resistance R_{xo} in operation without friction ($f_0 = 0$):

$$F_{ix} = R_{ix} - R_{ixo}; \qquad F_x = R_x - R_{xo}. \quad (8; 9)$$

Ratio λ_F of the friction resistance in the partial and total resistance (reaction), as well as ratio λ_R of the supporting reactions in the partial and total draft resistance is determined from their correlations:

$$\lambda_{F_i x} = R_i - R_{ix}^{-1}; \qquad \lambda_{Fx} = Fx - R_{ix}^{-1}; \qquad \lambda_{R_i} = R_i - R_{ix}^{-1}. \quad (10; 11; 12)$$

The cutting resistance R'_{Px} is proportional to soil hardness ρ_0 and the share edge surface area ω:

$$R'_{Px} = k_p \rho_0 \omega = k_p \rho_0 ib, \quad (13)$$

where: k_p – the coefficient involving the impact of the shape of the frontal surface of the ploughshare edge;
i and b – the thickness and width of the edge.
It is evident from formula (13) that friction of soil along the edge does not influence the cutting resistance.
At a sharp ploughshare (the rear bevel is absent)

$$R_{Pz} = 0. \quad (14)$$

At a blunt (threadbare) ploughshare having a rear bevel, the vertical reaction R_{Pz} on the hard soils can reach a summary value of vertical reactions, that arise from other forces acting on the share-mouldboard surface (soil gravity and inertia) and the weight Q of the body.

At an inclined ploughshare, a lateral reaction R_{Py} arises, its value being affected by the friction reaction:

$$R_{Py} = k_p \rho_0 ibctg(\gamma_0 + \varphi_0), \tag{15}$$

where: γ_0 – the inclination angle of the edge towards the direction of the movement (the wall of the furrow);

φ_0 – the angle of friction.

When friction is absent,

$$f_0 = 0,\ \varphi_0 = 0,\ R_{Py0} = k_p \rho_0 ibctg\gamma_0. \tag{16}$$

The friction of soil along the ploughshare edge reduces the lateral pressure of the ploughshare (the pressure of the plough body against the wall of the furrow).

The resistance of the supporting surface and the total cutting resistance is:

$$R''_{Px} = k_p \rho_0 ibf_0 ctg(\gamma_0 + \varphi_0) = F_{Px}'',\ \text{and}\ R_{Px} = k_p \rho_0 ib[1 + ctg(\gamma_0 + \varphi_0)] \tag{17; 18}$$

The lateral cutting resistance of the knife is determined by formulae, similar to those for the cutting resistance of the share. Consequently, similar to the above formulae will also be the formulae defining the impact of friction on the total resistance of the knife.

Forces caused by the gravity of the lifting soil slice:

$$\begin{aligned} R'_{Gx} \approx q\delta g k_y r \sin^{-1}\gamma \{ &[(\sin\gamma\cos\varepsilon_1 + \cos^2\gamma\sin^{-1}\gamma)e^{f_0\sin\gamma(\varepsilon_2-\varepsilon_1)} - \\ &- (\sin\gamma\cos\varepsilon_2 + \cos^2\gamma\sin^{-1}\gamma)]\cos\varepsilon_1 + (\cos\varepsilon_1 e^{f_0\sin\gamma(\varepsilon_2-\varepsilon_1)} - \cos\varepsilon_2) \\ &(\cos\varepsilon_1 - f_0\sin\varepsilon_1\sin\gamma)^{-1}\sin\varepsilon_1\left[\sin\varepsilon_1\sin\gamma + f_0(\sin^2\gamma\cos\varepsilon_1 + \cos^2\gamma)\right]\}, \end{aligned} \tag{19}$$

$$R_{Gy} \approx q\delta g r \sin^{-1}\gamma(\varepsilon_2 - \varepsilon_1)(\varepsilon_1 + 0.52)\, ctg\,\gamma, \tag{20}$$

$$R_{Gz} \approx q\delta g r \sin^{-1}\gamma(\varepsilon_2 - \varepsilon_1), \tag{21}$$

$$R''_{Gx} = f_0(R_{Gz} + R_{Gy}) = F''_{Gx}; \tag{22}$$

forces caused by the soil inertia:

$$\begin{aligned} R'_{Jx} = q\,\delta v^2 k_y^{-1}\sin\gamma\{&(\sin\gamma\cos\varepsilon_1 + \cos^2\gamma\sin^{-1}\gamma)e^{f_0\sin\gamma(\varepsilon_1-\varepsilon_2)} - (\sin\gamma\cos\varepsilon_2 + \cos^2\gamma\sin^{-1}\gamma) + \\ &+ (\cos\varepsilon_1 - f_0\sin\varepsilon_1\sin\gamma)^{-1}e^{f_0\sin\gamma(\varepsilon_2-\varepsilon_1)}\sin\varepsilon_1\left[\sin\varepsilon_1\sin\gamma + f_0(\sin^2\gamma\cos\varepsilon_1 + \cos^2\gamma)\right]\}, \end{aligned} \tag{23}$$

$$R_{Jz} = q\,\delta v^2 k_y^{-1}\sin\gamma\sin\varepsilon_2\, e^{f_0\sin\gamma(\varepsilon_2-\varepsilon_1)}, \tag{24}$$

$$R_{Jy} \approx q\,\delta v^2 k_y^{-1}\sin\gamma\cos\gamma(1 - \cos\varepsilon_2), \tag{25}$$

$$R''_{Jx} = f_0(R_{Jz} + R_{Jy}) = F''_{Jx}; \tag{26}$$

forces caused by soil adhesion:

$$\begin{aligned} R'_{Ax} = p_A b r \sin^{-1}\gamma(e^{f_0\sin\gamma(\varepsilon_2-\varepsilon_1)} - 1)\{&\sin\gamma\cos\varepsilon_1 + \cos^2\gamma\sin^{-1}\gamma + (\cos\varepsilon_1 - f_0\sin\varepsilon_1\sin\gamma)^{-1} * \\ &* \sin\varepsilon_1\left[\sin\varepsilon_1\sin\gamma + f_0(\sin^2\gamma\cos\varepsilon_1 + \cos^2\gamma)\right]\}, \end{aligned} \tag{27}$$

$$R_{Az} = 0, \qquad R_{Ay} \approx 0, \tag{28; 29}$$

$$R''_{Ax} = f_0(p_{Axy}S_{xy} + p_{Axz}S_{xz}) = F'', \tag{30}$$

where: q – the cross section area of the soil slice; δ – the density of soil; ky – the soil compaction coefficient in front of the operating part; f_0 – the soil friction coefficient against the surface of the operating element; v – the speed of the movement of the plough body; p_A – the specific force of soil adhesion; b – the surface width of the soil slice; ε_1 and ε_2 are correspondingly the initial and the final angles of the lifting (share–mouldboard) surface;

g – acceleration caused by gravity ($g = 9.81$).

The draft resistance caused by the ploughs weight Q:

$$R''_{Qx} = Qf_0. \quad (31)$$

The soil friction coefficient and the specific force of soil adhesion are not constant values. Their values decrease with the increase in speed (Rucins et al., 2003). This is considered in calculations.

The resistance of the supporting surfaces of the plough body depends on the values of the reacting forces. Yet their value is dependent, in many respects, on the manner of unification and perfection of the hydraulically mounted implements of the tractor. The vertical reaction of the plough with modern tractors having power regulation is transferred to the body of the tractor, and it affects the plough resistance to a considerably lesser degree. There are also solutions for the reduction of the lateral reaction. In such a way, the dominating component of the draft resistance of the plough body is the resistance of its share–mouldboard surface, to the research of which the present work is mainly devoted.

Results and Discussion

The presented work discusses, as an example, the results of the impact of the body parameters, the physical and mechanical properties of soil, such as the soil friction and the working modes, on the draft resistance of the plough body at various initial lifting angles ε_1, and at various angles γ of the horizontal generatrices, and at various working widths depending on the speed of operation when ploughing, for example, loamy soils, which predominate in Latvia (Rucins and Vilde 2004, 2005).

Calculations were carried out with a computer according to the foregoing formulae.

As an example, the calculation results of the impact of the soil friction coefficient f_0 upon the draft resistance of the plough body share-mouldboard (lifting) surface, as well as reacting forces on the supporting surfaces, the draft resistance and the total draft resistance of the entire plough body at the inclination angle ε_1 = 30° of the share (initial soil slice lifting angle), at the inclination angle γ = 30°…50° of the horizontal generatrix and at various speeds v are presented in the Figs 2 – 12.

The draft resistance of the lifting (share-mouldboard) surface and its components are presented in Figs 2 – 5, the reacting forces on the supporting surfaces – in Figs 6 – 10, the draft resistances of the supporting surfaces – in Fig. 11, and the total draft resistance of the plough body – in Fig. 12.

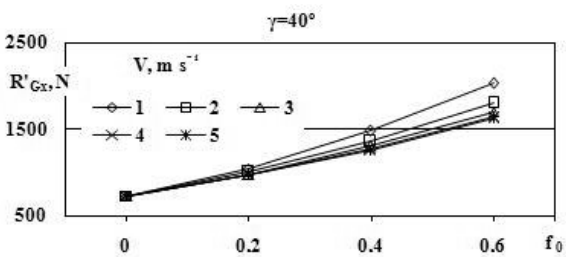


Fig. 2. Impact of the soil friction coefficient f_0 upon the draft resistance of the plough body share–mouldboard surface caused by the gravity of the soil slice.

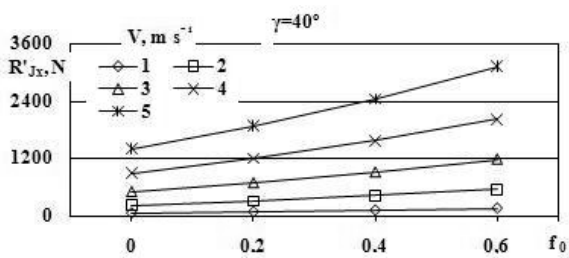


Fig. 3. Impact of the soil friction coefficient f_0 upon the draft resistance of the plough body share–mouldboard surface caused by the soil inertia forces.

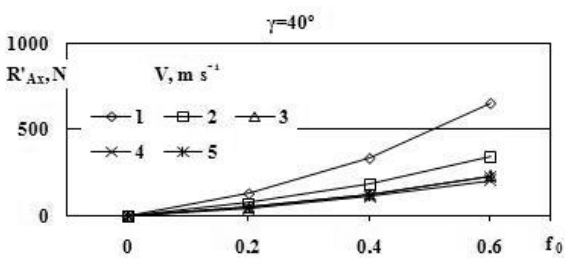


Fig. 4. Impact of the soil friction coefficient f_0 upon the draft resistance of the plough body share-mouldboard surface caused by adhesion.

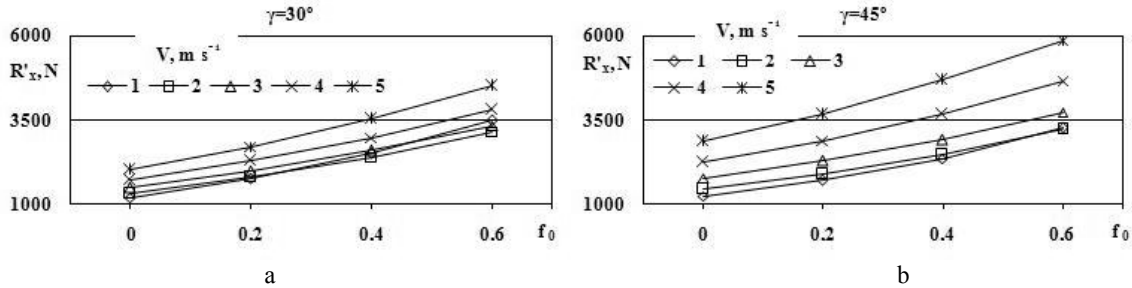


Fig. 5. Impact of the soil friction coefficient f_0 upon the total draft resistance of the plough body share-mouldboard surface caused by the soil gravity, the inertia forces, adhesion and soil cutting resistance at the inclination angle γ of the horizontal generatrix: a – γ =30°; b – γ =45°.

From Figs 2–5 it follows that at the soil friction coefficient f_0 = 0.3...0.4 and at the speed v=2…3 m s^{-1}, presently predominating in ploughing, the draft resistance caused by the soil friction takes 36…42% of the total draft resistance of the share–mouldboard surface.

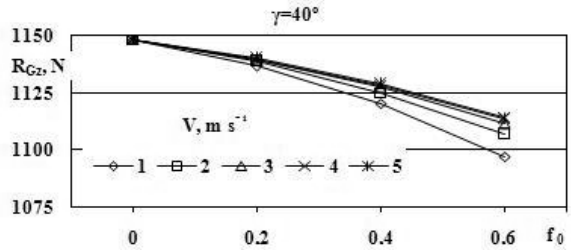


Fig. 6. Impact of the soil friction coefficient f_0 upon the vertical reaction of the plough body caused by the gravity of the soil slice.

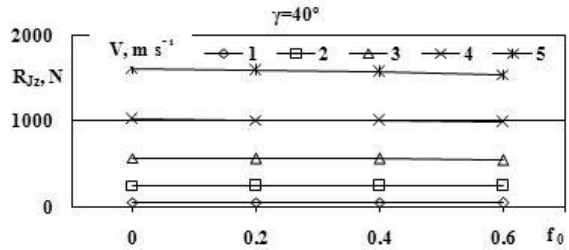


Fig. 7. Impact of the soil friction coefficient f_0 upon the vertical reaction of the plough body caused by the inertia forces of the soil slice.

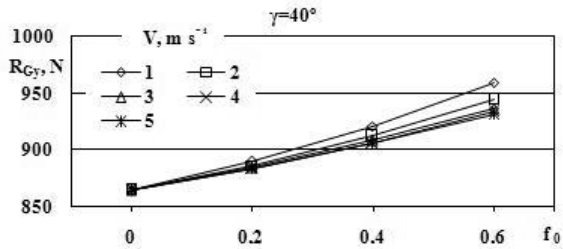


Fig. 8. Impact of the soil friction coefficient f_0 upon the lateral reaction of the plough body caused by the gravity of the soil slice.

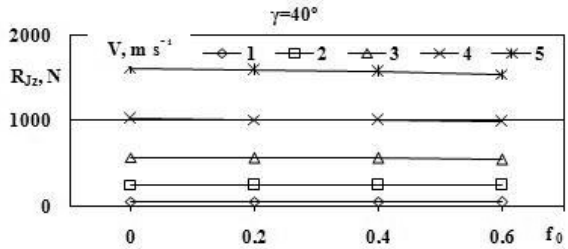


Fig. 9. Impact of the soil friction coefficient f_0 upon the lateral reaction of the plough body caused by the inertia forces of the soil slice.

The calculations and Figs 6–9 show that the value of the soil friction caused at the soil slice gravity, inertia forces and adhesion has only a little influence on the reactions of the supporting surfaces.

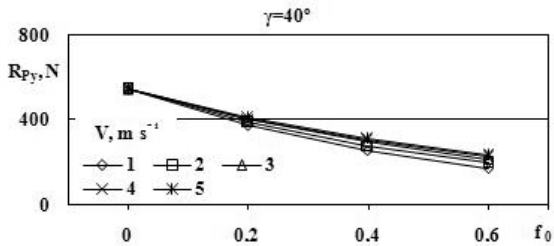
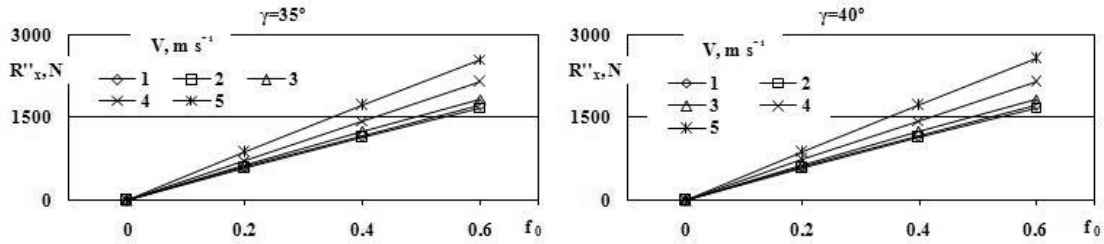


Fig. 10. Impact of the soil friction coefficient f_0 upon the lateral reaction caused by the soil cutting with the plough share at the inclination angle of the cutting edge γ_0 = 40°.

Fig. 10 shows that at the values of the friction coefficient f_0 = 0.3...0.4 the lateral reaction caused by the soil cutting decreases on 36…55%.



a b

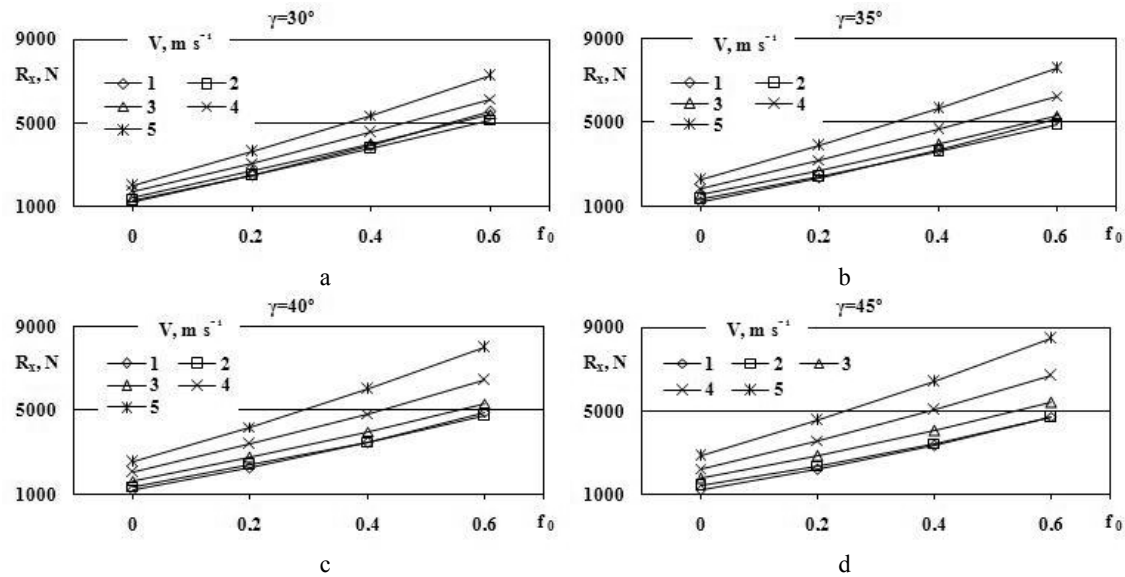
Fig. 11. Impact of the soil friction coefficient f_0 upon the draft resistance of the supporting surfaces of the plough body: a – γ =35°; b – γ = 40°.

It follows from Fig. 11 that the increase in speed increases the draft resistance of the supporting surfaces caused by soil friction. The value of the inclination angle of the horizontal genetratrix γ at the interval γ = 35°…45° has only a little influence on the draft resistance of the supporting surfaces.

It follows from Fig. 12 that at the values of the friction coefficient f_0 = 0.3...0.4 the draft resistance caused by the soil friction takes 46…62% of the total draft resistance of the plough body. It follows that the total draft resistance is approximately proportional to the friction coefficient. Increasing the speed decreases the share (ratio λ_F) of the friction resistance in the total draft resistance of the plough body. This phenomenon can be explained by the decreasing value of the friction coefficient when the speed is increasing (Vilde et al. 2007).

Fig. 12 also shows that at the values of the friction coefficient f_0 = 0.3...0.4, increasing the inclination angle of the horizontal genetratrix γ in the interval γ = 35°…45°, increases the draft resistance of the plough body to 6…10 %. This phenomenon is in agreement with the previous conclusions that the optimal values for the inclination angle of the horizontal genetratrix γ on the initial part of the share–mouldboard surface are 34…38^0 (Rucins et al., 2007).

It follows from formulae (17) – (30), too, that increasing the initial lifting angle ε_1 increases the draft resistance of the share-mouldboard surface, including the resistance of the soil friction (Rucins et al., 2007), but increasing the working width of the body decreases the specific draft resistance of ploughing (Rucins and Vilde, 2005). It was established from the formulae that the optimal values of the initial lifting angle are ε_1 = 28...32° and the optimal working width of the plough body b = 45...50 cm.



a b c d

Fig. 12. Impact of the soil friction coefficient f_0 upon the total draft resistance of the plough body: a – γ =30°; b – γ = 35°; c – γ = 40°; d – γ = 45°.

From the presented example it is evident that the draft resistance of the supporting surfaces is considerable. It can reach 25…30% of the total plough body draft resistance, or 36…44% of its share-mouldboard draft resistance (Figs 5, 11, 12).

Therefore it is very important for the reduction of the energy consumption of ploughing to reduce the draft resistance of the supporting surfaces. It may be obtained by using a contemporary hang-up device with the tractors, for example, power regulation allowing the transfer of the vertical reactions of the plough to the body of the tractor. It may decrease the draft resistance of the ploughs to 6…10%.

In the sources provided by other authors there are no materials about the application of the simulation methods in order to study the impact of the plough body parameters, as well as the soil friction properties on the draft resistance of the plough bodies. In order to obtain a better design of the plough body, a series of different bodies were built and tested (Larsen, 1968; Бурченко et al., 1976; Бурченко, 2001, Nikiforov and Ivanov, 1973). Yet it is bound with a great loss of resources, labour and time, so the best solution of the compared variants may not always be the optimum ones.

The materials of our investigations carried out by using the correlations indicated above present the values and regularity of the changes in the forces, the soil friction, acting on the share–mouldboard and the supporting surfaces, the draft resistance of the share-mouldboard and the supporting surfaces, as well as the total resistance of the plough body and its components under the working conditions depending on the body parameters, the soil friction coefficient and the working speed. In such a way it is possible to discover the draft resistance structure of the body, to assess the ratio of each element in the total resistance, to search and find possibilities how to reduce the tillage energy requirement.

Conclusions

1. The deduced analytical correlations and the developed computer algorithm allow assess the soil coercion forces upon the operating surfaces of the plough body, determinate the draft resistance and the optimal values of parameters, as well as the impact of the soil friction properties.
2. Presentation of the plough body draft resistance as the sum of its components – the cutting resistance of the soil slice, the resistance caused by its gravity, the soil inertia forces and adhesion including the soil friction resistance – allows analysing the forces acting upon the share-mouldboard and the supporting surfaces, finding out the character of their changes depending on the soil properties, parameters of the surfaces, of working speed, assessment of their ratio in the total resistance and determination of the optimal parameters of the body.
3. Increase in the inclination of the horizontal generatrix leads to a decrease in the draft resistance caused by the weight, adhesion and friction of the soil but it increases the resistance caused by the inertia forces, particularly, when the speed increases. The inclination of the generatrix (the edge of the share) does not affect the cutting resistance of the soil slice.
4. The impact of the soil–metal friction upon the draft resistance of the plough body is significant. It may reach 46…62% of the total draft resistance including the resistances of the supporting surfaces (25…30%). Therefore measures will be taken to diminish it, for example, by improving the body design, improving the mode of aggregation (joining) with tractors, using antifriction materials. The relief of the lower supporting surface may diminish the draft resistance of the body caused from the soil friction to 6…10%.
5. The optimal values of the main parameters of the body for contemporary ploughs, working at the speeds of 2…2.5 m s^{-1} are: the inclination angle of the share towards the furrow bottom – 28…32^0; the inclination angle of the horizontal generatrix towards the furrow wall on the initial part of the share-mouldboard surface – 34…38^0, on the top – not less than 48^0; the working width of the bottom – 45…50 cm.
6. The use of bodies having optimal parameters allows obtaining a good ploughing quality, reduction of the draft resistance by 12…20% and a corresponding rise in the efficiency, saving fuel and financial means.

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INFLAMMATORY FACTORS AND APOPTOSIS IN THE COW'S ENDOMETRIUM IN POSTPARTURITION PERIOD

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Abstract

Nine multiparous cows were biopsied twice – in the first and fifth week after parturition in winter 2004/2005 on the Research and Study farm "Vecauce" of Latvia University of Agriculture. The aim of the research was to reveal distribution of inflammatory factors and apoptosis in the cow's endometrium in post parturition period. Haematoxylin and eosin were used for routine staining of each sample. Tumor necrosis factor α (TNFα, w.d. 1:100, *Abcam*, England), and interleukin 10 (IL10, w.d. 1:400, *Abcam*, England) were detected immunohistochemically (IMH), and TUNEL method was used for detection of apoptosis. Distribution of these factors and substances was determined semiquantitatively by counting positive structures in visual fields. A significant increase in the total amount of inflammatory cells, as well as in the amount of the TNFα and apoptotic cells in endometrium between the first and fifth week after parturition ($p<0.01$) was observed. A significant positive correlation ($r=0.41$; $p<0.01$) between infiltration of endometrium with neutrophils and with macrophages was detected in the first week after parturition. A mild positive correlation ($r=0.52$; $p<0.01$) between neutrophils and lymphocytes, as well as between lymphocytes and macrophages ($r=0.35$; $p<0.01$) was found four weeks after parturition. A mild positive correlation ($p<0.05$) was observed between amount of inflammatory cells and TNFα ($r=0.52$), and number of apoptotic cells and TNFα ($r= 0.58$). The research suggests that inflammatory factors and apoptosis intensively act during the process of involution in the cows endometrium from the first up to the fifth week after parturition. Intensity, amount and activity of these components show individual variations in each case.

Key words: cow's endometrium, postparturition, inflammatory factors, apoptosis.

Introduction

Post partum period in dairy cows is very important from the reproductive perspective, because postpartum endometritis is one of the most common problems in cattle (Twardoň et al., 2002; Lewis, 2003; Gustafsson et al., 2004; Fischer et al., 2006). Often uterus invaded by microorganisms to variable extent depending on the cow's susceptibility and the hygienic condition of the environment at calving (Eduvie et al., 1984; DelVecchio et al., 1994; Gustafsson et al., 2004; Földi et al., 2006; Duļbinskis and Jemeļjanovs, 2006). Inflammatory factors possess an important role in a successful involution process, because increased infiltration of the endometrium with inflammatory cells like macrophages, lymphocytes, etc. is characteristic in postparturition period (Емельянова, 1974; Bondurant, 1999; Dhaliwal et al., 2001; Hammon et al., 2006).

Tumor necrosis factor α (TNFα) is known as a multipotent cell mediator. It is implicated in the control of uterine cell growth, differentiation, and function during oestrus cycle and gestation (Gamo et al., 2007). Interleukin 10 (IL10) and TNFα. take part in different processes, like inflammation, in cow uterus in post parturition period. Also TNFα, expressed by activated macrophages, is mentioned to be one of the inducers of apoptosis (Kliem, 2006).

Resumption of ovarian activity after parturition demonstrates an important role in cow's uterus regarding involution process. It is proved that the number of inflammatory cells in the endometrium is closely related to the different stages of the oestrus cycle (Kaoket, 2003). Also IL10 shows relationship to the ovarian activity, so the amount of IL-10 in

endometrium increases in the secretory phase of the reproductive cycle. In endometrium not only $CD4^+$T cells express IL-10, but also glandular and epithelial cells express that cytokine (El-Sherif et al., 2001; Sallinen et al., 2000).

Programmed cell death (PCD) or apoptosis is a genetically predicted biochemical specific cells death. PCD begins with specific signals and nonlisosomal activation of endogen endonucleasis which results in defragmentation of the nucleus DNS, thus releasing tissues from old, damaged, or needless cells. Morphologically PCD is expressed with death of separately, chaotically located cells. Inhibitors of apoptosis are growth factors, matrices of cells, steroids, and some proteins of viruses. Absence of growth factors, loss of intercellular connection, glucocorticoids, some free radicals, and ionized radiation are mentioned to be like activators of apoptosis (Goyeneche and Telleria, 2005). Cells loss by apoptosis has been demonstrated during involution and atrophy of a variety type of glands. It results in shrinkage of tissue without disruption of its basic architecture (Walker et al., 1989).

The aim of the research was to reveal distribution of inflammatory factors and apoptosis in the cow's endometrium in postparturition period.

Materials and methods

Biopsy samples from cow uterus were taken in winter 2004/2005 on the Research and Study farm "Vecauce" of Latvia University of Agriculture. Nine multiparous cows were biopsied twice – in the first and fifth week of the postparturition period. Histological investigations were performed at the Institute of Anatomy and Anthropology of Riga Stradins University. Routine staining with haematoxylin and eosin was performed for each endometrium sample (Aughey and Frye, 2001). Tumor necrosis factor α (Rabbit Polyclonal to TNFα / ab6671, w.d. 1:100, *Abcam*, England), and interleukin 10 (Rabbit Polyclonal to IL10 / ab 34843, w.d. 1:400, *Abcam*, England) were detected immunohistochemically (IMH) (Hsu et al., 1981). The TUNEL method was used for detection of apoptosis (Negoescu et al., 1998). Distribution of these factors and substances was determined semiquantitatively by counting positive structures in visual fields (0 – occasional, + – few, ++ – moderate, +++ – numerous positive structures in visual fields). For the data statistical processing the following methods were used: Student's t-test, Wilkinson's test, and statistical correlation analyses (Paura and Arhipova, 2002; Arhipova and Bāliņa, 2003).

Results and discussion

Hyperemia and different level of infiltration with inflammatory cells were observed in cow's endometrium from the first up to fifth week after parturition, as well as partial detachment of the lining epithelium and oedema in mucous membranes. Lymphatic follicules and proliferation of endometrial glands, periglandular and perivascular infiltration of endometrium with inflammatory cells were detected in the fifth week after parturition. A statistically significant increase ($p<0.01$) with neutrophils, macrophages and lymphocytes (Fig.1) and a significant positive correlation between infiltration of endometrium with neutrophils and macrophages was detected in the first week after parturition ($r=0.41$; $p<0.01$).

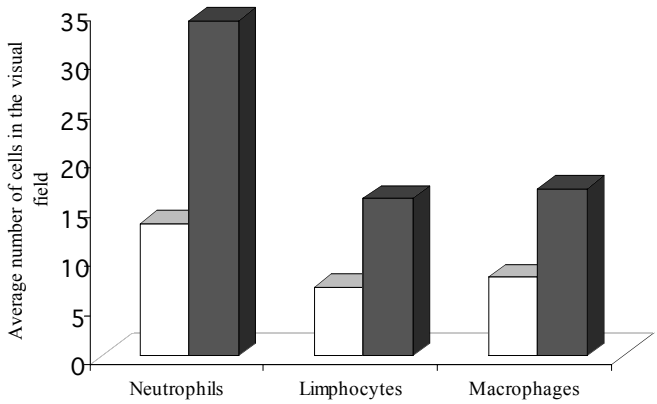

Figure 1. Average number of neutrophils, macrophages and lymphocytes in cows endometrium in the first and fifth week after parturition (□1st week; ■ 5 th week).

An important role of polymorphonuclear leukocytes and other inflammatory cells are mentioned regarding to postparturition period in different species, because these cells can migrate into tissues with negative consequences for the defense against infections at that time in uterus (Bondurant, 1999; Dhaliwal et al., 2001; Mateus et al., 2002; Meglia, 2004; Hammon et al., 2006). Also our finding regarding to the increasing of the total number of inflammatory cells in cows endometrium in post parturition period are similar to the above mentioned data.

A mild positive correlation ($r=0.52$; $p<0.01$) between neutrophils and lymphocytes, as well as between lymphocytes and macrophages ($r=0.35$; $p<0.01$) was found four weeks after parturition. IL-10 produced by glandular and epithelial cells of uterus was found around endometrial glands and in epithelial cells. No statistically significant correlation was found between cells expressing IL–10 and other mentioned parameters in the cow's endometrium in postparturition period. Possible it is connected with absence of cyclic ovarian activity. There were proved relationship of IL-10 containing structures in cows endometrium with ovarian activity, so increased expression of IL–10 observed in the secretory phase of the reproductive cycle, (El-Sherif et al., 2001; Sallinen et al., 2000), but we did not observed ovaries in our investigation.

A mild positive correlation ($p<0.05$) was observed between amount of inflammatory cells and TNFα ($r=0.52$), and number of apoptotic cells and TNFα ($r= 0.58$). TNF-α, produced by activated macrophages, is one of the inducers of apoptosis, and it acts like one of inflammatory factors in cows uterus (Zhdanov et al., 2003; Fischer et al., 2006; Kliem, 2006). TNF-α is mentioned to be involved in uterus cells growing and differentiation processes concerning to gestation, and in reproductive cycle physiological stages (Gamo et al., 2007).

Reduced oedema and more compact tissues in the fifth week than in the first week after parturition probably explain the increased amount of apoptotic cells in endometrium. It is a way, that occurs reducing and involution of the reproductive organs depending physiological stage after gestation and lactating (Walker et al., 1989).

The mind about duration and finishing of cows uterus involution after parturition is not common. Some affirm that cows uterus able renew a physiological environment in four weeks after parturition (Eduvie et al., 1984; LeBlank et al., 2002), other suggests that cows uterine involution appears not to be a barrier to a fertility after 5-6 weeks postpartum (O'Shea and Wright, 1984; Kiracofe, 1980; Miettinen, 1990), while Leslie (1983) reported that complete involution of cows uterus occurs 41–50 days post parturition. All these affirmations based on bacteriological, histological and statistical investigations.

An intensity of inflammatory and apoptotic processes varies in separate cows. It may be explained with the individual quality of the immune system.

Conclusion

Strong infiltration with inflammatory cells and increased amount of apoptotic cells are characteristic features for the cow's endometrium in the fifth week after parturition. TNF-α correlation with apoptotic cells suggest about possible connection between programmed cells death and inflammation at that time.

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EFFECTS OF TOPICAL AND SYSTEMIC ATROPINE SULFATE ON INTRAOCULAR PRESSURE AND PUPIL DIAMETER IN DOG'S EYE

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Abstract

The objective of this study was to determine the effects of topical 1% atropine sulfate and systemic atropine sulfate on intraocular pressure (IOP) and horizontal pupil diameter (HPD) in dog's eyes.

Ten adult dogs for each treatment were used in this study. Dogs of different age, breed and sex were examined clinically and ophthalmologicaly. All animals were clinically and ophthalmologically healthy.

One drop of topical 1% atropine sulfate was used in ten dogs unilaterally, with the contralateral eye acting as a control. IOP and HPD were measured every 5 minutes. In ten dogs systemic atropine sulfate were used intramuscularly (IM) with IOP and HPD measured every 5 minutes. In both study phases IOP and HPD were measured over a total duration of 60 minutes.

After unilateral application of topical atropine, IOP increased significantly in the treated eye. A maximum average IOP of 20.3 mmHg in the treated eye was observed 20 minutes after treatment. Maximal pupil dilatation in the treated eye was observed 35 min after treatment. Measurements made after systemic atropine showed an IOP increase in both eyes, showing maximum average IOP increase 25 minutes post-treatment. Maximum average values of HPD were obtained 25 minutes after treatment. The HPD started to decrease 30 minutes after treatment but it was still significantly higher than before treatment ($P < 0.05$).

Because of atropine sulfate's ability to cause significant increase in IOP, it should not be used for diagnosis and treatment of glaucomatous eyes.

Key words: atropine sulfate, dog, intraocular pressure, horizontal pupil diameter.

Introduction

It is known that atropine sulfate is a parasympatholytic agent which interacts with muscarnic receptors on effector cells and prevents acetylcholine from binding to the receptor area (Jones et al., 1977). Atropine blocks the cholinergic fibers of the short ciliary nerve and relaxes the sphincter muscle of the iris, dilating the pupils (Thurmon et al., 1996). It is a commonly used topical agent for a treatment of acute iritis, iridocyclitis and keratouveitis by relieving ciliary spasm and helping to prevent synechia formation (Smith and Reynard, 1992; Ward, 1998). Topical atropine or another parasympatholytic agent such as tropicamide is essential for the examination of the posterior segment of the eye (including retina, retinal vessels, optic nerve, and peripheral areas of the lens) (Ward, 1998).

It is proven that in humans increase of intraocular pressure (IOP) has been observed after use of topical mydriatics like atropine (Gartner and Billet, 1957), tropicamide and phenylephrine (Harris, 1968; Harris and Galin, 1969) together with sympathomimetics (Rengstorff and Doughty, 1982). Mydriatic drugs can cause a significant rise in intraocular pressure in patients with narrow angle (Harris and Galin, 1969) and primary open angle glaucoma (Shaw and Lewis, 1986; Marchini et al., 2003).

In a study with 10 adult cats the effects of local atropine and phenylephrine demonstrate a significant intraocular pressure (IOP) increase after atropine, but no effect after the phenylephrine. The highest IOP was measured in treated eye between 5 and 28 h after treatment and these differences were statistically significant at 1, 3, 6, 12 and 16 h post-treatment (Stadtbaumer et al., 2006). In a study with horses, topical 1% atropine did not show significant changes of IOP in the first and second day (Herring et al., 2000), or there was a small but significant

lowering effect (Mughannam et al., 1999).

Regarding on parameters of pupil diameter in the literature such research has been done on horses and cats. The maximum of pupil dilation was obtained 30-60 min after topical atropine in dogs, cats and cattle (Gelatt et al., 1973; Gelatt et al., 1995 a, b; Gelatt and MacKey, 1998). In cats, 24 hours after topical atropine, horizontal pupil diameter (HPD) started to reduce and after 96 hours the pupil returned to the initial size (Stadtbaumer et al., 2006). In the study with horses, a significant increase in vertical pupil diameter (VPD) was observed 30 min after treatment, but maximum values appeared between two and four hours. No significant differences were obtained in maximum VPD based on age, breed or sex (Mughannam et al., 1999; Davis et al., 2003). In another study with horses where VPD was measured every 24 hours for 14 days, significant increase of VPD was measured in all time points; and it was ascertained that duration of mydriasis after topical 1% atropine sulfate application was greater than 14 days (Davis et al., 2003).

Topical ocular use of atropine sulfate can cause salivation in dogs and cats. Apparently, the mydriatic exits through the nasolacrimal system and, when in contact with the glosal mucosa, elicits copious salivation (Gelatt, 1978). This could cause systemic effects of topical atropine used unilaterally.

For a long time ophthalmologic atropine has been known for its mydriatic and cycloplegic effect. Contradictory findings regarding the effects of atropine on the dynamics of aqueous humor outflow have been reported (Bill, 1967; Bill, 1969; Green and Elijah, 1981; Miichi and Nagataki, 1982). In a study with monkeys, atropine was shown to increase uveoscleral outflow through the relaxing of the ciliary muscle (Bill, 1967; Bill, 1969). There are authors who have mentioned that atropine could change aqueous outflow (Harris, 1968; Valle, 1974), but others have found that mechanical obstruction of iridocorneal angle could be the possible cause of IOP increase (Stadbaumer et al., 2006). Author has observed that maximum dilatation of the pupil lasts longer than statistically significant increase on IOP, arguing against mechanical obstruction of iridocorneal angle (Stadbaumer et al., 2006).

Systemic atropine is frequently used to control smooth muscle spasms and is routinely used as adjunct to general anesthesia, particularly with inhalant anesthesia, to decrease salivary and airway secretation.

It is mentioned that systemically administrated atropine has wide systemic effects acting on the cardiovascular, gastrointestinal, bronchial, urinary, central nervous system, sweet gland and ocular systems (Jones et al., 1977; Ward, 1998; Birģele et al., 2005).

In the literature there are no clear data about influence of systemical atropine on IOP and HPD in the dog. Therefore the aim of our study was to determine the effects of topical and systemical atropine sulfate on functional state of the eye.

The purpose of this study was:

1) to determine the effects of topical 1% atropine sulfate on IOP and HPD in dog's eye;
2) to determine specific intraocular effects after systemic atropine sulfate application in dog.

Materials and Methods

All animals were outpatients examined at Preclinical Institute of the Faculty of Veterinary Medicine of the Latvia University of Agriculture in 2007. This study was accepted by the Animal Protection and Ethical Commission of Latvian State Food and Veterinary Service. In all cases an informed consent was obtained from the pet owners for the study.

All animals included in this study were examined clinically and ophthalmologically. Examination included slit lamp-biomicroscopy, direct ophthalmoscopy and monocular indirect ophthalmoscopy with *Pan Optic®*. Information about animal breed, age and sex were noted. Prior to the study, all patients were determined to be free of ocular lesions which could alter IOP from normal.

This study was organized in two phases. In the first phase we used 10 healthy dogs of different sex and breed: mixed breed (n=5), Golden Retriever (n=2), Boxer (n=1), Staffordshire Bull Terrier (n=1), and Dachshund (n=1). In these dogs the effect of local 1% atropine sulfate on IOP and HPD was ascertained. All animals received one 30µ drop of 1% atropine sulfate (Martindale Pharmaceuticals Ltd. UK) in the right eye; the left eye served as a control. The first measurement was taken before treatment, avoiding any tension on the animal's neck. After treatment, IOP and HPD were measured every five minutes (T_0; T_5…T_{55}; T_{60}.) for a complete period of 60 minutes.

In the second phase 10 dogs (mixed breed (n=9) and Golden Retriever (n=1)) were used to ascertain

the effect of systemical atropine sulfate on IOP and HPD. Atropine sulfate at the dose of 0.06 mg kg^{-1} (Jones et al., 1977) was administered systemically by intramuscular injection. IOP and HPD were measured every 5 minutes for a total period of 60 minutes.

All tonometric measurements were performed by the same person with the rapid and minimally stress- inducing method of rebound tonometry with tonometer (*TonoVet®, Tiolat Ltd. Finland*), using values that achieve less than 5% standard deviation. For this tonometer it is not necessary to use topical anaesthesia. Some authors have noticed that endothelial and systemic toxicity could occur with a frequent use of topical anesthesia (Judge et al, 1997; McGee and Fraunfelder, 2007).

Horizontal pupil diameter was measured with *Jameson* callipers under fixed light conditions at the same time of day.

To determine the effect of topical and systemical atropine sulfate, arithmetic mean values (X) and standard deviation (SD) of the IOP and HPD were calculated for each eye. Changes in IOP and HPD between eyes and in a time period were evaluated using a paired two-sample T-test. P values less than 0.05 were considered to be statistically significant.

Results and Discussion

During this study no signs of irritation or pain were detected.

At first we estimated initial position of the animals' eye – IOP before application of atropine sulfate, and established that normal IOP varies between 14.2 ± 3.58 mmHg till 17.7 ± 3.13 mmHg. Data from the literature shows that normal IOP in dogs varies between 16.7 ± 4 mmHg (Miller et al., 1993) and 18.7 ± 5.5 mmHg (Gellat and MacKey, 1998). Therefore, our results about normal IOP in dogs are similar to those in the literature.

It should be mentioned that before treatment there were no significant differences in IOP between the left and right eye ($P > 0.05$). The average IOP before application of 1% atropine sulfate in the right eye was 17.7 ± 3.12 mmHg and 17.3 ± 2.75 mmHg in the left eye.

The dynamics of IOP increase after topical application of 1% atropine sulfate is shown in Fig. 1. The radical increase of IOP began five minutes after treatment and continued till 20 minutes after treatment. IOP started to decrease 20 minutes after treatment and 25 minutes after treatment it reduced to 19.5 ± 2.55; the lowest level of IOP (18.5 ± 2.32) was measured 30 minutes after treatment. There was a small increase of IOP 35 minutes after treatment reaching 19.1 ± 2.42, but this was not statistically significantly different from the value at 30 minutes. Slight decreases of IOP were measured till 60 minutes after treatment but values did not decrease lower than pre-treatment values ($P < 0.05$).

The average IOP in the treated eye compared to the untreated eye was significantly higher ($P < 0.05$) from 10 till 25 minutes after treatment (Fig. 1).

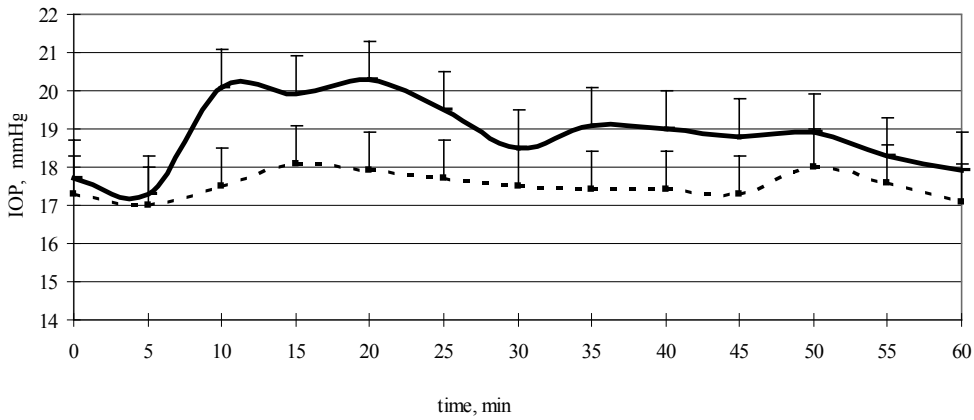

Figure 1. IOP changes after unilateral application of 1% atropine sulfate (–– right eye, ·····left eye).

In the control eye, where topical atropine sulfate was not administrated, IOP varied from 17 ± 3.23 to 18.1± 3.90. There was no significant increase in IOP compared to pre-treatment values (P > 0.05). It can be concluded that during monocular topical administration of topical atropine sulfate there do not appear to be any systemic effects on the contralateral eye, which also indicated in a similar study with horses (Herring *et al.,* 2000).

Our results about influence of topical 1% atropine on horizontal pupil diameter (HPD) show that average HPD before topical atropine in the right eye was 7.8 ± 3.58 mm and 7.7 ± 3.59 mm in the left eye (Fig. 2). There were no significant differences in HPD between eyes before treatment. We established that after application of 1% atropine, pupil diameter in treated eye started to dilate ten minutes after treatment, gaining 8.1 ± 3.46 mm and continued to increase in size till 55 minutes after treatment gaining maximum of average values - 12.13 ± 1.55 mm. The pupil remained at maximal dilatation level till 60 minutes after treatment (Fig. 2). Differences in HPD between the treated and untreated eye were statistically significant (P < 0.003).

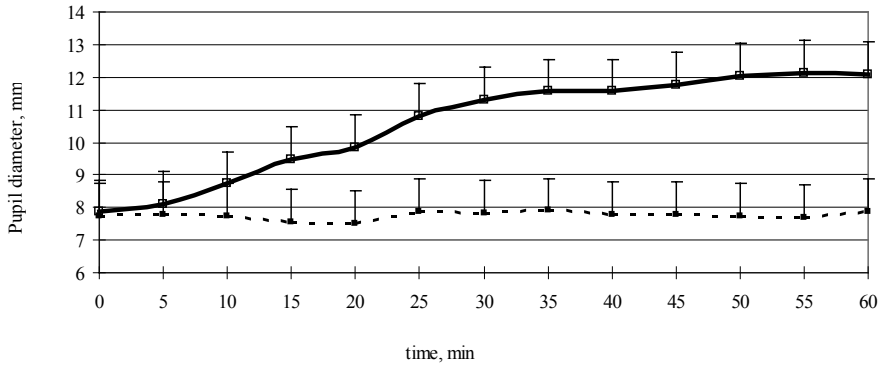

Figure 2. Changes in horizontal pupil diameter after unilateral application of 1% atropine sulfate (–– right eye, ·····left eye).

In the second phase we investigated the changes in intraocular pressure (IOP) in dogs after injection of atropine sulfate at the dose of 0.06 mg kg^{-1}. The average IOP before systemic atropine application was 14.2 ± 3.58 mmHg in the right eye and 14.4 ± 3.50 mmHg in the left eye (Fig. 3). The differences between the right and left eye in average IOP values were not significant (P > 0.05). Five minutes after IM application of atropine sulfate, IOP increased reaching 16.3 ± 4.47 in the right eye and 16.2 ± 4.56 in the left eye. Increase of IOP compared to pre-treatment values was statistically significant in both eyes (P < 0.02). IOP continued to increase and 25 minutes after application reached the greatest IOP gaining 17.1 ± 5.23 mmHg in the right eye and 17.3 ± 4.57 mmHg in the left eye (P < 0.05). IOP slightly decreased 30 minutes after treatment gaining 16.4 ± 4.88 in the right eye and 16.4 ± 5.05 in the left eye, but these values are still significantly higher than pre-treatment values (Fig. 3). There were no significant differences in IOP between eyes (P > 0.05). In conclusion the significant bilateral increase of IOP confirms a systemic influence of topical atropine.

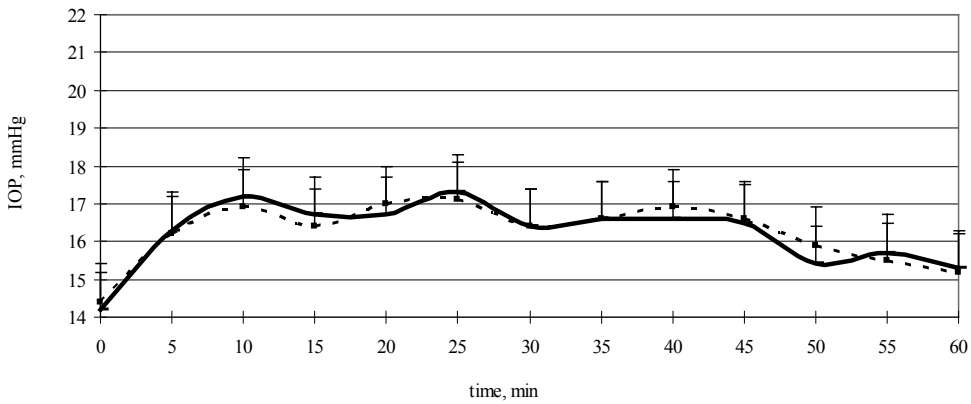

Figure 3. IOP changes after systemic administration of atropine sulfate (–– right eye, ·····left eye).

In relation to HPD we observed that average HPD before systemical administration of atropine sulfate was 6.75 ± 2.13 mm in both eyes. There were no differences in HPD between eyes before treatment. HPD increased significantly ten minutes after systemic atropine sulfate administration in both eyes (Fig. 4) and linearly continued to increase until 25 minutes after treatment ($P < 0.05$). There were no significant differences between eyes ($P > 0.05$). Maximum of average values (9.75 ± 3.61 mm and 9.93 ± 2.56 mm) in right and left eyes were obtained by 25 minutes after administration. The value of HPD started to decrease 30 minutes after administration but was still significantly higher than before treatment throughout the study period ($P < 0.05$). Sixty minutes after treatment, HPD was 8.8 ± 2.85 in the right eye and 9.3 ± 2.96 in the left eye; these values were significantly higher than pre-treatment values.

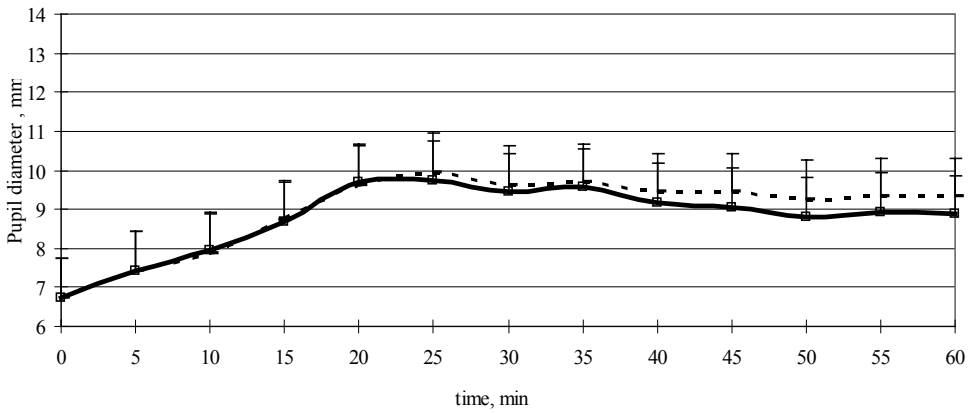

Figure 4. Changes in horizontal pupil diameter after systemic application of atropine sulfate (–– right eye, ·····left eye).

Our research demonstrates that systemic administration of atropine sulfate does have a significant influence on IOP and HPD in dog's eyes.

These results are novel, since there has been no similar or analogical research done on influence of systemical atropine sulfate on IOP and HPD in animals, nor research on the effects of topical atropine on intraocular pressure in the canine eye as shown here. The research in this field is still in process.

Conclusion

Results based on this study show that topical atropine does have a significant influence on IOP and HPD in the treated eye but not in the contralateral untreated control eye. Systemic use of atropine influences IOP and HPD in both eyes. It is thus important not to give atropine topically or systemically to dogs predisposed to, or actually affected by glaucoma. Further research is required to more completely define the mechanism of influence of atropine on aqueous humor production and outflow in the dog.

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LOCATION OF HELICOBACTERS IN THE GASTRIC MUCOSA OF DOMESTIC DOGS (*CANIS FAMILIARIS*)

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Abstract

This study was done to evaluate the prevalence and colonization density of helicobacters in the gastric mucosa of domestic dogs (*Canis familiaris*). Mucosal samples were taken from several places of cardiac, fundic and pyloric gland region of the stomach to detect helicobacters with urease test, brush cytology, and light histological examination. Fourteen dogs of fifteen sampled animals showed positive urease test and the presence of tightly spiraled helicobacters. Positive urease test was observed in 80.4% of all examined samples. Helicobacters were detected in 82.7% of all examined samples by brush cytology and 80.8% of all examined samples by histological examination. Compared to gastric regions, in all employed detection methods showed significantly higher prevalence of helicobacters in cardiac and fundic gland region than in the less effected pyloric gland region of the stomach. Histological examination showed the location and colonization density of the bacteria at the superficial epithelium, gastric pits, and deep glandular epithelium of the gastric mucosa in different regions of the stomach. Colonization density of bacteria was evaluated in 4 groups: as absent, mild, moderate, and severe colonization density of helicobacters. Occurrence of helicobacters in the cardiac and fundic gland region showed mild and moderate colonization density of helicobacters at the superficial epithelium and at the gastric pits of the gastric mucosa. Colonization density of spiral-shaped bacteria between the deep glandular epithelium was more pronounced in the pyloric gland region than in the cardiac and fundic gland regions of the gastric mucosa in the domestic dogs.

Key words: helicobacters, dogs, gastric, superficial epithelium, pits, glands.

Introduction

Many *Helicobacter* species colonize the stomachs and intestines of humans and several domestic and wild species of animals (Neiger et al., 1998). Some helicobacter species have been formally recognized and have often been associated with condition of gastric and/or enterohepatic disease including gastroenteritis, gastric ulcers, hepatitis, and cancer (Fox et al., 1997; Solnick, Schauer, 2001). However, not all *Helicobacter* species are considered pathogenic and instead may form part of the host's indigenous gastrointestinal microflora (Simmons et al., 2000).

Since the first isolation of *Helicobacter pylori* from humans with gastritis and gastric ulcer in 1984 (Marshall and Warrens, 1984), helicobacters have been detected in several animal species, such as dogs, cats, pigs, cheetahs, ferrets, polar bears, sea lions, monkeys, and rodents (Bronson et al., 1991; Lee et al., 1992; Eaton et al., 1993, 1996; Fox and Lee, 1995; Jalava et al., 1997; Neiger et al., 1998; Hwang et al., 2002; Oxley et al., 2004). Our previous study shows that helicobacters are detected also in the gastric mucosa of feral raccoon dogs (Bērziņa, Birģele, 2006). Several *Helicobacter* species have been isolated from the stomach of dogs: *H.felis*, *H.bizzozeronii*, *H. salmonis*, and *H. rappini* (Jalava et al., 1997, 1998; Hanninen et al., 1998).

Literature shows that *Helicobacter* species are mostly microaerophillic, gram-negative, spiral-shaped bacteria with multiple terminal flagellae and high-level urease activity, which allows them to survive in an acidic environment (Eaton et al., 1996). The sources and routes of transmission have been established following numerous studies, which suggested oral-fecal and oral-oral transmission of *Helicobacter* like microorganims (Bussac, 1999).

Up to now many diagnostic methods have been developed to detect *Helicobacter pylori* infection: some invasive, such as rapid urease test, brush

cytology, histology, electronmicroscopy, culture, polymerase chain reaction, and others non-invasive, such as serology, urea breath test (Happonen et al., 1996) and recently *H.pylori* antigen is also determined in feces (Happonen et al., 1998). It is reported that appearance of helicobacters and histopathological changes in the mucosa of stomach can be detected with several histological staining methods, such as hematoxylin and eosin, Giemsa-Wright and Warthin-Starry stains (Hermanns et al., 1995; Happonen et al., 1996; Neiger et at., 1998). Previous investigations show that helicobacters are detected at superficial epithelium, gastric pits and deeper in the glandular epithelium of the gastric mucosa (Hermanns et al., 1995; Happonen et al., 1996; Otto et al., 1994). Histological examination also allows evaluation of the mucosal status and shows high sensitivity and specificity. This is also pointed out in other studies (Megraud, 1996); however, it is comparatively expensive and labor intensive (Chu et al., 1997).

The aim of our study was to detect the prevalence and colonization density of helicobacters in the gastric mucosa of domestic dogs (*Canis familiaris*).

The main tasks of this work:

1) to detect helicobacters in the mucosal samples of the stomach with three different diagnostic methods – urease test, brush cytology, and histological examination;
2) to establish the prevalence of helicobacters in different parts of the stomach – cardiac, fundic, and pyloric gland region;
3) to evaluate helicobacters at different parts of gastric mucosa: superficial epithelium, gastric pits, and deeper glandular epithelium.

Materials and Methods

Mucosal samples of the stomach were taken from fifteen domestic dogs immediately after the death of animal (under agreement of the owner) in the Center of Veterinary Education, Latvia within one year period.

Mucosal samples were obtained from strictly determined seventeen sites of the stomach: four sites of cardiac gland region, eight sites of fundic gland region, and five sites of pyloric gland region. In total, during this study there were examined 255 gastric mucosal samples of domestic dogs for detection of helicobacters. Mucus and mucosal samples for brush cytology, urease test, and light histological examination were obtained from each sample site within two hours after the death of animals (Happonen et al., 1996).

Small gastric mucosal samples were cut with scissors and placed in 24 well plates for urease test. The samples were incubated in 1 ml of reagent containing 10% unbuffered urea in distilled water and phenol red indicator (pH 6.3). The results were recorded in 10min, 30min, and 60min after each sample was placed in reagents (Bērziņa, Birģele, 2006). A color change from pale yellow to bright pink was considered positive to helicobacters.

Collection of mucus for brush cytology was performed using sterilized small cotton brushes. The brush was rolled over the gastric mucosa at the sample site and subsequently rolled on the clean slide. The preparations were then air dried and stained with *Diff-Quick* staining method (Happonen et al., 1996). Helicobacters were observed with light microscope *Leica* oil immersion lens at 1000 magnification.

Gastric mucosal samples for histological examination were fixed in 10% neutral buffered formalin, routinely processed in Tissue Auto processor *Tissue-Tek II*, embedded in paraffin, sectioned in 4 µm thick sections with microtome *SLEE Mainz Cut 4055* and stained with *Diff–Quick* method (Happonen et al., 1996). Helicobacters were detected at the gastric mucosa with light microscope at 1000 magnification.

Histological examination of each sample included evaluation of location and colonization density of helicobacters at the superficial epithelium, gastric pits, and deeper glandular epithelium of the cardiac, fundic and pyloric gland regions of the stomach. The presence of helicobacters was evaluated in accordance to 4 grades: as absent with no bacteria seen in the visual field, as mild with 1-10 bacteria seen in the visual field, as moderate with 10-50 bacteria seen in the visual field, and as severe with more than 50 bacteria seen in the visual field (Happonen et al., 1998; Neiger et al., 1998).

Statistical analyses of results were performed by SPSS 11.5 program. Differences between the results produced by urease test, brush cytology and histological examination were treated by nonparametric *K-related Cochrans`s Q test*. Occurrence and colonization density of helicobacters at the different parts of mucosal epithelium in the investigated gastric gland regions were analyzed with *Chi-Square test* of independence (Paura, Arhipova, 2002; Arhipova, Bāliņa, 2003).

Results and Discussion

Fourteen of fifteen examined domestic dogs showed positive results by all used detection methods for helicobacters. Statistical analyses did not show significant difference between all of our used diagnostic methods ($p>0.05$) in domestic dogs. Urease activity was observed in 205 (80.4%) of examined 255 gastric samples after 60 min of incubation. Spiral-shaped organisms were observed in 211 (82.7%) of 255 brushes of gastric mucosa by brush cytology and in 206 (80.8%) of examined 255 samples of gastric mucosa by histological examination.

Brush cytology is recommended for practical use as it is relatively simple, cheap, and rapid method for screening infection with helicobacters. Histological examination is also sensitive, but it is comparatively expensive and requires special laboratory skills and equipment. It is used to evaluate location and colonization density of helicobacters and to detect histopathological changes in the mucosa of the stomach.

The results of urease test in domestic dogs are demonstrated in Figure 1. It is seen that urease activity after 10 minutes of incubation was detected in 43.3% of samples within the cardiac gland region, in 50.0% samples within the fundic gland region, and in 28.0% of samples within the pyloric gland region. Whereas urease activity after 30 minutes of incubation was detected in 83.3% of samples within the cardiac gland region, in 91.7% of samples within the fundic gland region, and in 50.7% of samples within the pyloric gland region. So, detection rate after 30 minutes of incubation increased approximately twice ($p<0.05$) in all examined gland regions. Eventually, urease activity after 60 minutes of incubation was detected in 86.6% of samples within the cardiac gland region, in 94.2% of samples within the fundic gland region, and in 53.3% of samples within the pyloric gland region. This suggests that a longer incubation period increased the detection rate of helicobacters. These results are quite close to our studies of *Helicobacter spp*. in the gastric mucosa of feral raccoon dogs (Bērziņa, Birģele, 2006).

Comparised to *Helicobacter spp.* positive results in different parts of the stomach, positive rate of cardiac and fundic gland region in domestic dogs was significantly higher ($p<0.05$) than in pyloric gland region of the stomach. These results are quite close to other studies of *Helicobacter* like microorganisms in domestic dogs where the highest detection rate of *Helicobacter spp.* has been found in fundic gland region of the stomach (Happonen et al., 1996). Whereas, our study shows that detection rates of helicobacters in domestic dogs are different in comparison with the prevalence of helicobacters in the gastric mucosa of feral raccoon dogs. There were no significant differences ($p>0.05$) in occurrence of *Helicobacter spp.* in the samples of different gastric parts in the feral raccoon dogs (Bērziņa, Birģele, 2006).

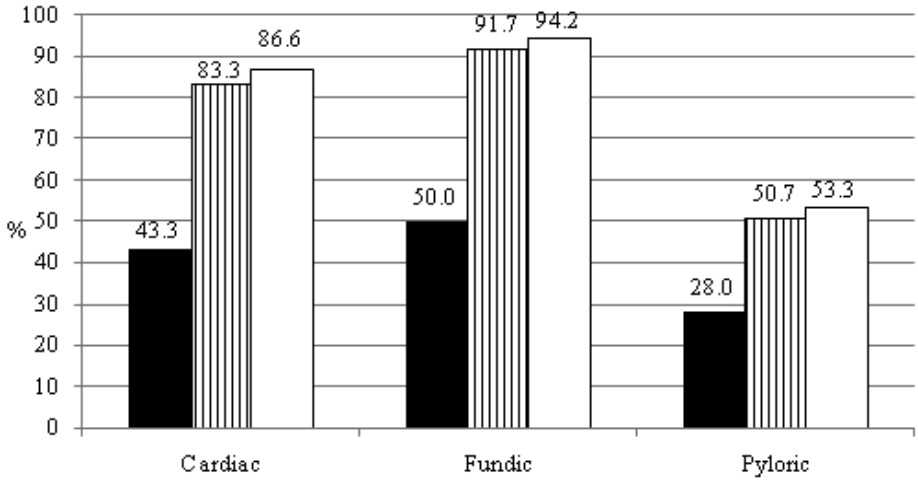

Figure 1. Percentage of Helicobacter positive mucosal samples from different sites by urease test (■ 10 min ▥ 30 min □ 60 min).

The detection rates of helicobacters in domestic dogs by brush cytology are presented in Figure 2. We established that there is no significant difference ($p>0.05$) in occurrence of helicobacters in the cardiac and the fundic gland region of the stomach: the spiral-shaped bacteria were observed in 91.7% of samples from cardiac gland region and in 94.2% of samples in the fundic gland region. It should be emphasized that brush cytology, equally to urease test, also showed that detection rate of helicobacters in the pyloric gland region is approximately twice less ($p<0.05$) than in the cardiac and fundic gland region. The brush cytology detected only 57.3% of positive samples in the pyloric gland region (Figure 2). These results are quite similar to other studies were gastric *Helicobacter* like microorganisms were mainly found in the fundic gland region of domestic dogs (Happonen et al., 1996).

Detection of helicobacters by histological examination showed similar detection rates as urease test and brush cytology (Figure 2). Spiral-shaped bacteria were observed at the gastric mucosa of domestic dogs in 88.3% of samples from the cardiac, and in 93.3% of samples from the fundic and in 54.7% of samples from the pyloric gland region.

Histological examination also showed that detection rate of helicobacters in the cardiac and fundic gland region was significantly higher ($p<0.05$) than in the pyloric gland region of the stomach.

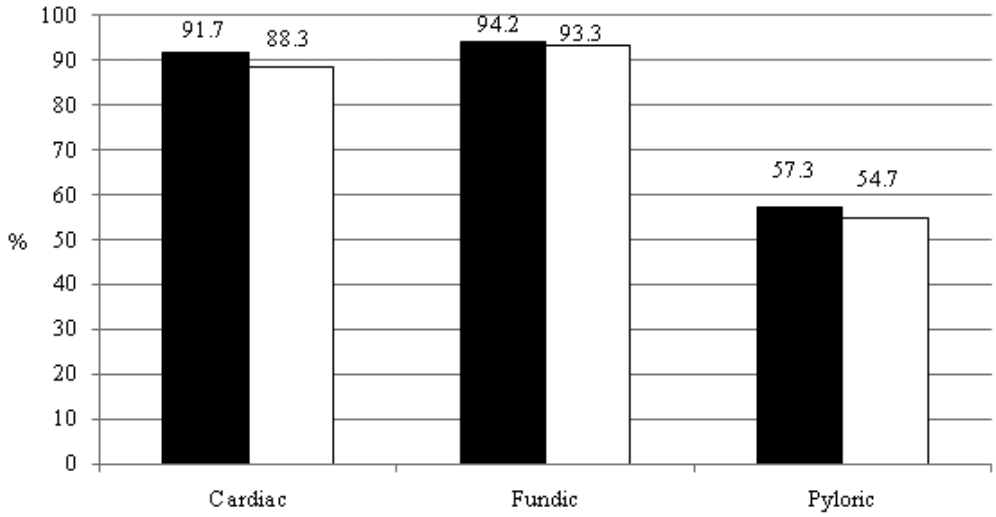

Figure 2. Percentage of Helicobacter positive mucosal samples from different sites by brush cytology and histological examination
(■ Brush cytology □ Histological examination).

Concerning the study of colonization density of helicobacters at the different parts of gastric mucosa, firstly we will discuss the results of the cardiac gland region (Figure 3). It was established that the amount of samples with mild colonization density of helicobacters was significantly higher ($p<0.05$) at the superficial epithelium and the gastric pits of the mucosa. Mild colonization density of spiral-shaped microorganisms was observed at the superficial epithelium in 67.9% of samples, and at the gastric pits in 69.8% of samples in the cardiac gland region. Moderate colonization density was observed at the superficial epithelium and the gastric pits in 11.3% of samples. Severe colonization density was only in 9.4% of samples at the superficial epithelium and in 9.4% of samples at the gastric pits of the gastric mucosa. There were no bacteria at the superficial epithelium in 11.3% of samples, and at the gastric pits in 9.4% of samples. Between the deep glandular epithelium there were no helicobacters in most (86.6%) of samples. Whereas mild, moderate and severe colonization density of helicobacters between the deep glandular epithelium was only in 9.4% of samples in each part of mucosa in the fundic gland region, wich means that helicobacters are less distributed between the deep glandular epithelium in both cardiac (Figure 3) and fundic (Figure 4) gland regions.

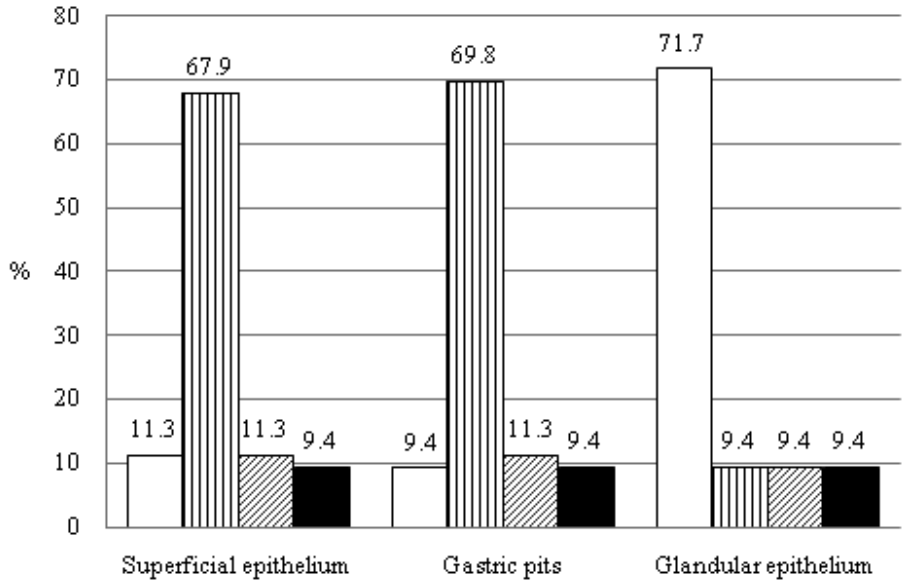

Figure 3. Percentage of samples with different colonization density of helicobacters at different sites of mucosal epithelium in the cardiac gland region
(□Absent ▥Mild ▨Moderate ■Severe).

Colonization density of helicobacters at different sites of gastric mucosa in the fundic gland region is presented in Figure 4. Occurrence of spiral-shaped bacteria was evidently higher ($p<0.05$) at the superficial epithelium and the gastric pits of the mucosan. Moderate colonization density of helicobacters was observed at the superficial epithelium in 74.1% of samples and at the gastric pits in 83.9% of samples. At the superficial epithelium there were 14.3% of samples with mild, and 4.5% samples with severe colonization density of helicobacters, but 7.1% of samples with no bacteria in the fundic gland region. At the glandular epithelium of mucosa there was a significantly higher ($p<0.05$) amount (86.6%) of samples with no bacteria. Whereas mild, moderate and severe colonization density of helicobacters between the deep glandular epithelium was only in 4.5% of samples in the fundic gland region. Thus, the amount of samples with no bacteria between the deep glandular epithelium was significantly higher ($p<0.05$) in both cardiac and fundic gland regions.

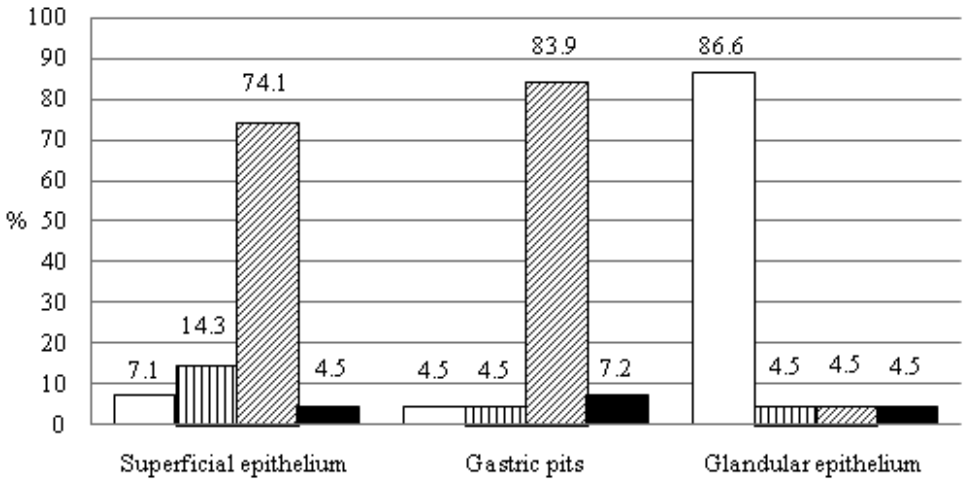

Figure 4. Percentage of samples with different colonization density of helicobacters at different sites of mucosal epithelium in the fundic gland region
(□Absent ▥Mild ▨Moderate ■Severe).

Colonization density of helicobacters at different sites of gastric mucosa in the pyloric gland region is presented in Figure 5. There was no significant difference (p>0.05) in colonization density of helicobacters between different parts of gastric mucosa in the pyloric gland region. At the superficial epithelium there were 41.5% of samples with mild, 34.1% of samples with moderate, and 12.2% of samples with severe colonization density of helicobacters, as well as 12.2% of samples with no bacteria in the mucosa. At the gastric pits there were 48.8% of samples with moderate, 26.8% of samples with mild, and 12.2% of samples with severe colonization density of helicobacters, as well as 12.2% of samples with no bacteria in the mucosa. Between the deep glandular epithelium there were 41.5% of samples with moderate, 21.9% of samples with mild, and 17.1% of samples with severe colonization density of helicobacters, but 19.5% of samples with no bacteria in the mucosa. Thus, the amount of samples with moderate colonization density of helicobacters between the deep glandular epithelium in the pyloric gland region was significantly higher (p<0.05) than in the cardiac and fundic gland region. This study is going to be continued to investigate the association between location, colonization density of helicobacters in the different parts of stomach.

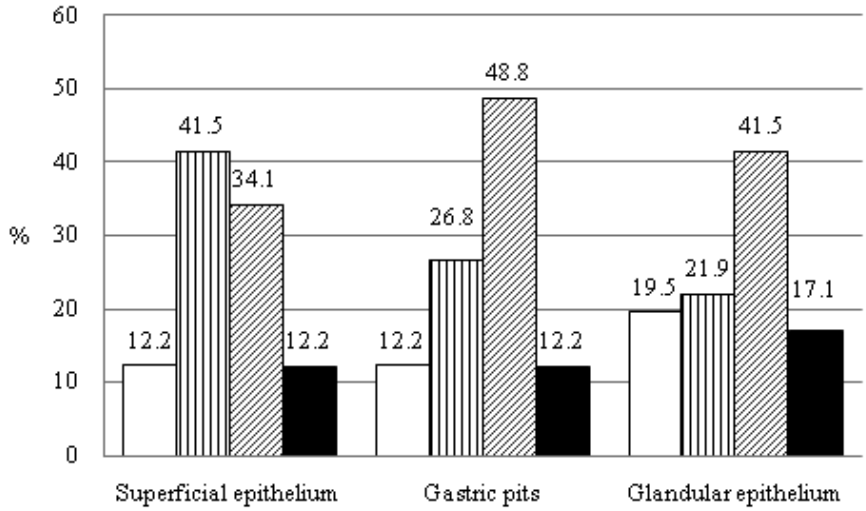

Figure 5. Percentage of samples with different colonization density of helicobacters at different sites of mucosal epithelium in the pyloric gland region
(□Absent ▨Mild ▨Moderate ■Severe).

Conclusions

1. All used detection methods showed that in comparison to gastric parts, the cardiac and fundic gland region is the most affected site by helicobacters in domestic dogs.
2. The location of helicobacters in the cardiac and fundic gland region showed mild and moderate colonization density of helicobacters at the superficial epithelium and at the gastric pits of the gastric mucosa.
3. The colonization density of spiral-shaped bacteria between the deep glandular epithelium is more pronounced in the pyloric gland region than in the cardiac and the fundic gland regions of the gastric mucosa in domestic dogs.

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CHANGES IN POULTRY MEAT MICROSTRUCTURE DURING CHILLED STORAGE

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Abstract

Researchers have found that morphology of muscle structure (original or after processing) is closely related to meat tenderness, which is very important attribute for consumer. The aim of the study was to evaluate changes in microstructure of poultry meat during the chilled storage.

In the study, the cross-cut microstructure of parents stock hen and broiler muscles were analyzed during the storage at + 1 ± 0.5 °C temperature. The changes were determined for the following muscles: *musculus pectoralis* and *pars praeacetabularis musculus iliotibialis lateralis* in seven hours after slaughter and on the 7th day of storage. Parents stock (PS) hens were slaughtered on 61st week, but broilers at the age of 42 days (on the 6th week).

The decrease in area of muscle fibres of hens and broilers' *musculus pectoralis* was found in both types of meat when comparing the sample on 7th hour and 7th day, but the smaller decrease was observed in broilers meat. Comparing muscle fibre area of broiler and hen *pars praeacetabularis musculus iliotibialis lateralis [musculus biceps femoris]* in hen meat it was reduced in higher proportion, but the distance between the fibres was increased reaching similar values for both sample types.

Key words: broiler, parents stock hen, cross-cut microstructure, muscle fibre area.

Introduction

Researchers have found that muscle texture (original or after processing) is closely related to meat tenderness, which is very important attribute for consumer. The most important factors determining meat texture are myofibrillar proteins, muscle cytoskeleton, and intramuscular connective tissue (Wattanachant et al., 2005).

Muscle tissues consist mainly of proteins, which are the most valuable component of meat. It is formed from single fibres (10 - 100 µm in diameter, and up to 12 cm in length), which contain longitudinal protein filaments – myofibrils, which caising the contraction of muscles. Each muscle fibre is covered by thin, flexible connective tissue membrane – sarcolem. The space among fibrils is filled with sarcoplasm, which is formed by semi-liquid proteins. Inclusions of glycogen, lipids and other water insoluble substances are found in sarcoplasm. Myofibrils contain proteins with various light refraction coefficients (Varnam and Sutherland, 1995).

The active part of muscles is the longitudinal muscle fibers, but the passive part – connective tissues. Each muscle fiber is surrounded by the connective tissue – endomysium. Muscle fibers are bound together by perimysium into bundles called fasciciles; the bundles are then grouped together to form muscle, which is enclosed in a sheath of epimysium, which is connected to perimysium. The thickest connective tissues are visible in the muscle cross-cut. Epimysium encloses each muscle separating it from other muscles and providing the independent contractions (Brūveris, 2007).

Bird muscles can generally be divided in two types: white and red muscles. White or pale muscles typically are little loaded (for example, hen's breast). These muscles contain bigger amount of myofibrils and smaller amount of sarcoplasm (Brūveris, 2007).

A muscle consists of approximately 750 g kg^{-1} of water, 200 g kg^{-1} of protein, 30 g kg^{-1} of fat and 20 g kg^{-1} of non-protein nitrogen. Water is found between muscle fibers, within sarcoplasmic reticulum and in the sarcopasm itself. Mainly it is found as free water within the space between actin and myosin filaments (Lawrie, 1991).

The aim of the study was to evaluate changes in the microstructure of poultry meat during the chilled storage.

Materials and methods

Broilers and parents stock hens of the cross Ross 308 were used for the study. The age of broilers before slaughter was 42 days (on the 6th week). Among slaughtered birds, about 60% were hens and 40% - cocks. An average carcass weight of a bird was 1.67 kg. The slaughter and primary treatment was performed at a meat processing plant (line Stork PMT). Broilers were stunned, then killed with a knife, bleeded for 2.25 minutes, scalded in a steam bath at 56 ± 0.2 °C for 2.35 minutes, defeathered, eviscerated and chilled for 100 minutes at +1 ± 0.5 °C.

The age of PS hens of the cross Ross 308 used for study were 61 week, an average hen's carcass weight was 2.9 kg. The slaughter and primary treatment was performed at a meat processing plant (line Stork PMT). PS hens were stunned, then killed with a knife, bleeded for 4.26 minutes, scalded in a steam bath at 60.2 ± 0.2 °C for 4.44 minutes, defeathered, eviscerated and chilled for 100 minutes at +1 ± 0.5 °C.

Two carcasses of each sample group were selected randomly and divided obtaining fillet *musculus pectoralis* and legs *pars praeacetabularis musculus iliotibialis lateralis [musculus biceps femoris]*. The divided poultry meat was stored in a cold room at +1 ± 0.5 °C for 7 hours after slaughtering and seven days before sample preparation.

In the process of muscle anatomic section preparation, the following main operations were completed:

- cutting of the sample piece (1x1x0.5 cm) from raw poultry meat of broiler and hen *musculus pectoralis* un *pars praeacetabularis musculus iliotibialis lateralis [musculus biceps femoris]* and placing of those in special moulds;
- fixing of the material in 10 % formaline solution at 20 ± 1 °C for 24 h;
- dehydrating of the material and defattening in 70° ethanol for 1 h in 80° - 90° ethanol for 1 h in 95° - 96° ethanol for 2h and in absolute ethanol for 24 h at 37± 1 °C;
- inclusion in paraffin:
  - at 37± 1 °C: in chloroform for 30 min.; another time in clean chloroform for 30 min.; for 30 min. in a mixture of chloroform and paraffin at ratio 1:1;
  - at 60 ± 1 °C and keeping in paraffin for 1 hour, one more time in clean paraffin for 2 h;
- placement of samples in single - use moulds and filling with paraffin;
- chilling and hardening of the samples.

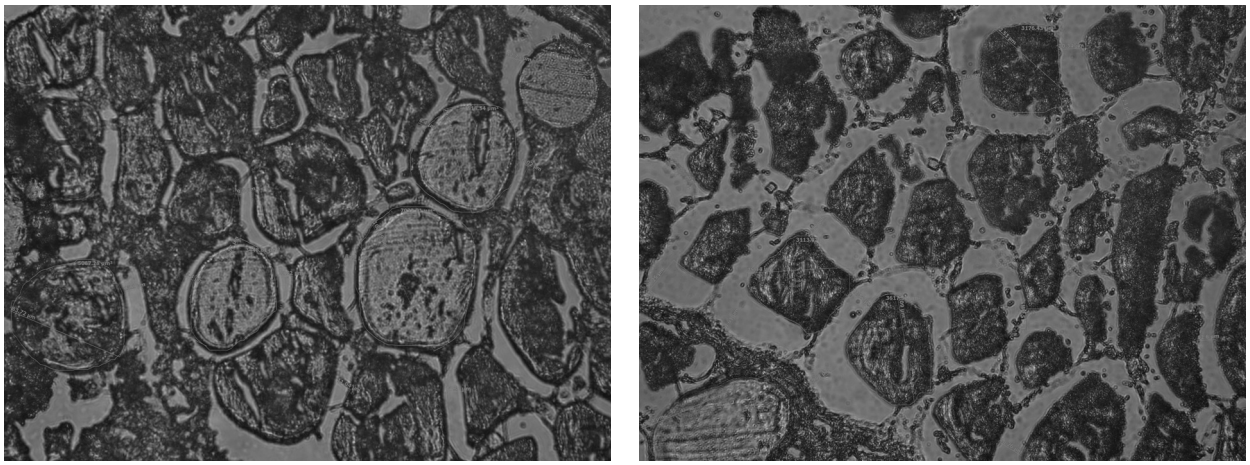
For cutting of the prepared samples in 5 µm layers, a device Microm HM315 was used. Preparations were placed on a glass slide and air dried. For paraffin dissolving, the slide glass with the sample was subsequently placed in chloroform and ethanol, with holding time - 5 minutes in each (Kondratovics, 1976).

The observation of muscle fiber transversal section was completed under the triocular microscope Axioskop 40 ('Zeiss'). The pictures of the microstructure were taken with digital camera using the 10 x 40 magnification of the microscope. Triplicate analyses were completed per each sample type. Fiber area and distance between fibres was measured using software Axiovision Le Rel 4.5. Ten measurements were done for muscle fiber area, and 20 measurements - for distances. The average values are presented in figures and in the paper.

Results and discussion

The muscle structure varies depending on muscle types, species, and breed of animal, all of which contribute to differences in the texture of the muscles. Peremysium thickness varied depending on the muscle types of chicken, and had a high correlation with the shear value (Wattanachant et al., 2005; Liu et al., 1996).

The photos of transversal muscle section of each sample were obtained in a microscope (Figure 1).



A B

Figure 1. Transversal section microstructure of broiler musculus pectoralis in 7 hours after slaughter (A) and on 7th day of storage (B).

The results obtained after measuring the areas of muscle fibers of broiler and hen *musculus pectoralis* after 7 hours and 7 days of storage are presented in Figure 2.

Various researchers have stated that the changes are observed during the raw meat storage, as well as after meat processing. Endomysial shrinkage and subsequent changes in muscle cell diameter with heating have been noted (McCormick, 1999). Comparing broiler muscle *m. pectoralis* fiber area in seven hours and seven days, the fiber shrinkage by 32.43% was observed. The change in area size of hen muscle *m. pectoralis* fiber in seven hours and seven days of storage was 56.59%.

The researchers shows that the hen *m. pectoralis* muscle fiber area, compared to broiler muscle area seven hours after slaughter, was by 33.61% bigger. Differences in muscle fiber diameter may have been due to the differences in age, rate of rigor onset, and degree of sarcomere shortening (Smith and Fletcher, 1988). But the area size of muscle fiber of this muscle group after seven day storage was similar for both samples. During rigor, the cross-sectional area of the muscle declines due to lateral shrinkage causing the myofibril space of decrease. This results in loss of fluid from the myofibrillar space (Offer and Trinick, 1983).

The changes in broiler and hen muscle fiber *pars praeacetabularis musculus iliotibialis lateralis [musculus biceps femoris]* area observed during the chilled storage after seven hours and seven days are presented in Figure 2. Comparing the muscle *m. biceps femoris* fiber area after seven days it can be concluded that the area is reduced by 9.21 % and 36.86 % for broiler and hen muscles respectively.

Comparing muscle fiber area of broiler *m. biceps femoris* in 7 hours after slaughter and on the 7th day of storage it was found that the area shrank by 9.21%, but the area of hens' muscle fibers reduced by 36.86%.

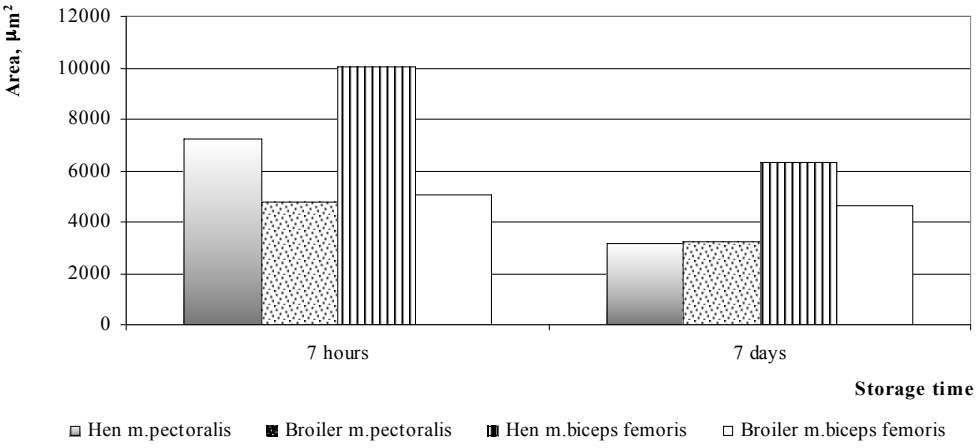


Figure 2. The transversal section area of broiler and hen musculus pectoralis and musculus biceps femoris measured in a picture of microscopic structure.

The changes in a distance between broiler and hen muscle *m. pectoralis* fiber during the storage are presented in Figure 3.

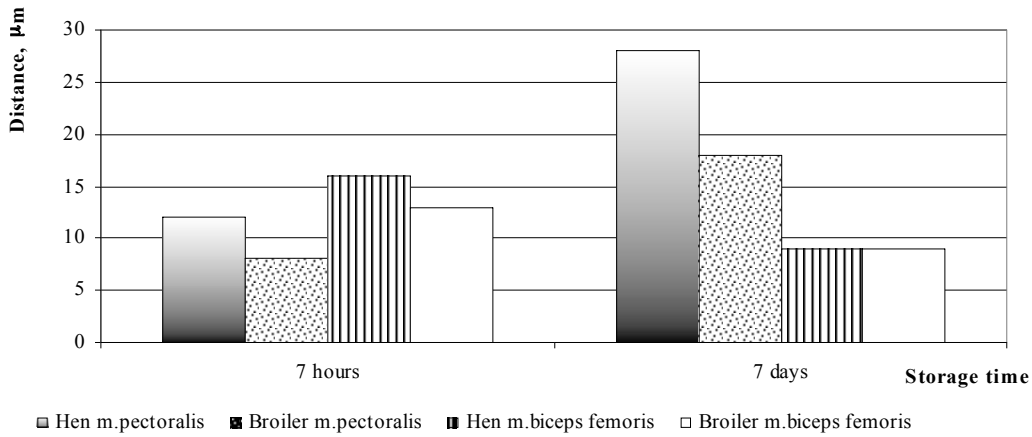


Figure 3. The distance between muscle fibers in transversal section of broiler and hen musculus pectoralis and musculus biceps femoris measured in a picture of microscopic structure.

Comparing the distance between broiler muscle *m. pectoralis* fibres taken in µm in 7 hours after slaughter and on the 7th day of storage, the increase of 2.25 times can be observed; whereas the distance in hens' muscle fibers increased 2.33 times.

The changes in a distance between broiler and hen muscle *m. biceps femoris* fiber during the storage are also presented in Figure 3. The distance between fibers of hen *m. biceps femoris* seven hours after slaughter was 1.28 times bigger, but on the seventh day of storage the average distances were very similar.

Comparing the distance between broiler muscle *pars praeacetabularis musculus iliotibialis lateralis* fibers in the samples taken seven hours or seven days after slaughter, a difference was observed: the distance was 1.44 times smaller; whereas the distance between hen muscle *pars praeacetabularis musculus iliotibialis lateralis* fibers decreased 1.78 times from 7th hour to 7th day of storage during the storage.

Stiffening (*rigor mortis*) follows slaughtering, therefore muscles become more dense and stiff. If the animal is fatigued then stiffening takes place very fast, sometimes even during slaughter. In 24 hours meat becomes tender, juicy; it obtains flavour and little sour aroma. After pressing on the muscle, juice is exuded. This process is called ''meat maturation''. Muscle enzymes and proteins participate in the mentioned process (Лебедева, et al., 1985).

Conclusions

The decrease in area of muscle fibres of PS hen and broiler *musculus pectoralis* was found in both types of meat when comparing the sample on 7th hour and 7th day of storage: 32.43% for broilers and 56.59% for hens respectively. The distance between bird muscle fibers was increased.

Comparing muscle fibre area of broiler and hen *musculus biceps femori* in hen meat it was reduced in higher proportion: 9.21% for broilers and 36.86 % for hens respectively. The distance between the fibres was increased reaching similar values for both sample types.

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EFFECT OF STORAGE TIME, TEMPERATURE AND SOLVENT ON THE STABILITY OF STERIGMATOCYSTIN STANDARD SOLUTIONS

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Abstract

The influence of solvent, storage time and temperature on the stability of the mycotoxin sterigmatocystin (STC) was investigated. STC calibrants (1.0 µg ml^{-1}) in acetonitrile, methanol and mixture of acetonitrile and methanol (50:50, volume/volume) were stored in dark glass bottles at (– 25), 4 and 25 °C for up to 8 weeks. Samples were analysed by high performance liquid chromatography (HPLC) with ultraviolet (UV) detection. Obtained results indicate that more suitable solvents for storage of STC standard solutions at (–25 °C) are acetonitrile and mixture of acetonitrile and methanol (50:50, v/v), but not longer than for one week; for storage at 4 °C more suitable is mix of acetonitrile and methanol, but not longer than for one week.

Keywords: sterigmatocystin, mycotoxin, stability, solvents, standard solutions

Introduction

STC is a mycotoxin produced by fungi of many *Aspergillus spp.* (Atalla et al., 2003). Its molecular structure is similar to aflatoxin B_1 (AFB). It is a precursor of AFB in the biological transformation (Betina, 1989).

STC is a carcinogenic compound that has been shown to affect various species of experimental animals (Purchase et al., 1970), and it is classified as a 2B carcinogen by the International Agency for Research on Cancer (IARC) (IARC, 1976). There are many reports about toxicity, carcinogenity, mutagenity and teratogenity of STC (Shroeder et al., 1975; Sweeney et al., 1999; Tong-xi et al., 2000).

Chromatographic analysis is carried out by a variety of techniques, all of which require calibration with defined calibrants in order to make precise and accurate determinations (Van Egmond et al., 1986).

STC is often purchased as crystalline material and calibrants are often prepared in organic solvent and stored in a freezer. Different organic solvents have been used for the extraction and storage of standard solutions of STC (Van Egmont, 1990; Lepom, 1986; Robb et al., 1990; Stoloff et al., 1971; Takahashi et al., 1984). Most suitable organic solvent for cold and frozen storage of STC stock standard solutions is chloroform (Septien et al., 1993). Acetonitrile and methanol are generally used for the extraction of different mycotoxins from different food commodities, especially for multidetection methods (Stoloff et al., 1971). Acetonitrile and methanol are suitable solvents due to those water miscibility and UV transparency at wavelengths < 245 and 325 nm where STC adsorbs and there is a good suitability for HPLC.

The aim of this study is to establish conditions under which the STC calibrants in acetonitrile, methanol and mixture of acetonitrile and methanol (50:50, v/v) could be held for extended periods without decomposition and to test stability of STC in above mentioned solvents during 8 weeks.

Materials and Methods

STC standard solutions were prepared in different solvents (acetonitrile, methanol and mixture of both mentioned) and stored in dark glass bottles under different temperature conditions for a short-term stability (2 weeks) and up to 8 weeks for a long-term stability (Table 1).

Table 1

Storage Conditions and Sampling Scheme for STC Calibrants in Acetonitrile, Methanol and in Mixture of Acetonitrile and Methanol

Storage temperature (°C)	Stability tested (weeks)			
	1	2	4	8
– 25	x	x	x	x
+ 4	x	x	x	x
+ 25	x	x	x	x

To provide storage at (–25 °C) temperature, dark glass bottles with standard solutions were stored in the laboratory freezer Kryolab 350V from Angelantoni (Massa Martana (PG), Italy), to provide storage at 4 °C they were stored in laboratory refrigerator FRL 360V from Angelantoni (Massa Martana (PG), Italy) and to provide storage at 25 °C they were stored in the laboratory microbiological incubator with forced convection BF53 from Binder (Tuttlingen, Germany).

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, Mosheim, France). STC standards were purchased from Sigma (St Louis, MO, USA).

Preparation of Standard Solutions

A stock solution of a concentration of 500 µg ml^{-1} was prepared by dissolving 5 mg of crystalline STC standard material in 10 ml of chloroform. Three aliquots 500 µl of the stock solution were evaporated to dryness under oxygen-free nitrogen at ambient temperature and immediately re-dissolved in different solvents – the first aliquot was dissolved in acetonitrile (5 ml), the second – in methanol (5 ml) and the third – in mixture of acetonitrile: methanol (50:50, v/v) (5 ml).

The calibrated stock solutions (50 µg ml^{-1}) were used to prepare standard stock solutions of 1.0 µg ml^{-1} of STC.

These solutions were used for HPLC – UV analysis after storage under different conditions and time periods mentioned above.

HPLC-UV Analysis

A Waters Alliance 2695 liquid chromatograph (Waters) was connected to a 2998 scanning Photodiode Assay Detector (PAD) (Waters Co., Milford, MA, USA). Empower software was used to control the system and process signals. Separation was performed on a Phenomenex Luna (2) C_{18} (5 µm), 150 x 3.0 mm (Phenomenex, Torrance, CA, USA). The mobile phase consisted of 40 % of water in acetonitrile used in isocratic regime. The flow rate was 0.4 ml min^{-1}, column temperature was 30°C and the injection volume was 50 µl. Quantification of STC was performed by measuring its peak area. STC was monitored λ = 325 nm.

Statistics and Calculations

The control value of the calibrants in each solvent is derived from the peak area of three replicate measurements of calibrants prepared on the first day. The stability of the toxin for different time periods and at different temperatures in different solvents is expressed as the ratio of each result to the corresponding control value. Each ratio is the mean peak area of three replicates.

The most widely used test for comparison of analytical results is t-test (Meier et al., 2000). To compare obtained results, a Microsoft Office Excel 2003 integrated statistical function – t-test (Paired two sample for means) was applied (p = 0.05).

Confirmation of Stability

A tolerance of ± 5.0% from initial STC content (100%) accepted for confirmation of stability of STC in standard solutions.

Results and Discussion

Comparing results of storage in acetonitrile at (– 25 °C) and 4 °C, the conclusion is that the storage at (– 25°C) is better, because of significant statistical differences between the results (t_{stat} (7.2) > t_{crit} (2.9)).

Comparing results of storage in methanol at (– 25 °C) and 4 °C, the conclusion is that the storage at (– 25°C) is better, because of significant statistical differences between results (t_{stat} (3.3) > t_{crit} (2.9)).

Comparing results of storage in mixture at (– 25 °C) and 4 °C, we can conclude that statistically there are no significant differences (t_{stat} (0.8) < t_{crit} (2.9)).

Our results are comparable with other studies published on stability and solubility of STC in different solvents (Septien et al., 1993). After one week of STC storage in acetonitrile and methanol at 4 °C temperature, results are the same. After one week of STC storage in acetonitrile and methanol at (– 25 °C) temperature, our results are better for about 6.5% for storage in acetonitrile and for about 7% for storage in methanol; however, in Septien's studies storage temperature was (– 20 °C). Therefore, in this case we can conclude that the storage at (– 25 °C) is better.

After four weeks of STC storage at 4 °C, our results are better for about 7% for the storage in acetonitrile and for about 3.4% for the storage in methanol, but they are the same as Septien's for the storage at (– 25 °C) temperature.

The results from the stability of STC in acetonitrile at different temperatures are shown in Figure 1.

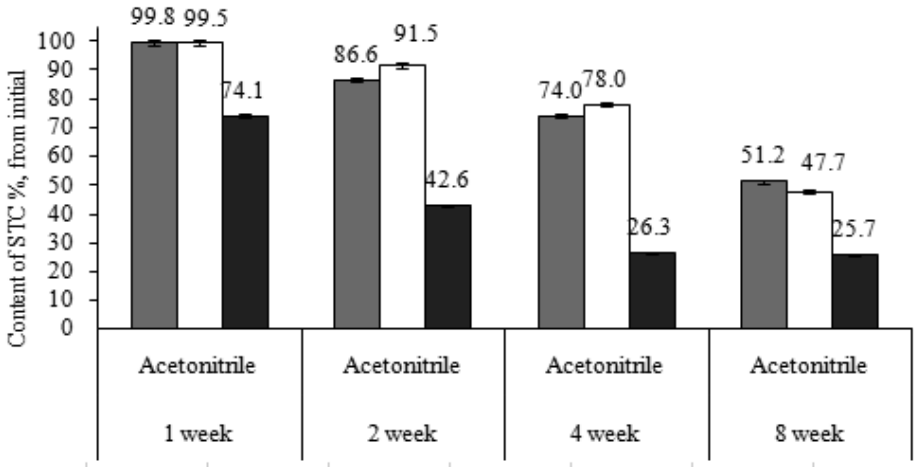

Figure 1. Stability of STC at different temperatures in acetonitrile.
Г °C = (– 25); Г °C = 4; T °C = 25

The results from the stability of STC in methanol at different temperatures are shown in Figure 2.

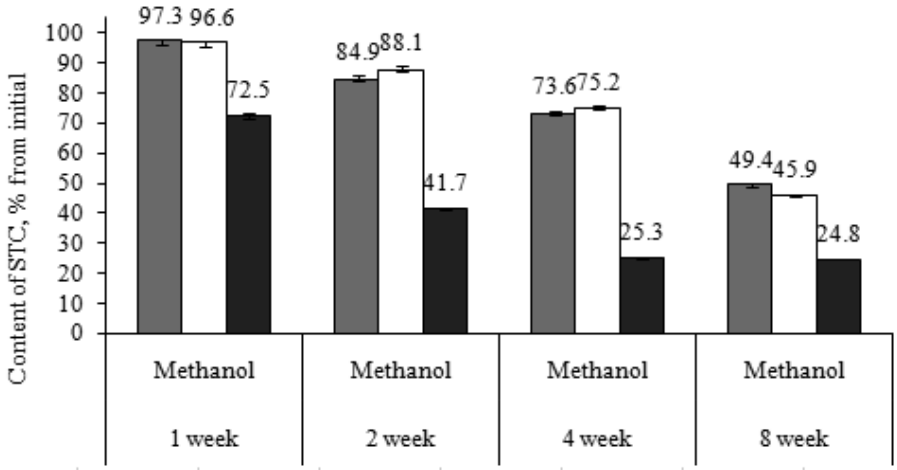

Figure 2. Stability of STC at different temperatures in methanol
Г °C = (– 25); Г °C = 4; T °C = 25

For the comparing, there were used results obtained only after one week of storage at (– 25 °C) and 4 °C temperatures.

Comparing results obtained for STC storage in different solvents at (– 25 °C): we can conclude that the storage in acetonitrile is better than the storage in methanol, because of significant statistical differences (t_{stat} (22.4) > t_{crit} (2.9)); the storage in mixture is better than the storage in methanol (t_{stat} (19.8) > t_{crit} (2.9)); and there is no significant differences between the storage in acetonitrile or in mixture (t_{stat} (1.3) < t_{crit} (2.9)).

Comparing results obtained for the storage of STC in different solvents at 4 °C: we can conclude that the storage in acetonitrile is better than the storage in methanol (t_{stat} (20.6) > t_{crit} (2.9); the storage in mix is better than the storage in methanol (t_{stat} (18.2) > t_{crit} (2.9)); and the storage in mixture is better than the storage in acetonitrile (t_{stat} (3.4) > t_{crit} (2.9)).

The results from the stability of STC in mixture at different temperatures are shown in Figure 3.

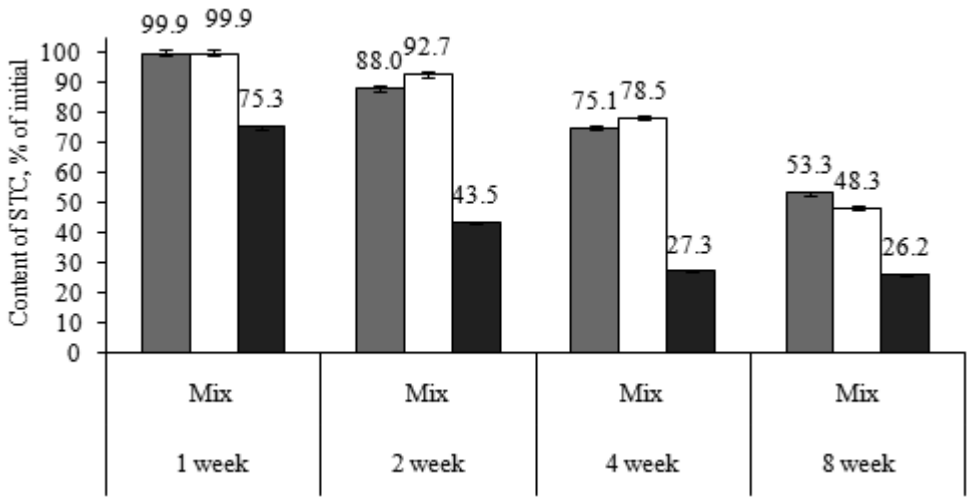

Figure 3. Stability of STC at different temperatures in mixture
■T °C = (– 25); □T °C = 4; ■T °C = 25

Comparing results obtained for storage of STC in different solvents at (– 25 °C) and 4 °C: we can conclude that the storage in acetonitrile at (– 25 °C) is better than the storage in methanol at 4 °C (t_{stat} (16.9) > t_{crit} (2.9)); the storage in acetonitrile at (– 25 °C) is the same as the storage in mix at 4 °C (t_{stat} (0.75) < t_{crit} (2.9)); the storage in acetonitrile at 4 °C is better than the storage in methanol at (– 25 °C) (t_{stat} (19.1) > t_{crit} (2.9)); the storage in acetonitrile at 4°C is worse than the storage in mixture at (– 25 °C) (t_{stat} (5.2) > t_{crit} (2.9)); the storage in mixture at (– 25 °C) is better than the storage in methanol at 4 °C (t_{stat} (50.9) > t_{crit} (2.9) and the storage in mixture at 4°C is better than the storage in methanol at (– 25 °C) (t_{stat} (37.6) > t_{crit} (2.9)).

STC is an intracellular mycotoxin (Filtenborg et al., 1983), which could interfere with the action of the solvents during extraction and obtained results show that one of the possible reasons why it was reducing during the storage in investigated solvents is an action with the solvents and, of course, increasing temperature can accelerate this process; this is why at 25 °C temperature decomposition process was faster. The second possible reason is the presence of small amounts of interferences (impurities) in solvents; however, they are HPLC – grade (it is not possible to provide 100% clearance of solvents) or in standard of STC (not possible to get 100% clear standard).

Conclusions

Our research indicates that STC standard solutions are stable at the set tolerable stability level (initial content of STC ± 5.0%) only at (– 25 °C) and 4 °C temperatures not longer than for a one week.

Best solvents (from researched in our study) for the storage of STC solutions at (– 25 °C) temperature are acetonitrile and mixture; however, methanol is

also suitable for the storage of STC at a set tolerance level.

The best solvent (from researched in our study) for the storage of STC solutions at 4 °C temperature is a mixture of acetonitrile and methanol (50:50, v/v); however, other solvents are also suitable for storage of STC at the set tolerance level.

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THE POSSIBILITY OF APPLICATION OF IODIZED SALT IN PICKLE MANUFACTURING

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Abstract

Iodine is a mineral that is added to the table salt and found in a variety of foods. It is important for good health and, fortunately, our bodies require it in minute quantities. Iodine is part of a hormone, thyroxin, which is responsible for maintaining a person's metabolic rate. Iodine is the basic constituent part of the hormone of the thyreoid gland. On the whole, the amount of T3 un T4 correlates with the number of the iodine atoms. Therefore, without iodine the thyreoid gland cannot synthesize hormones and, therefore, cannot function. The role of iodine intake in both of these conditions was recognized in the 20th century, and since they are fully preventable through diet, public health advocates hope to entirely eliminate them at some point. Many things are natural sources of iodine. Saltwater fish and sea vegetables, for example, both contain abundant amounts of iodine. The material can also be found in plants grown on soil which is rich in sea materials, and in animals grazed on such soils. In some regions of Latvia, however, access to iodine is limited, and conditions like goiter is realistic of iodine deficiency situations. In Latvia, some fear exists for manufacturers of food who use iodized salt. They are afraid that it will collide with changes of color or taste of their products and will infringe on interests of the consumer. The main question for such problems is: is it a myth or the truth? In Latvia, starting using iodine salt in manufacturing, the most important question is: 'What quantity of iodine remains after the technological processing?'

Key words: iodized salt, iodine salt, quantity, stability, food processing.

Introduction

Salt iodization has been adopted as the main strategy to eliminate IDD (Iodine Deficiency Disorders) as a public health problem, and universal salt iodization by the year 2005 has been set as a global target (Agency for International Development, 1992). While other foodstuffs can be iodized, salt has the advantage of being widely consumed and inexpensive. It has routinely been iodized in some industrialized countries since the 20th century. World experts in iodine deficiency today urged a renewed international commitment to help prevent loss of IQ due to fetal brain damage by facilitating access to iodized salt for the final 30 percent of world households that don't yet have it most of them found in just 20 countries (Burgi, 1993). Chemically, iodine is the least reactive of the halogens, and the most electropositive halogen after astatine (WHO, 1989; WHO, 2006). Iodine is used in pharmaceuticals, antiseptics, medicine, food supplements, dyes, catalysts, and photography. It is required in trace amounts by most living organisms. Iodine deficiency gives rise to goiter. Endemic goiter is a disease characterized by a swelling of the thyroid gland, usually resulting in a bulbous protrusion on the neck (Mannar et al., 1995). Iodine salt is table mixed with a minute amount of potassium iodide or iodate, of sodium iodide or iodate is used to help reduce the chance of iodine deficiency in humans (Aquaron, 2000). If people are eating plenty of seafoods, saltwater fish and/or sea vegetables they don't need more iodine. If people are eating a varied diet, they are probably taking in sufficient iodine. However, if they avoid most of the foods mentioned here, people may want to reconsider getting iodized salt, just to be on the safe side (Reed, 1970). The Recommended Dietary Allowance (RDA) for iodine is 150 micrograms (µg) a day for adults. The daily need of the person for iodine depends on its age and physical activities. The highest need – for the teenagers experiencing hormonal reorganization, for pregnant and nursing women. The newborn should receive per day about 50 micrograms of iodine. From 1 year up to 6 years 90 micrograms, from 7 up to 12 years 120

micrograms are required for children, from 12 years and older 150 micrograms. To pregnant women and feeding ones, a higher dose 200 - 220 micrograms is necessary.

If daily average consumption of iodine is less than 20 micrograms, the risk is high (Jooste, 2000; WHO, 1996). The products from salted water are rich in iodine.

Table 1

Content of iodine in foods (micrograms per 100 grams of food) (Gorelikova et al., 2001)

Food source	Iodine content
Salt, iodized, 1 tsp.	400
Fat of a liver of a cod	350 - 700
Sea seaweed	from 500 µg - 5g
Cod	263
Haddock, 3 oz.	104 - 145
Cottage cheese, ½ cup	26 - 71
Shrimps	Of 110
Cheddar cheese, 1 oz.	5 - 23
Bread	3 - 8.4 (100g)
Groats	1.5 - 4.5
Milk, kefir	14 - 30
Sour cream, sweet cream	8 - 9.5
Eggs	20
Potato	5 - 7
Peas	10
Bean	12.8
Fruit	2 - 4
Berries	1
Beef, pork	7
Freshwater fish	4 - 5

If we have too little or no salt in our body and food? Why do we need salt? The minerals sodium and chloride make up table salt. Inside human bodies, salt dissociates into these two minerals, which carry electrical charges, hence, their name is electrolytes. Electrolytes play a vital role in fluid balance, nerve transmission, and muscle contractions (Gerasimov et al., 2000). Our need for them is small, especially compared to the amount most people take in. People may be surprised to discover that some of the following items are high in sodium: cheese, ham, canned tomato products (e.g., ketchup, sauces, juice), soups, salad dressing, mayonnaise, cereals, cakes, cookies, quick breads, and donuts. Sodium also occurs naturally in some vegetables, such as celery, although not in as large amounts (Gorelikova et al., 2001).

Healthy bodies are quite efficient at conserving sodium. The first mechanisms for sodium regulation are thirst and other fluid shifts. Hormones act more slowly to regulate sodium levels. Food containing iodine is available everywhere. It is much less likely for people, even those living far from the sea or ocean, to have goiter nowadays (Hetzel, 1998). However, salt is still iodized because iodine levels can vary greatly in foods, as levels of iodine in the soil are quite variable, and fortification offers a margin of safety. Today, goiter is more prevalent in developing countries than in the EU, because they don't have access to as many foods, such as plant foods that are grown in iodine-rich soil, they dont eat seafood, and the populations of some regions of countries are malnourished in general. Iodine and dietary salt is the consensus means of increasing iodine intakes in populations to combat Iodine Deficiency Disorders (UNICEF, 2004). There is little iodine in natural sea salt. For 75 years of a life, an incomplete teaspoon of iodine is necessary to an organism of the person. Iodine is found in food stuffs which we consume, but 80% of it is lost with urine already the next day. In other words, iodine is enough if the person consumes products rich in this element (Kunn, 1995).

The recommended dietary allowance in Latvia

for sodium is 5-6 g per day (SVA). This amount may be found in a ¼ teaspoon of salt or ½ cup of canned chicken broth. Processed foods are the greatest source of sodium in human diet. Our physiological need is 1.25 g of salt per day. We actually eat it from 5 up to 11 g. Usually the day-time portion of salt we scoop from the following sources: 10% of salt from vegetables, fruit and other natural products containing it in small amounts, 15% are made with salt which meaningly we add in dishes, and 75% of salt is absorbed in the structure of the products made in the industrial way (Reed et al., 1970; Diosady et al., 1997). And it is not only found in various canned foods and concentrates, salt is much enough in the structure of practically any products made outside of the house kitchen. As to iodine, it is found to be enough in vegetables and fruit if they have been grown on soils rich in iodine. In Latvia, little shrimps, mussels, sea kale, fish, crabs and so forth are rich in iodine. These products are not regardened as the most popular among our fellow citizens. To the majority of our compatriots, salt with iodine is useful. However, it is necessary to remember that iodized salt is counter-indicative to those persons whom functioning of the thyroid gland is raised (Kunn, 1995).

The state can get rid of iodine deficiency among the population using the law or legislation in relation to universal salts iodization (USI). However, the first argument of the population against general iodization is possible adverse influence of iodized salts on the tinned vegetables (cabbages, cucumbers), and food stuffs. Questions of the influence of iodine additives on flavouring qualities of food products also come forth.

Therefore, such research is necessary and answers to the all questions asked on the influences of additives of iodine on flavouring qualities of food products are still lingering in the air. Any large-scale program of preventive maintenance is both a policy and commerce. The outcomes of the initial research on adding iodine to vegetables under tinning were published long ago. In the first publication, such tinned vegetables were viewed as green peas, corn, cayenne, olives and tomatoe juice which were flavored with iodized salt in their manufacturing (Kojima, 1955). All the publications were focused on organoleptics, and sensory estimation was carried out. However, in literature reviews, data are not available which could be of any interest for the manufacturers of tinned vegetables in Latvia-how much iodine is expected to be found in the final outcome if instead of the ordinary salt there will be used the iodized salt? Which is the simplest way to enrich food with iodine so necessary for the person?

For this purpose we also suggest to continue joint research not to cause proof aversion of using iodized salt in pickle manufacturing. There are some data published in the press that using iodate potassium (namely, this substance is used now as the additive to salt) does not leave influence on organoleptics properties of the tinned, pickled, baked products. Being a rather stable product, KIO_3 practically is not subject to further oxidation. Besides, it is necessary to remember that in Latvia salt is not produced but imported and delivered from well-known salt countries. Therefore, it is necessary to know how salt influences tinned and pickled products flavored with iodized salts as other salts in the majority of countries do not make such products. Actually, for the enterprise any technological complexity– in pickling, manufacturing of tinned products (cucumbers, cabbages), baking bread with iodine salt, with tinned juice, jelly, does not represent any problem, but it is a question of replacement of one salt with another. Many producer in Latvia to be afraid and ask about possibility of overdose of iodine in manufacture of such products. A total of 40 countries use only iodized salt, and in one country there has not been fixed a case of overdose of iodine with salt, and its lack has been on the contrary marked (Aquaron, 2000; Kunn, 1995). The world organization of public health services at the United Nations (CART) has published the application for safety of iodized salts. For 80 years of its use, in ten countries of the world, no message has been published on its collateral actions (WHO et al., 1996). Overdoses from daily acceptance of products which are rich with iodine, it is impossible, because the person use such products on one or to two. Overdoses by iodine probably if expect food which is rich with iodine, the person uses also tablets with iodine. In the companies in Latvia which make pickled and tinned vegetables are opinion that salt with iodine gives to these ready products easy a smell of iodine and a yellowish shade.

Different comments are made on the existing proof of the unwillingness of Latvias food manufactures to use iodine salt in pickling, baking and cooking. This is a rather emotional opinion, as a rule, not based on our practical experience (Unicef, 1995). In the initial research, before 11 new vegetable

preserves were prepared for manufacturing with a set amount of iodine, we only verified the storage stability, color changes, organoleptic and sensory properties of tinned vegetables at 'Balttur–R' LTD., which was done by the employees themselves when the ordinary salt was replaced with the iodized salt. The tinned vegetables were stored for 1.5 months, then the organoleptic and sensory evaluation was carried out. After evaluation and making conclusions that the organoleptic properties of all the samples comply with the requirements, when the ordinary salt is replaced with the iodized salt, and having obtained satisfactory results, a further assignment was set forth which is the primal task and assignment of the given research, namely, to make a repeated vegetable tinning using iodized salt and to determine how much iodine is in the final outcome if the amount of salt is stable according to the company's technological maps for tinned vegetables.

We tested pickled vegetables – cucumbers, cabbages, tomatos, and champignons – using base of compounding of a cannery 'Balttur-R' LTD. In testing, we considered the storage period, relative humidity, and temperature at which the canned food was stored. As a result, all the received parameters completely corresponded to the requirements of the standards of the given production.

Then we led expanded tastings in which experts food technologists, representatives of 'Bang & Bonsomer' LTD, Ministry of Health - have took part. Nobody from the participants in the tasting could find distinction between the samples, which were samples with iodized salt and wheals - with ordinary salt (string beans, corns, champignons, tomatos, and cucumbers). The most significant aim of the research was to get an answer to the question moved forward by the manufacturers of tinned vegetables in Latvia:' How much iodine can be found in the final outcome of manufacturing tinned vegetables with ordinary salt and with iodized salt? Perhaps, vegetables themselves contain iodine. Where with, in the final outcome, in the amount of iodine significant diferences cannot be found when manufacturing tinned vegetables with iodized salt and ordinary salt. Where with, the spent money cannot be justified purchasing a more expensive salt with iodine. The manufacturer of tinned vegetables wants to make sure and to elicit not only the organoleptic stability of the products themselves as in Latvia an opinion exists (that it is proxhibited to preserve and pickle with iodized salt due to the above reason, but also to be aware of the exact amount of iodine in the tinned vegetables manufactured by 'Balttur–R' LTD. Paralelly, at the Latvian Certification Center (LATSERT), salt samples taken from the manufacturers of Denmark and Belarus were analysed to state the quantitative amount of NaCl and iodine there. These two initial types of salt were used in the experiment carried out with tinned vegetables. Also, food sea salt 'Marsel' was analysed which was not used in manufacturing of tinned vegetables. However, the aim of this salt research was to state how much iodine the food sea salt contains.

Materials and Methods

1**.** In the research, the tinned vegetables and pickled vegetables can be divided in two groups which are

prepared using ordinary salt and iodized salt. For the research, 11 samples of tinned and pickled vegetables with addition of the ordinary food industry salt 'Extra' manufactured at 'Mozyr salt' JSC, Belarus, and the ordinary food industry salt 'Suprasel' with iodine manufactured at 'Akzo Nobel Salt' JSC, Denmark, were prepared. The product samples are shown in figure.

2.Salt was added to every sample according to the recipe developed by 'Balttur-R' LTD adding 1.5-3 tablespoons of salt to 1 liter of marinade.

In preserving and pickling of the vegetables, such vegetables as cucumbers, cucumbers with tomatoes in jelly, champignons, grated cabbage with tomatoes and cucumbers, pickled cucumbers, pickled cabbage were used. Every sample was prepared both with ordinary salt and with iodized salt.

3. Paralelly, three salt samples were analyzed together with 'The chemical laboratory of national public health investigation center' in Vilnius, Lithuania: 1) 'Suprasel' salt with iodine manufactured by 'Akzo Nobel Salt' AS. During the experiment at 'Balttur-R' LTD, the iodized salt 'Suprasel' was used with the chemical composition: NaCl-99.8% with iodine (I) added as KIO_3-43 mg kg^{-1}. 2) 'Extra' type salt manufactured at 'Mozyr salt' JSC, Belarus, with chemical composition: NaCl-99.5%, and 3) 'Marsel' sea salt manufactured at 'G.C. RIEBER' JSC, Norway, which was not added to any of the products during the experiment.

3. Bottled pickled preserves such as pickled cucumber, champignones, cabbages and tomatos were stored at simulated market conditions for 3-5 months. The color, moisture content, water activity, pH, salt content, salinity of brine solutions, iodine content of salts and test foods products, and iodine quantity were analyzed using standard methods of determination.

Were analyzed 11 kinds of different samples of pickled products, from each kind was analyzed 5 bottles samples, in the sum completely analyzed 55 definable samples.

All samples of products has been prepared in Latvian company 'Balttur-R' LTD, and all samples of the pickled vegetables, were analyzed using the normative document methods of the Lithuanian Standard Board.

The samples were forwarded to 'The chemical laboratory of national public health investigation center' in Vilnius, Lithuania, as the amount of iodine in food products is not determined by any of the accredited laboratories in Latvia. Besides, methods are not developed to carry out such research. In all the samples, the amount of iodine was determined. The samples were taken to the laboratory in Vilnius 10 days after their preparation at the company's laboratory. From each type of tinned vegetables of 2 pieces of the sample have been left for the control in company 'Balttur-R' LTD and 1 piece pickled cabbages and a cucumbers for 'LSTK'LTD.

The samples were analyzed using the 'Determination of iodine standard operating procedure according to Analyst, 1980, vol.105' with test method (CH)-SVP-5.4-64. Iodine was determined by SVP standard operating procedure according to Analyst, 1980, vol.105. The analysis of samples was made in 'The chemical laboratory of national public health investigation center' in Vilnius. Each kind of a product type was analysed in the laboratory from the company of 5 samples. The task of the experiment was to determine how much iodine contain pickled vegetable products with salt and with iodized salt.

4. Iodine determination at 'The chemical laboratory of national public health investigation center' in Vilnius, Lithuania, in salt by a very sensitive colorimetric and automatic method was realized in natural sea, iodized and pure vacuumsalt from Denmark, Belarus and Norway. For this 1g of a salt sample was dissolved in 10 ml of water. For natural salts, poor in iodine, this solution was directly analysed by flow analysis in an entirely automatic auto analyzer 'Technicon Type 2'. Iodine present as iodate or iodide in the sample was transformed first by acidic digestion into iodate. Then, after reduction to iodide, iodide was monitored by the colorimetric method of Sandell and Kolthoff. For iodized salts, rich in iodine, appropriate dilutions (1/10 to 1/100) in water were done before analysis, according to the expected iodine level in the salt indicated by the manufacturer.

Table 2

Iodine analysis in pickled vegetable samples

Sample No.	Product sample	Piece/ litre	Salt g/ per litre, tbsp	Salt type, salt manufacturer	Manufacturer
1	Pickled cucumbers with 'Suprasel' iodized salt	5x3	44	Iodine salt, 'Akzo Nobel Salt' JSC	Balttur-R Ltd
2	Pickled cucumbers with 'Extra' salt	5x3	44	'Extra' salt, 'Mozyr salt' JSC	Balttur-R Ltd
3	Pickled cucumbers with 'Suprasel' iodized salt	5x0.750	36	Iodine salt, 'Akzo Nobel Salt' JSC	Balttur-R Ltd
4	Pickled cucumbers+tomatos in jelly with 'Suprasel' iodized salt	5x 0.350	36	Iodine salt, 'Akzo Nobel Salt' JSC	Balttur-R Ltd
5	Pickled champignons with 'Suprasel' iodized salt	5x0.350	27	Iodine salt, 'Akzo Nobel Salt' JSC	Balttur-R Ltd
6	Pickled cabbage+tomato+cucumbers with 'Suprasel' iodized salt	5x1	36	Iodine salt, 'Akzo Nobel Salt' JSC	Balttur-R Ltd
7	Pickled cabbage+tomato+cucumbers with 'Extra' salt	5x1	36	'Extra' salt, 'Mozyr salt' JSC	Balttur-R Ltd

Sample No.	Product sample	Piece/ litre	Salt g/ per litre, tbsp	Salt type, salt manufacturer	Manufacturer
8	Pickled cabbage with 'Extra' salt	5x2	44	'Extra' salt, 'Mozyr salt' JSC	Balttur-R Ltd
9	Pickled cabbage with 'Suprasel' iodized salt	5x2	44	Iodine salt, 'Akzo Nobel Salt' JCS	Balttur-R Ltd
10	Pickled cucumbers with 'Extra' salt	5x0.750	36	'Extra' salt, 'Mozyr salt' JSC	Balttur-R Ltd
11	Pickled champignons with 'Extra' salt	5x0.350	27	'Extra' salt, 'Mozyr salt' JSC	Balttur-R Ltd

Results and Discussion

In the tinned vegetable under the research (11 types x 5 pieces=55 samples), salt delivered from the 'Latvian Salt Trading Company' LTD was used.

The company 'Balttur-R' LTD uses salt from different manufacturers of Denmark and Belarus. All the experimental salt and pickled vegetables mentioned above were collected and used from the products of Latvia. All the vegetables and salt used in the experiment are purchased from Latvian companies.

Table 3

Iodine content in pickled product samples

Sample No.	Parameter	Test method (ND)*	Result ± U**	Measures
1	Iodine amount	(Ch) –SVP- 5.4-64	97.4	µg 100g $^{-1}$
2	Iodine amount	(Ch) –SVP- 5.4-64	< 1.0	µg 100g $^{-1}$
3	Iodine amount	(Ch) –SVP- 5.4-64	74.8	µg 100g $^{-1}$
4	Iodine amount	(Ch) –SVP- 5.4-64	62.1	µg 100g $^{-1}$
5	Iodine amount	(Ch) –SVP- 5.4-64	114.2	µg 100g $^{-1}$
6	Iodine amount	Ch) –SVP- 5.4-64	32.9	µg 100g $^{-1}$
7	Iodine amount	Ch) –SVP- 5.4-64	5.6	µg 100g $^{-1}$
8	Iodine amount	Ch) –SVP- 5.4-64	3.0	µg 100g $^{-1}$
9	Iodine amount	Ch) –SVP- 5.4-64	70.3	µg 100g $^{-1}$
10	Iodine amount	Ch) –SVP- 5.4-64	50.8	µg 100g $^{-1}$
11	Iodine amount	Ch) –SVP- 5.4-64	15.6	µg 100g $^{-1}$

**ND - normative document 'Determination of iodine standard operating procedure according to Analyst, 1980, vol.105'*

***U - extended uncertainty estimated with references to 'Estimation and expression of measurement uncertainty in chemical analysis' (1997).*

1. During the experiment we tested salt 'Extra', iodine salt 'Suprasel', and 'Marsel' sea salt. We found 52.9 - 84.6 micrograms of iodine/gram of 'Suprasel' iodine salt, 0.4 - 0.9 micrograms of iodine/gram in 'Extra' salt, and 1.2 - 1.4 micrograms of iodine/gram in sea salt. The result can be noticed in two salt sample data of iodine substances in food that list the maintenance of iodine in foodstuffs.

2. So, for iodine, it is unrealistic to rely on individual food analyses except for natural seafoods, instead one must use averages over food groups. And foods that have salt added during processing must be separated into those that use iodized salt, sea sea, and those that use purified salt.

For example:

- prepared pickled cucumbers with iodized

salt have iodine concentrations that average 97.4 µg of iodine per 100 g of cucumber, where in such sample only with 'Extra' salt of iodine was <1 µg.

- pickled champignons with iodized salt have iodine concentrations that average 114.2 µg of iodine per 100 g of champignons, where in such sample only with 'Extra' salt of iodine was 15.6 µg per 100g.
- pickled cabbages with iodized salt have iodine concentrations that average 70.3 µg of iodine per 100 g of cabbage, where in such sample only with 'Extra' salt of iodine was 3.0 µg per 100g.
- pickled cucumbers with iodized salt have iodine concentrations that average 74.8 µg of iodine per 100 g of cabbage, where in such sample only with 'Extra' salt of iodine was 50.8 µg per 100g.

3. No significant difference in the physico-chemical properties of test food products with iodine salt and extra salt during processing was noted, except for color and iodine content. In general, the color of test food products with iodine salt was enhanced. Food products with iodine salt have significantly higher iodine content per serving size. Products samples with iodine salt was highly acceptable and rated close to 'like very much'.

4. During storage, test food products were stable in terms of color and iodine content. The percent of iodine retention during storage ranged from 42% to 86%. The final food products were microbiologically safe.

5. The iodized salt can be used in production of pickled vegetables, processing of cucumbers, tomatos, champignons to increase the iodine content.

6. The iodized salt can not be used pickled cabbage processing to increase the iodine content because organoleptics quality of products changes in 3 weeks. The crunchy quality of cabbage decreases.

Conclusions

1. The iodized salt can be used in pickled vegetables cabbage, champignons, cucumbers, and tomatos in jelly - to increase the iodine content and to improve the color quality of vegetable products.

2. However, iodized salt may lengthen the fermentation period of the *alamang* and *dilis*. The use of iodized salt during cucumber and cabbage fermentation may not be advisable due to the loss of iodine during subsequent washing and pickling. It is recognized that the level of iodine in iodized salt varies depending on the initial level of iodine, method of iodization, handling, packing and storage, among others. It is important that quality assurance is put in place before iodized salt can be used for processing.

3. In this way, the right level of iodine in the final outcome can be assured. In general, the use of iodized salt in food processing can be used as a unique selling proposition or as a claim that a product contains iodine. The significant amount of iodine retained in test food products salted with iodized salt during storage and after cooking may increase iodine availability and intake among risk citizens and this may help reduce iodine deficiency in the deficient areas of Latvia.

4. To provide a database on the maintenance of iodine in the crude and processed foodstuffs of Latvia, the maintenance of iodine in foodstuffs is recommended to be still analysed.

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THE EVALUATION OF SENSORY PROPERTIES OF LATVIAN SEMI-HARD CHEESES

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Abstract

Annual judging of dairy products including sensory evaluation of local cheesemakers' cheeses proved that the quality of Latvian classical cheeses is various. In fact, in last three competitions three different manufacturers gained the first place in category of Krievijas and Holandes types' cheeses. It indicates instability of Latvian cheese quality. Two types of semi-hard cheeses (Krievijas and Holandes) were selected for testing the quality of Latvian semi-hard cheeses in the beginning of 2008. Krievijas type cheese was selected from three different manufacturers, but Holandes type cheese – from five different manufacturers. Sensory properties such as flavour, structure and colour were measured using line scale method. Statistical analysis of obtained data showed differences between such assessed properties as colour (yellowness), texture (firmness), holes, flavour (acidity and bitterness) in Krievijas type cheese, and colour (yellowness), texture (firmness), flavour (saltiness) in Holandes type cheese.

Key words: cheese, texture, flavour.

Introduction

The main sensory properties of cheese such as flavour and texture depend on the number of processes which occur in cheese during its ripening. Degradation of protein, fat and carbohydrate affect the sensory quality of cheese. Through many reactions different precursors of flavour compounds (such as short chain fatty acids, peptides, amino acids, diacetyl, etc.) and gases that satiate cheese flavour and are liable to cheese texture are rendered (Singh et al., 2003).

As emphasized before, the formation of sensory properties is a complex of complicated biochemical processes occurring during cheese maturation, where enzymes of starter and milk indigenous flora play significant role. Nowadays identification of new volatile compounds and studying sensory properties of cheeses is still central aim of many debates.

Transformation of initial constituents into final compounds depends mainly on cheese milk quality, sanitary and cheese milk treatment conditions (Buchin et al., 1998). Due to failure of noted factors, advanced flora may get into the milk after pasteurization or survive during it, which leads to out-of-balance of compounds derived from protein, fat and carbohydrate, and influence different defects of sensory properties especially off-flavour and texture defects (Fox and McSweeney, 2004; Wendorff and Smukowski, 2007). As it is mentioned before, also ripening conditions play a significant role in formation of cheese sensory properties and their no observance can cause different deviations in sensory assessment of cheese (Singh et al., 2003; Kujawski et al., 2003).

Annual judging of dairy products in Latvia, including sensory evaluation of local cheeses, has proved that the quality of Latvian classical cheeses is various. In fact, in last three competitions three different manufacturers have gained the first place in category of Krievijas and Holandes types' cheeses (Dieziņa, 2006; Tamane, 2004).

The objective of this paper is to estimate sensory properties of such popular semi-hard cheeses as Krievijas and Holandes produced in Latvia and to clear up possible distinctions between samples of one type cheese from different cheesemakers.

Materials and Methods

The sensory properties of two types of Latvian semi-hard cheeses (Krievijas and Holandes) were evaluated by scaling methods using line scale.

Before sensory evaluation, cheeses were stored at room temperature for one hour, then cut into 2 cm^3 pieces and put into plates randomly labeled

with three number codes. Krievijas type cheese from three different manufacturers and Holandes type cheese from five different manufacturers were selected for sensory assessment. Krievijas cheese was selected from following cheesemakers: JSC 'Smiltenes piens', JSC 'Trikātas piens' and JSC 'Rīgas piena kombināts'. Holandes cheese was selected from following cheesmakers: JSC 'Smiltenes piens', JSC 'Rīgas piena kombināts', JSC 'Trikātas piens', JSC 'Cesvaines piens', and LTD 'Mālpils piensaimnieks'. Cheese with different fat content in a dry matter was tested. For evaluation were used Holandes cheese with 450 g kg^{-1} and 500 g kg^{-1} fat content in a dry matter, and Krievijas cheese – with 500 g kg^{-1} fat content in a dry matter.

Sensory evaluation was carried out in the Laboratory of Sensory Evaluation at the Department of Food Technology of the Latvia University of Agriculture in the beginning of 2008. All cheese samples were simultaneously evaluated by twenty seven panelists. During one session, panelists were offered to assess one type of cheese (e.g., Krievijas) from various manufacturers. The panelists were provided with water to rinse their mouth between samples.

In order to represent the perceived intensity of the properties, the panelists were asked to note intensity of such cheese properties as colour (yellowness, evenness), texture (firmness, crumbliness, elasticity), holes, and flavour (acid, bitter, salty, sharp, rancid) on a line scale by placing a mark (Meilgaard et al., 2007; Strautniece, 2004).

The marks from line scale were measured with ruler and converted into numbers. Obtained data was averaged across panelists, then analysed using statistical analysis of variance (ANOVA), and differences among cheese samples were evaluated in the experiment. When significant ($p<0.05$) differences were found among treatments, mean was compared using Tukey's test. The StatistiXL (Version 1.8) program was used.

Results and Discussion

The obtained data given in Table 1, showed highly significant difference between holes and bitterness of Krievijas type cheese samples. Other distinctions were found between yellowness, firmness and acidity of samples.

The sample from JSC 'Smiltenes piens' was noted as the best with less acidity and bitterness and good quality holes. The same opinion was declared by experts at annual judging of dairy products one and half year ago (Dieziņa, 2006; Tamane, 2004). That confirms the invariable sensory quality of this cheesemaker's product. The sample from JSC 'Rīgas piena kombināts' was bitter with high acidity.

Table 1

Evaluation of sensory properties of Krievijas type cheese (mean±SD)

Properties		'Smiltenes piens' JSC	'Rīgas piena kombināts' JSC	'Trikātas siers' JSC	p value
Colour	Evenness	8.99±1.82	8.22±2.55	7.74±2.79	0.18
	Yellowness	7.49^{a}±1.87	7.06^{a}±2.42	5.13^{b}±2.37	0.001
Texture	Firmness	$5{,}04^{b}$±2.26	5.65^{b}±3.10	7.54^{a}±2.60	0.003
	Crumbliness	4.73±2.36	5.15±2.86	4.42±2.48	0.56
	Elasticity	2.96 ±2.43	4.69 ±2.98	4.21 ±2.81	0.07
Holes		8.67^{a}±2.35	6.27^{b}±2.42	3.20^{c}±2.42	$3.02*10^{-11}$
Flavour	Acid	4.95^{b}±2.31	7.33^{a}±1.85	5.57^{b}±2.36	0.001
	Bitter	2.78^{b}±2.07	5.46^{a}±2.18	5.02^{a}±3.09	$4.13*10^{-4}$
	Salty	5.45±2.24	6.37±2.44	5.67±2.40	0.33
	Sharp	3.27±2.46	4.12±2.43	3.76±2.80	0.49
	Rancid	2.71±2.31	3.67±2.22	4.02±2.58	0.13

^{a,b,c} – samples within property with a similar letter superscripts do not differ significantly (P>0.05). Letters are subordinated from the highest value to the least. As emphasized in some papers investigating origin

of cheese off-flavours, the bitterness is nearly the one of the main problems in the manufacture of many cheese varieties, especially those made with mesophylic starter cultures (Singh et al., 2003). Bitter flavour explains as deficiency, in the used strain, of proteolytic enzymes capable of hydrolyzing bitter primary breakdown products of the cheese protein (Lemieux and Simard, 1991; Mullan, 2002). In addition to noted, bitterness is caused not only by peptides but also a number of other compounds such as amino acids, amines, amides, long-chain ketones and some monoglycerides that can contribute to bitter off-flavour (McSweeney et al., 2000).

Cheese manufacturing and ripening conditions are also two of the main factors contributing to bitterness formation and excess acidity of cheeses (Buchin et al., 1998; Hill, 1995b). Higher temperatures of ripening intensify the enzymatic processes, but allow growing of secondary flora that is responsible for contribution to off-flavours; whereas low temperatures of ripening are liable to absence or rare holes in cheeses (Hill, 1995a; Kujawski et al., 2003) and allow the formation of bitter flavour due to slow reactions of protein breakdown in cheese.

Significant differences between yellowness, firmness and saltiness were observed among the samples of Holandes type cheese. These results are indicated in Table 2. The vast majority of samples were evaluated similarly. JSC 'Trikātas siers' Holandes cheese was acknowledged as the best cheese with typical cheese taste and good appearance.

This evaluation differs from experts' conclusion for Holandes type cheese at annual judging of dairy products. In the period of last three competitions, JSC 'Trikātas siers' did not gain any awards in comparison with 'Mālpils piensaimnieks' LTD and JSC 'Smiltenes piens'. (Dieziņa, 2006; Tamane, 2004)

Cheese from JSC 'Cesvaines piens' was evaluated as hard and salt, but the saltiest was sample from JSC 'Rīgas piena kombināts'.

Both of these properties depend on cheese manufacturing process; firmness also depends on composition of cheese milk. The role of fat in the development of sensory qualities of cheese appears to be decisive. Fat affects texture of cheese, too. Reduction of fat content leads to increase in the moisture and protein content of cheese.

Table 2

Evaluation of sensory properties of Holandes type cheese (mean±SD)

Properties		'Smiltenes piens' JSC	'Rīgas piena kombināts' JSC	'Trikātas siers' JSC	'Cesvaines piens' JSC	'Mālpils piensaimnieks' LTD	p value
Colour	Evenness	8.45±2.28	8.22±3.04	8.42±2.50	7.76±3.12	8.20±2.60	0.90
	Yellowness	7.01^{b}±2.25	4.30^{c}±2.21	7.55^{b}±2.23	9.79^{a}±2.41	4.29^{c}±2.01	$1.23*10^{-17}$
Texture	Firmness	4.02^{b}±2.31	6.91^{a}±2.52	6.87^{a}±2.59	8.20^{a}±2.88	6.63^{a}±2.62	$1.03*10^{-6}$
	Crumbliness	2.81±2.14	2.72±1.91	3.74±2.83	4.16±3.20	4.13±2.46	0.14
	Elasticity	2.44±2.77	2.36±1.93	2.84±2.83	3.73±2.00	3.62±2.84	0.14
Holes		2.52±2.19	3.84±3.27	3.44±3.15	4.39±2.62	4.28±3.09	0.12
Flavour	Acid	5.03±2.34	6.22±2.71	4.97±2.30	5.38±2.67	5.78±2.34	0.30
	Bitter	4.90±2.47	4.62±2.06	3.72±1.93	4.13±2.24	4.16±2.05	0.30
	Salty	3.77^{b}±1.69	5.84^{a}±2.08	4.92^{a}±2.50	5.54^{a}±2.94	5.70^{a}±1.97	0.006
	Sharp	3.05±2.06	3.91±2.71	3.42±2.58	3.74±2.40	4.02±2.33	0.59
	Rancid	3.09±1.99	3.46±1.86	3.36±2.25	4.18±2.69	4.15±2.46	0.31

[a,b,c] – samples within properties with a similar letter superscripts do not differ significantly (p>0.05). Letters are subordinated from the highest value to the least.

The influence of ripening conditions on product firmness plays a significant role. Cheese maturation at low temperatures leads to a chain of chemical reactions that contribute not only to holes and flavour quality, as mentioned before, but also to changes in cheese texture. Low ripening temperatures or deficit of proteolytic enzymes contribute to significant increase in primary proteolysis when changes in the α-$_s$, β- and γ-caseins occurs and peptides with high content of hydrophobic amino acids are derived. It

relates to firmness of the texture of cheese (Early, 1998).

The results of sensory study show that the quality of Holandes and Krievijas cheeses is variable. The next stage is evaluated the protein, fat and carbohydrate degradation products and their concentration, the role of cheese microflora and enzymes that are responsible for biochemical processes during the maturation of cheese. Obtained results should allow promoting and developing of Holandes and Krievijas cheese quality in Latvia.

Conclusions

The results of this study indicate that Holandes cheese from different manufacturers differs in yellowness, firmness and saltiness.

The sensory properties of Krievijas cheese principally differ between samples and mainly depend on quality, technology and producer.

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LACTIC ACID BACTERIA IN RYE SOURDOUGH FROM CRUDE AND PEELED RYE FLOUR

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Abstract

In Latvia the spontaneous sourdough is used in traditional rye bread baking whose microflora is determined in flour and in microorganism cultures presented in external environment. Almost all spontaneous sourdough cultures, especially those that have been maintained for a long time, contain both lactic acid bacteria (LAB) and yeasts. The main purpose of the current research was to analyze growth dynamics of LAB in spontaneous rye flour sourdough and to isolate some of its representatives. Experiments were carried out in Department of Food Technology, Faculty of Food Technology, Latvia University of Agriculture in January and February 2008. Considering differences in constituents, two types of flour were used in the research – peeled and crude rye flour. There were three stages of spontaneous sourdough preparation in 72 hours totally; the renewal of sourdough was realized each 24 hours. The dynamics of LAB plate count in every stage of fermentation was investigated as well as changes of pH was observed using standard methods. The results of experiments show substantial increase in amount of LAB in both sourdoughs, particularly in sourdough from peeled flour, reaching 6.06 log10 cfu ml^{-1}. A significant decrease of pH value from pH 6.7 to pH 3.8 during fermentation process was observed. As a result, the sourdough from peeled flour had desirable properties for preparation of sourdough starter. LAB cultures isolated and identified from current sourdoughs using API tests: *Lactobacillus brevis* and *Lactobacillus fermentum* are also typical members of sourdoughs found in other countries.

Key words: lactic acid bacteria, sourdough, rye flour.

Introduction

Sourdough is essential in rye bread making and the tradition of rye sourdough fermentation correspond to the rye-growing areas in north, central and eastern European countries including the Baltic states, where rye bread constitutes a considerable amount of the bread consumption (Rocken, 1996). Traditional sourdough bread technology is based on a spontaneous fermentation process from Lactic acid bacteria (LAB) and yeast occurring naturally in flour. Classic sourdough preparation is a multiple stage process that starts with a mixture of flour and water left for a specific period of time. Every next stage is prepared with fresh flour and water added to the previous stage (Linko et al., 1997; Kariluoto et al., 2004). In the first stage of sourdough fermentation the temperature vary from 25 °C to 26 °C, which is optimal for yeast development. In the second and third stage of sourdough fermentation an average temperature of 32 °C is applied – optimal for lactic acid bacteria (Kramer, 2002).

The character of the process results from the growth of microorganisms in different environmental conditions. Temperature, dough consistence and dough resting time at each stage determine development of active microflora (Javanainen and Linko, 1993; Muller et al., 2001).

In addition to environmental influence, flour is largely responsible for the properties and quality of spontaneously fermented sourdough. Crude rye flour contains more cereal outer layers resulting in greater diversity of microorganisms inhibiting growth of LAB comparing with peeled rye flour. Rye flour naturally contain a wide variety of yeasts and bacteria – *Candida crusei, Erwinia herbicala, Bacillus spp.*, moulds, *Saccharomyces spp.,* heterofermentative LAB and acid – tolerant yeasts (Kramer, 2002).

Sourdough fermentation begins with aerobic growth immediately upon mixing flour and water. Once oxygen is depleted, anaerobic fermentation begins with the growth of LAB, which produces acids that enhance their rapid growth when the pH value has dropped too low for other microorganisms to develop. Thereby LAB becomes the most abundant microorganisms in the sourdough and they are therefore responsible for the final stages of the sourdough processing (Savič et al., 2006).

Genera of LAB identified from sourdoughs

are *Lactobacillus, Leuconostoc, Pediococcus* and *Streptococcus*, and the majority of the sourdough LAB belongs to the genus *Lactobacillus*. The taxonomy of LAB is still under revision. *Lactobacillus* present in sourdough has been divided in three groups according to their carbohydrate fermentation patterns:

- Obligately homofermentative LAB: *L. acidophilus, L. delbrueckii ssp. bulgaricus, L. farciminis* etc. Hexoses are almost completely fermented to lactic acid (>85%) by the Embden-Meyerhof-Parnas (EMP) pathway. Fructose is also fermented, but neither gluconate nor pentoses are fermented.
- Facultatively heterofermentative LAB: *L. casei, L. curvatus, L. plantarum* etc.

Hexoses are almost completely fermented to lactic acid by the EMP pathway. Pentoses are fermented to lactic acid and acetic acid by an inducable phosphoketolase.

- Obligately heterofermentative LAB: *L. brevis, L. fermentum, L. fructivorans* etc.

Hexoses are fermented to lactic acid, acetic acid, ethanol, and CO_2. Pentoses are fermented to lactic acid and acetic acid. In general, both pathways involve phosphoketolase (Kandler and Weiss, 1986).

Scientific publications show that application of spontaneous sourdough in rye bread production may cause unstable quality of rye bread (Reed and Nagodawithana, 1995). Selected LAB starter cultures should be used in Latvian bakeries to provide controlled sourdough fermentation. Though LAB starters selected in Europe frequently does not satisfy Latvian bakers. Therefore, the aim of the research was to analyze growth dynamics of LAB in spontaneous sourdough from peeled and crude rye flour at every fermentation stage and to isolate some of its representatives.

When the above mentionedis clarified, it is possible to promote viability and development of LAB providing the highest acidity and preferable sensory properties accommodating technological processes of sourdough fermentation – length of every stage, temperature of fermentation and flour – water proportion in favour of it.

The aim of the current research was to analyze growth dynamics of LAB in spontaneous rye flour sourdough and to isolate some of its representatives.

Material and Methods

Current research was carried out in Latvia University of Agriculture in the Department of Food Technology in Scientific Laboratory of Microbiology in 2008.

The rye flour from stock company 'Jelgavas dzirnavas': peeled rye flour (ash content 1.45%, moisture content 14.5%), crude rye flour (ash content 1.85%, moisture content 14.5%) and water were used in all samples. There were three stages of sourdough preparation totally 72 hours; the renewal of sourdough was realized each 24 hours (Figure 1).

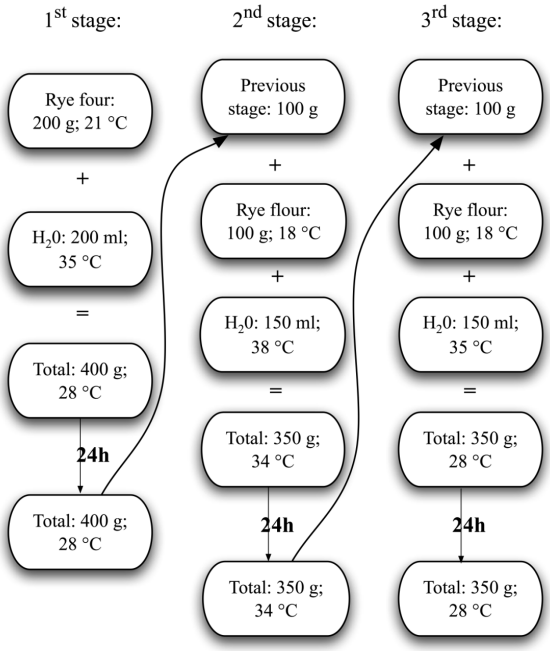

Figure 1. Three-stage technological process of spontaneous rye flour sourdough preparation.

Ten grams of sourdough in 90 ml 0.5% sterile physiological liquid were mixed in BagMixer® at speed 7 for 60 seconds after each stage of sourdough preparation.

Plate counting method was used for microbial detection. The samples for investigation were taken in: 0, 4th, 8th, 24th, 28th, 32nd, 48th, 52nd, 56th, 72nd hour of fermentation.

Lactic acid bacteria plate count was investigated on MRS agar (dilutions 1:100; 1:1000) in two replications. Incubation was performed at 35 °C for 24 hours to develop the colonies.

Counting of colonies formed and calculating the number of CFUs was accomplished by Acolyte colony counter.

Changes of pH (Jenway 3250 pH meter) in sourdough were observed using standard methods with reference to 'Standard - Methoden fur Getreide, Mehl und Brot' (Spicher and Stephen, 1993).

Dilution and Lindner methods were applied to obtain pure cultures. After isolating pure LAB cultures API CH 50 identification method was applied to identify microorganism species.

A standard method of arithmetic mean was used in data processing.

Results and Discussion

Three-stage method was used in spontaneous rye sourdough preparation (Figure 1). At the end of each stage, dynamics of LAB development was investigated.

Results shown in Figure 2 characterize growth dynamics of LAB in spontaneous sourdough fermentation process using two types of flour – peeled and crude rye flour. Initial rate of plate count was 3.48 log10 cfu ml^{-1} for crude flour sourdough and 4.27 log10 cfu ml^{-1} for peeled flour sourdough. It could be explicable with variety of microorganisms inhibiting growth of LAB in crude rye flour (Kramer, 2002). In the first stage of fermentation the development of LAB was significant in crude flour sample – an amount of LAB increased by 54% reaching 5.37 log10 cfu ml^{-1} exceeding plate count of LAB in peeled flour sourdough by 13%. After the first renewal of sourdough LAB count in crude flour sourdough decreased by 8% and remained stable at the level of 5 log10 cfu ml^{-1} until the middle of the third stage of fermentation. LAB plate count in peeled flour sourdough increased gradually reaching 6.02 log10 cfu ml^{-1} at the end of second stage of fermentation and remained stable until the end of fermentation process. The second renewal at the beginning of the third stage of fermentation had insignificant influence on development of LAB in both sourdoughs. It is possible that LAB cells were ageing and metabolites present in dough were inhibiting its regeneration. Finally, the amount of LAB in peeled flour sample exceeded the amount of LAB in crude flour sample by 13%, evidencing the advantage of using peeled rye flour instead of crude rye flour as a starter.

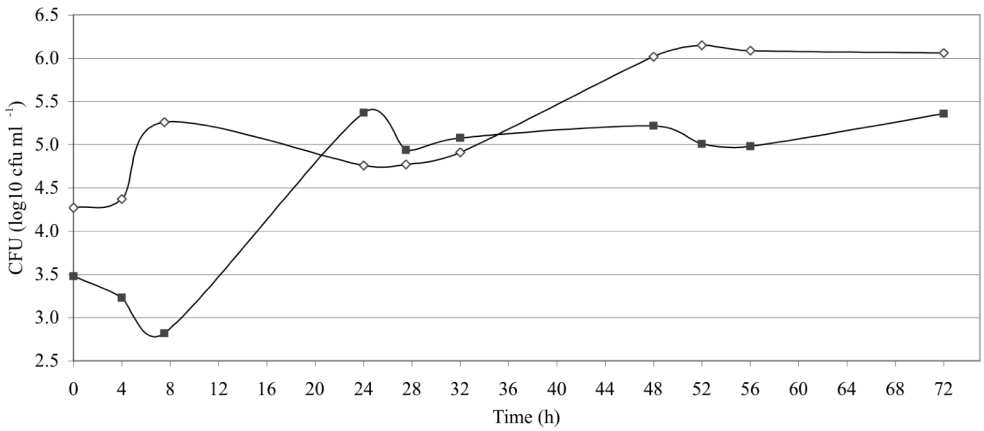

Figure 2. Development of LAB in spontaneously prepared sourdough from peeled and crude rye flour during 72 hours (◊ - sourdough from peeled rye flour; □ - sourdough from crude rye flour)

Figure 3 represent development of LAB and changes of pH value in peeled flour sample during three- stage fermentation process. At the first four hours of fermentation changes in total amount of LAB and pH value were not relevant – microorganisms remained in lag – phase and adapted to the new nutrients available. After four hours LAB started an intensive exponential phase although at the

end of the first stage of sourdough fermentation LAB plate count started to decrease caused by limitation of nutrients. Generally, in the first stage of fermentation pH value decreased substantially as a result of intensive development of microorganisms – from initial rate of pH 6.7 to pH 4.26.

Immediately after the first renewal of sourdough pH value increased rapidly to pH 5.37 but after four hours it returned close to a previous level to pH 4.36. At the same time LAB started a new lag-phase. At the end of the second stage of spontaneous sourdough preparation, LAB were developed rapidly in exponential growth phase by 26% and reached 6.02 log10 cfu ml^{-1}. In the third stage of fermentation an amount of LAB cells remained relatively high and stable. Furthermore, the pH value continued to decrease until the end of the third stage reaching pH 3.83 representing that current sourdough has desirable properties for preparation of rye flour sourdough starter.

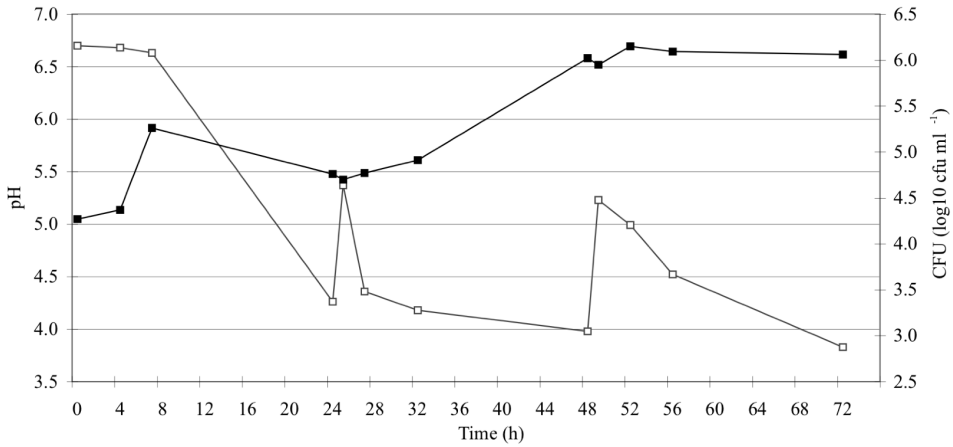

Figure 3. Development of LAB and changes of pH value in spontaneously prepared sourdough from peeled rye flour during 72 hours (□ - pH; ■ - CFU)

Figure 4 represents development of LAB and changes of pH value in crude flour sourdough. Analogical to peeled flour sourdough, pH changes in the first hours of fermentation were not relevant, but the amount of LAB cells even decreased by 19%. After eight hours of fermentation, LAB developed rapidly in exponential growth phase by 90% and reached 5.37 log10 cfu ml^{-1} at the end of fist stage of fermentation. Considering vast changes in growing media, the first renewal of sourdough inhibited growth of LAB by 8% although at the end of the second stage of fermentation, LAB cell count continued to increase gradually. During the second stage of fermentation value of pH decreased substantially by 38% reaching pH 3.81 as a result of metabolites produced by LAB in stationary phase. Despite the final pH value 3.80, during the third stage of fermentation LAB continued to develop reaching 5.36 log10 cfu ml^{-1} which is not sufficient for preparation of rye flour sourdough starter.

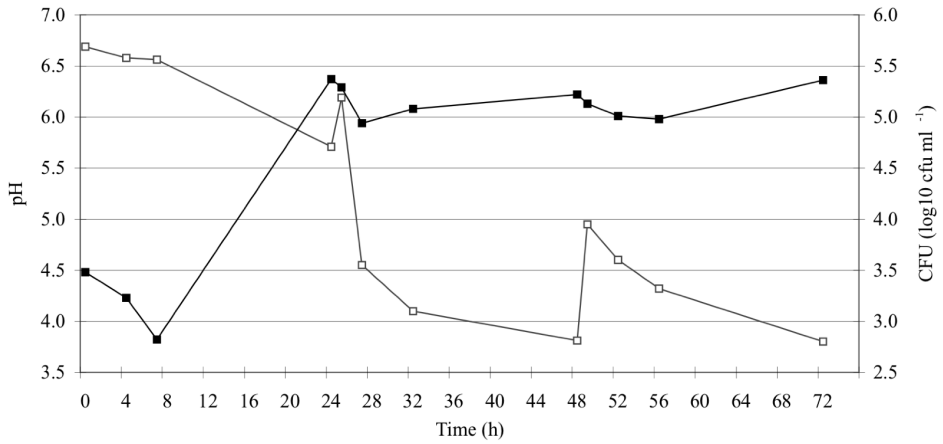

Figure 4. Development of LAB and changes of pH value in spontaneously prepared sourdough from crude rye flour during 72 hours (□ - pH; ■ - CFU)

Results of API tests reveal LAB that are typical members of rye flour sourdough microflora - *Lactobacillus brevis* and *Lactobacillus fermentum*. With reference to 'Bergey's Manual of Systematic Bacteriology' (Kandler and Weiss, 1986): *L. brevis* and *L. fermentum* belong to heterofermentative LAB, producing about 50% of end products from glucose as lactic acid, with considerable amounts of CO_2, acetic acid and ethanol; mannitol from fructose; *L. fermentum* are able to grow at 45 °C, but not at 15 °C; *L. brevis* are able to grow at 15 °C, but not at 45 °C. The latter properties ensure activity of LAB in every stage of spontaneous sourdough preparation. With reference to 'Handbook of food science, technology and engineering' (Hui, 2006): heterofermentative LAB *Lactobacillus brevis* are found in rye bread sourdough from Russia, Germany and Sweden; *Lactobacillus fermentum* are found in German, Austrian and Swedish rye bread sourdoughs.

Conclusions

1. During 72 hours of rye sourdough preparation process, the amount of LAB increased by 42% in sourdough from peeled flour and by 54% in sourdough from crude flour, though activity of LAB increased significantly considering pH value changes from pH 6.7 to pH 3.83 (peeled rye flour) and from pH 6.69 to pH 3.80 (crude rye flour).

2. High amount of LAB reaching 6.06 log10 cfu ml^{-1} and a final pH value 3.83 represent that sourdough from peeled rye flour has desirable properties for preparation of sourdough starter.

3. After 72 hours of fermentation, spontaneous sourdough from peeled rye flour contains 13% more LAB than sourdough from crude rye flour. This interconnection is stable during fermentation process.

4. LAB cultures isolated and identified from current sourdoughs: *Lactobacillus brevis* and *Lactobacillus fermentum* are also typical members of German, Russian, Swedish etc. traditional rye flour sourdough.

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NUTRITIONAL CHANGES IN SEVERAL POTATO VARIETIES DURING HEAT TREATMENT PROCESSES

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Abstract

Processing and cooking methods can greatly affect the nutritional value of fruits and vegetables including potatoes. In human nutrition potatoes before consumption are always prepared by several cooking methods and are one of the central components of warm meals. During treatment processes considerable changes in nutritional composition and nutritional quality of the product are induced. Hence the aim of the study was to determine the amount of basic nutrients (carbohydrate, fat and protein) as well as essential amino acids in five Latvian potato varieties prepared by the following heat treatment methods: baking in oven, shallow frying and deep fat frying and to compare the obtained results with recommended daily intake (RDI). Achieved results show significant differences in total carbohydrate amount within potato varieties (p=0.007) while within the type of heat treatments were no significance (p=0.065). Changes in fat content between heat treatment processes were considerable (p=0.000) whereas significance were discovered between control – pan fried, control – deep fat fried, baked in oven – pan fried, baked in oven – deep fat fried as well as pan fried – deep fat fried samples while no significance found among potato varieties (p=0.391). In protein amount neither within potato varieties nor between heat treatment processes significance was discovered, but the amount of essential amino acids significantly differs per each potato variety and type of heat treatment processes. Results on RDI per each nutrient group (fat, carbohydrates and protein) show significance on % RDI per each basic nutrient.

Key words: Potato varieties, heat treatment, RDI, nutrients.

Introduction

Traditionally, potato is a staple component of warm meals in many European countries (Wandel et al., 2001). In the research by Nordic and Baltic countries' authorities within the type of potato cooking methods, it was discovered that in Latvia fried potatoes consumption level comparing with neighbour countries was one of the highest (Norbagreen, 2003).

Over the past 40 years, changes in lifestyle and requirements for convenience, accompanied by an increased consumption of pasta and rice, have led to a considerable decrease in potato consumption in most Northern and Central European countries (decrease by 30–45% from 1961 to 2002; FAO, 2004). However, high annual intakes above 80 kg per capita are maintained even today in the Baltic countries, Poland, The Netherlands, Ireland and the UK (FAO, 2004).

In one of the studies about vegetable and fruit consumption it is mentioned that overall consumption frequency of fruits, vegetables and potatoes should be increased to meet the recommended five servings of vegetables and fruits a day (Seppa, 2002).

The potato tuber contains carbohydrates, protein, vitamin C and other essential substances, and it varies with the potato cultivar, growing area, storage and cooking method (Liu et al., 2007). Hence the aim of the study was to determine the amount of basic nutrients (carbohydrate, fat and protein) as well as essential amino acids in five Latvian potato varieties prepared by the following heat treatment methods: baking in oven, shallow frying and deep fat frying and to compare the obtained results with RDI.

Materials and Methods

In the cooperation with State Priekuli Plant Breeding Institute (Latvia) five table potato varieties which can be used for production of French fries and other processed potato products were chosen:

'Lenora', 'Brasla', 'Imanta', 'Zile' and 'Madara' which are selected and cultivated under the control of the institute. Selected potato varieties were analyzed after a short period (2 weeks during sizing) of storage at temperature 5±1 ºC and relative air humidity (RH) 80±5%.

Washed and hand-peeled potato tubers were cut/sliced in three ways: for shallow frying, potatoes were sliced into 0.7 x 1.0 and 3 – 4 cm long strips while for deep fat frying – into 0.6 × 0.6 and 4–5 cm long strips, but potatoes prepared for oven baking were cut horizontally into halves. Henceforward, a raw potato is indicated as a control sample.

Sunflower-seed oil was used for frying. Potatoes were baked in oven (210 ± 5 °C), shallow fried on the pan (150 ± 5 °C), and deep fat fried in the deep fat fryer (180 ± 5 °C). Throughout the oven and deep fat frying procedure time/temperature was recorded by USB TC-08 Thermocouple Data Logger PICO-Technologist equipment.

Total protein content was determined by LVS ISO 5983:1997, Amino acids by AOAC official method 994.12, fat content by ISO 6492 and dry matter (DM) content by LVS ISO 6496:1999. All the analyses mentioned above were performed on the same day. The results are presented on the wet weight (w/w) and DM basis g 100 g $^{-1}$. Analyses were done in triplicates.

Obtained values were evaluated and estimated based on the report of a joint WHO/FAO/UNU Expert consultation on Protein and Amino Acid Requirements in Human Nutrition (WHO, 2007) and direction about "Recommended amount of energy and nutrients for Latvian inhabitants" Nr. 233 issued by Ministry of Welfare of Republic of Latvia, 23 of January, 2001.

For statistical analysis, statistical software S-PLUS 6.1 Professional Edition was used. By means of specifying the differences between independent groups *Two-Way Analysis of Variance* and for the multiple comparisons of the means *Tukey* test was applied. Conclusions were done at 95% significance level.

Results and Discussion

In the research attention was focussed on total fat, total carbohydrate, total protein and essential amino acid changes during several heat treatment processes within five Latvian potato varieties and analysed from nutritional point of view. Moisture content was determined as well, and its changes vary per type of heat treatment and potato variety. Above mentioned fact on water loss can be influenced by several factors: potato structure, type of cutting/slicing and as well as the type of heat treatment method. During frying when potatoe strips are placed in hot oil, the surface temperature rises up rapidly and water is vaporised as steam and moisture loos occurs (Fellows, 2000). According to the total carbohydrate amount significant differences were found (p=0.007) within 'Brasla' – 'Imanta' and 'Lenora' – 'Imanta' while within the type of heat treatment no significant differences were discovered (p=0.065). The highest carbohydrate amount was determined in potato variety 'Brasla' (Figure 1) while the lowest in different potato varieties depending on the type of the heat treatment. In the control samples lower carbohydrate amount was determined in the potato variety 'Zile' and 'Imanta' prepared in oven as well as like in fried on the pan, but regarding to deep fat fried potato variety, the lowest carbohydrate amount was determined in 'Madara'.

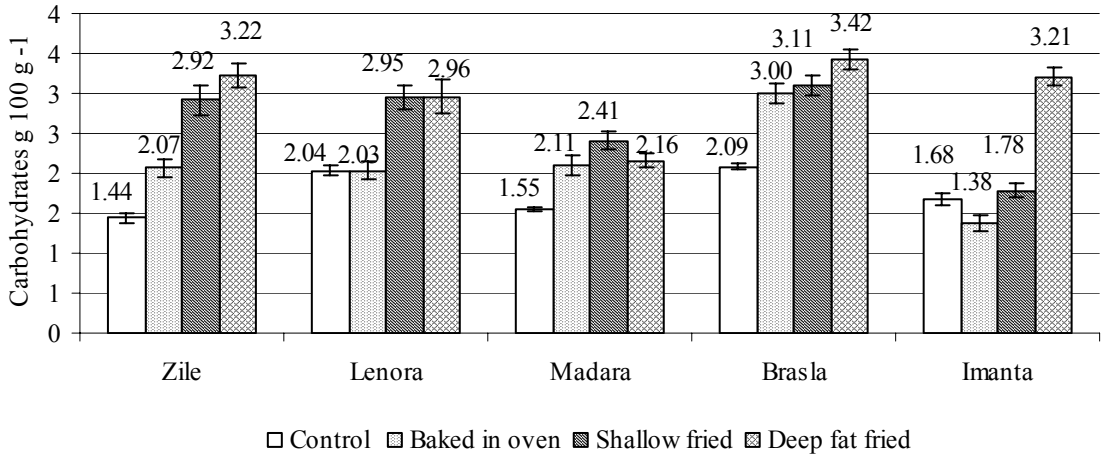

Figure 1. Carbohydrate amount in five potato varieties prepared by several heat treatment methods.

Changes in fat content between heat treatment processes were considerable (p=0.000). Extensive differences were discovered between control – pan fried, control – deep fat fried, baked in oven – pan fried, baked in oven – deep fat fried as well as pan fried – deep fat fried samples while no significance were found within potato varieties (p=0.391). The highest fat amount was set up in deep fat fried potatoes (Figure 2), which can be explained by a larger potato sample surface through which more rapid mass transfer occurs. As a result, water is expelled more rapidly and fat is absorbed. Regarding the potato consumption per type of heat treatment, Norbagreen survey (2003) data shows that deep fat fried potato consumption in comparison within Nordic and Balticcountries was the highest in Latvia (Norbagreen, 2003). By consuming baked and deep fat fried potatoes in comparison with potato varieties selected in the research, the lower fat content would be ingested by 'Madara' while as a pan fried would be 'Lenora'. On the contrary, higher fat uptake by consuming baked potatoes would be with 'Zile', as a pan fried with 'Brasla' and deep fat fried – 'Lenora'. Various fat amount in one and the same variety per each type of heat treatment method can be pointed out by the type of cutting, time and temperature used in each cooking method as well as chemical composition and microstructure changes during all mentioned processing factors are applied (Aguilera, 1999). As the result, it can be concluded that persons who are suffering from a tendency to become overweight or obese would be suggested to use in daily menu potato variety 'Madara' and 'Lenora' depending on the type of heat treatment applied and between varieties baked in oven 'Imanta', shallow fried 'Brasla' and deep fat fried 'Lenora' wouldn't be suggested due to higher amount of fat absorption during frying process.

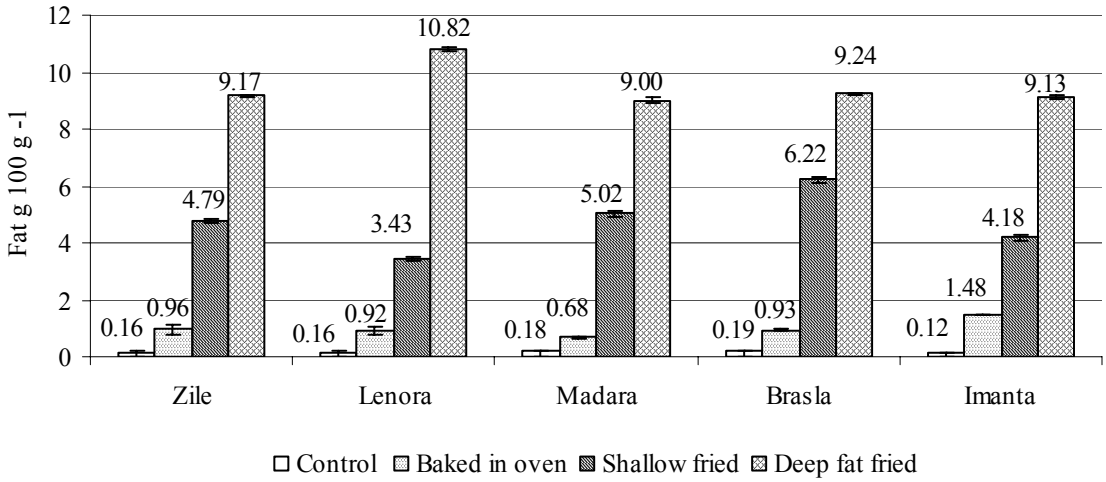

Figure 2. Fat amount in five potato varieties prepared by several heat treatment methods.

In protein amount neither within potato varieties nor between heat treatment processes significance was found. With the highest total protein content between control samples was 'Lenora' while among baked potato samples 'Brasla', shallow fried – 'Zile' and deep fat fried – 'Imanta' (Figure 3). During heat treatment process protein denaturation and amino acids decomposition occur (John, 1999). From the control samples low protein content was in potato variety 'Brasla' but as baked in 'Zile', shallow fried – 'Lenora', furthermore, within deep fat fried – 'Lenora'.

In potatoes protein consists of significant amount of essential amino acids, but during heat treatment processes several reactions occur from which the most important is Maillard reaction. Based on this reaction, cooked product obtains appetizing taste, odour and colour (Fellows, 2000).

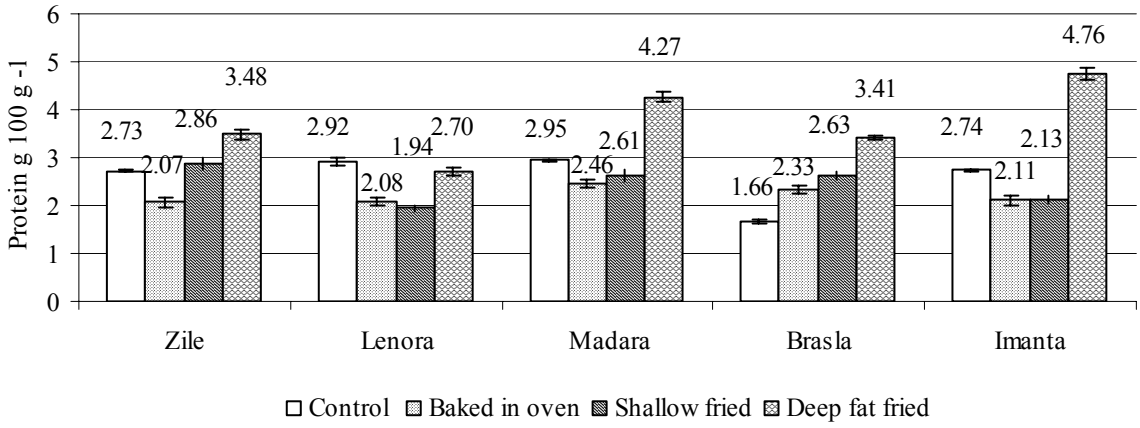

Figure 3. Protein content in potato varieties prepared by several cooking methods, g 100 g $^{-1}$.

By Norbagreen (2003) survey, the fact that potato covers significant part from total vegetable amount consumed daily is well approved. Therefore, it is important to know how much nutrients are ingested with potatoes, and its coverage from RDI. Several calculations have been done based on direction about "Recommended amount of energy and nutrients for Latvian inhabitants" Nr. 233 issued by Ministry of Welfare of Republic of Latvia, 23 of January 2003. RDI of energy for female is 2000 kcal but for male – 2400 kcal where in average 12.5% should cover from protein, 27.5% - fat and as the highest energy part comes from carbohydrates – 60%.

Results of RDI per each nutrient group (fat, carbohydrates and protein) show significance on % RDI in fat amount between all heat treatments (p=0.000) and gender (p=0.007) while no significance was noticed among potato varieties (p=0.773). According to the % RDI on carbohydrates significance in nutrient coverage was discovered between each factor: potato varieties (0.0002) heat treatment (p=0.000) and gender (p=0.0014) whereas the % of RDI of protein significantly differs between type of heat treatment (p=0.000) and gender (p=0.020), but within the variety (p=0.682) there was no significance in protein coverage of RDI.

In a view of the fact that potato protein consists in significant amount of essential amino acids, but notable loss occurs during frying and baking processes, it is important to compare the amount of essential amino acids between each type of heat treatment within each potato variety, too (Table 1).

Table 1

Essential Amino Acid Amount in Potato Varieties per Treatment

Variety	Amino acid	Amount, mg 100 g $^{-1}$ per treatment			
		Control	Baked in oven	Shallow fried	Deep fat fried
Brasla	Thr	66.0	120.0	100.0	120.0
	Val	73.0	80.0	70.0	80.0
	Met	22.0	26.0	29.0	38.0
	Ile	39.5	50.0	40.0	60.0
	Leu	90.0	130.0	110.0	150.0
	Phe	72.0	90.0	70.0	90.0
	Lys	84.0	110.0	90.0	120.0

Variety	Amino acid	Amount, mg 100 g $^{-1}$ per treatment			
		Control	Baked in oven	Shallow fried	Deep fat fried
Total		446.5	606.0	509.0	658.0
Imanta	Thr	75.5	90.0	100.0	120.0
	Val	54.0	60.0	90.0	100.0
	Met	16.5	28.0	36.0	37.0
	Ile	36.5	40.0	60.0	70.0
	Leu	104.5	110.0	150.0	160.0
	Phe	77.0	70.0	90.0	100.0
	Lys	70.5	90.0	110.0	140.0
Total		434.5	488.0	636.0	727.0
Lenora	Thr	63.5	70.0	70.0	100.0
	Val	60.5	70.0	90.0	130.0
	Met	22.5	31.0	39.0	43.0
	Ile	41.0	40.0	50.0	70.0
	Leu	89.0	80.0	80.0	130.0
	Phe	62.0	60.0	60.0	110.0
	Lys	89.0	70.0	80.0	110.0
Total		427.5	421.0	469.0	693.0
Madara	Thr	65.0	90.0	110.0	120.0
	Val	72.0	90.0	100.0	120.0
	Met	22.5	36.0	35.0	37.0
	Ile	39.5	60.0	60.0	80.0
	Leu	65.0	120.0	130.0	150.0
	Phe	47.0	70.0	70.0	90.0
	Lys	61.5	90.0	100.0	120.0
Total		372.5	556.0	605.0	717.0
Zile	Thr	58.5	80.0	130.0	100.0
	Val	45.0	80.0	90.0	110.0
	Met	18.5	27.0	34.0	42.0
	Ile	36.5	60.0	50.0	80.0
	Leu	83.0	140.0	110.0	180.0
	Phe	46.5	80.0	80.0	120.0
	Lys	73.0	100.0	100.0	150.0
Total		361.0	567.0	594.0	782.0

The amount of essential amino acids significantly differs per each potato variety and type of heat treatment. If potato varieties are compared with the control samples, the highest total essential amino acid content was determined in the potato variety 'Brasla' while the lowest was in the potato variety 'Zile'. For deep fat fried potatoes it was opposite: the highest essential amino acid content was in 'Zile' whereas the lowest - in 'Brasla'. It could be substantiated by the chemical composition of each potato variety e.g. reducing sugar amount, starch content etc. which are involved in the Maillard reaction with amino acids. Concerning the baked potato varieties, the highest essential amino acid

content was in 'Brasla' but the lowest one in 'Lenora' while for shallow fried potato varieties, higher amount of amino acids was in 'Imanta' but lower – in 'Lenora'.

The most significant differences within the potato varieties on the type of essential amino acids were found on Val, Met and Ile (Table 2) while within the heat treatment – on Val, Ile, Phe, His and Lys (Table 3).

Table 2

Differences within the Potato Varieties in the Type of Essential Amino Acids

Amino acid	Brasla	Imanta	Lenora	Madara	Zile
Val**	A	A	AB	B	A
Met*	A	A	B	AB	AB
Ile**	A	A	B	B	AB

*The same letter within each component is not significantly different at the 5% level by the Tukey multiple-comparison test. * p≤0.01; ** p≤0.001*

Table 3

Differences within the Heat Treatment on the Type of Amino Acids

Amino acid	Control	Backed in oven	Shallow fried	Deep fat fried
Val*	A	AB	AB	B
Ile*	A	AB	B	B
Phe**	A	AB	B	B
His***	A	B	B	AB
Lys**	A	AB	B	B

*The same letter within each component is not significantly different at the 5% level by the Tukey multiple-comparison test. * p≤0.05; ** p≤0.01; *** p≤0.001*

Changes could be explained by Maillard reaction where pleasant odour, favour, colour and taste are formed. Some amino acids have a specific role in colour formation while some in taste, odour and flavour; therefore, almost all amino acids are involved in the Millard reaction. Previously mentioned properties of the Maillard reaction in food acceptance from consumer point of view could be indicated as a positive factor, but at the same time from nutritional point of view loss of essential amino acids occurs; therefore, it is relevant to be informed about their requirements as well.

Essential amino acids and their requirements for female and male are presented in Table 4.

Table 4

Essential Amino Acid Requirement for Female and Male

	RDI, g kg $^{-1}$ per day*	Female (65 kg), mg	Male (75 kg), mg
Thr	15	975	1125
Val	26	1690	1950
Met	10	650	750
Ile	20	1300	1500
Leu	39	2535	2925
Phe	25	1625	1875
Lys	30	1950	2250

** Recommended amount of energy and nutrients for Latvian inhabitants, 2001*

To meet the RDI of essential amino acids per day, it is important to pay attention to how much essential amino acids can be ingested by the food prepared by several heat treatment methods. Especially well known fact that common potato frying methods in Latvia are pan frying, deep fat frying and baking in oven where research results present that significant changes in essential amino acid profile occur.

Conclusions

1. Significant changes of total carbohydrate amount were within potato varieties 'Brasla' – 'Imanta' and 'Lenora' – 'Imanta' (p=0.007) while within the treatment types there was no significance (p=0.065).
2. Distinction in fat content between several heat treatment processes was considerable (p=0.000). Differences were discovered between control – pan fried, control – deep fat fried, baked in oven – pan fried, baked in oven – deep fat fried as well as pan fried – deep fat fried samples.
3. In protein amount neither within the potato varieties nor between heat treatment processes significance was mentioned. With the highest total protein content between control samples was 'Lenora' whereas among baked potato samples - 'Brasla', shallow fried – 'Zile' and deep fat fried – 'Imanta'. The lowest protein content in control sample was for 'Brasla', baked in oven - for 'Zile', shallow fried – 'Lenora', furthermore, within deep fat fried – 'Lenora'.
4. Protein and carbohydrate changes can be explained by the reaction during heat treatment processes while fat amount increase - by potato structure, heat and mass transfer during frying process as well as time and temperature per each cooking method. All those factors affect each type of potato variety differently.
5. Results on RDI per each nutrient group (fat, carbohydrates and protein) show significance on % RDI on fat amount between all types of treatments (p=0.000) and gender (p=0.007) while no significance was among potato varieties (p=0.773).
6. According to the % RDI, carbohydrates significance in nutrient coverage was found between each factor: potato varieties (p=0.0002), heat treatment (p=0.000), and gender (p=0.0014) whereas the % of RDI on protein significantly differs between type of heat treatment (p=0.000), but within the variety (p=0.682) and gender (p=0.020), whereas within the variety (p=0.682) there was no significance in protein coverage of RDI.
7. The amount of essential amino acids significantly differs per each potato variety and type of heat treatment; therefore, in order to meet the RDI of essential amino acids per day, it is relevant to pay attention how much essential amino acids can be ingested by the food prepared by several heat treatment methods.

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EVALUATION OF TEXTURE PARAMETERS OF VACUUM AND MODIFIED ATMOSPHERE PACKED FRESH CARP (*CYPRINUS CARPIO* L.)

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Abstract

Investigations of textural parameters of vacuum, protective gas atmosphere (MAP), and at air ambiance packed fresh carp (*Cyprinus carpio* L.) farmed in Latvia were carried out. The samples of carp were stored at two different temperatures (0 ± 0.5 and +4 ± 0.5 ºC) applying three different types of packaging – vacuum, MAP, and wrapping at air ambiance. Gas mixture used for MAP consisted of 40% CO_2 and 60% N_2. Samples were analyzed before packaging (day 0) and after 2, 4, 6, 8, 11 and 14 storage days. Textural parameters – hardness and shear force were evaluated by texture analyzer TA.XT.plus (Stable Micro System Ltd.). Two instrumental methods were applied for evaluation of textural properties. One method was based on compression test, using spherical probe, 25.4 mm in diameter (type P/1S), and measuring the hardness of the fillet and other method was based on cutting the fillet with a blade (type HDP/BSK) and measuring the shear force. The instrumental hardness and shear force of fresh carp fillets decreased during storage time. Texture variables significantly correlate with storage time, respectively, r = -0.723 and r = -0.748, the hardness and shear force. The storage time, temperature and packaging type with probability of 95 % substantially influence the textural parameters of carp fillets ($P < 0.05$).

Key words: carp, packaging, storage, texture, quality.

Introduction

Common carp is the main aquaculture in Latvia. Change in consumer's attitude to carp may be achieved by application of new carp processing technologies. The perspective method of shelf life extension for fish is packaging in vacuum and modified gas atmosphere (MAP). Modified atmosphere packaging (MAP) extends shelf-life of most fresh fishery products by inhibiting the bacterial growth and oxidative reactions (Sivertsvik et al., 2002).

Texture analysis for fish and fish products are important parameters in the research of quality control and product development in the seafood industry (Jain et al., 2007). Texture is a general quality trait related to fish freshness quality (Olafsdottir et al., 1997). Live fish muscle is relaxed and elastic (Venugopal, 2005). Fish stored for various times post-mortem show a rapid loss of muscle hardness and a slower resolution of rigor stiffness (Taylor et al., 2002) indicating that these are separate events.

Texture of raw fish fillets is commonly tested in the industry by the 'finger method'. A finger is pressed on the skin or the fillet and firmness is evaluated as a combination of the hardness when pressed on the fillet and mark or hole left in the fillet after pressing. This method depends to a large extend upon subjective evaluation of the person who is performing the measurements (Sigurgisladottir et al., 1997).

In raw fish, the texture softens during chilled storage because proteolytic enzymes break down the muscle structure (Sveinsdottir et al., 2002). The fat content of fish flesh appears to influence the texture. When the fat content is high, the flesh is softer and juiciness is increased. The total lipid content of common carp's fillet was reported by Lengyel et al. (2001) and Hancz et al. (2003) in natural waters (3.1 ± 3.3%) and farmed (10.0 ± 4.5%) in Hungary. Schrenkenbach et al. (2001) determined the total body composition of a large number of fish originating from lakes and ponds in Germany and found that common carp (*Cyprinus Carpio* L.) had very high variance of fat (8.5 ± 4.4%).

Reproducibility of texture measurements is affected by sampling technique because of the heterogeneity of the fillets (Sigurgisladottir et al., 1999). Therefore, it is difficult to find a representative average sample, and measurement of textural properties may depend on the location within the fillet. However, raw fish should be tested in the form of a fillet or a part of a fillet. Texture of fish fillet is also related to the diameter of the muscle fibres. The strength is higher with smaller diameter and, therefore, higher numbers of fibres, than with larger diameter and lower numbers of fibres (Hatae et al., 1990). Thus, sampling is an important factor in the evaluation of fish fillet texture, because hardness and shear force increased from fish head to tail (Sigurgisladottir et al., 1999).

The goal of this study was to evaluate the texture of fresh carp filets at the storage time applying different packaging technologies.

Materials and methods

Sample preparation and packaging

The experimental work was performed at the Faculty of Food Technology, Latvia University of Agriculture. The common carp (*Cyprinus Carpio* L.*)*, weight 1.5 to 2.5 kg, farmed in one of the large-scale carp breeding companies in Latvia, "Skrunda" Ltd, were used in the studies during February-March 2008.

The carp after slaughtering and preconditioning (scale removal, cleaning, washing, filleting, and portioning with weight of 150 to 180 g) were placed on the thermoformed ready-made polypropylene (PP) trays (size 210 × 148 × 35 mm), sealed on a chamber type machine TECNOVAC Pratica with laminated film BIALON PP (thickness 65 µm). Gas mixture used for MAP packaging consisted of 40% CO_2 and 60% N_2.

The vacuum packed samples of carp were placed on the expanded polystyrene (EPS) trays (size 185 × 140 × 25 mm), inserted in PA/PE polymer pouches (size 300 × 200 mm, thickness 20/45 µm) and sealed by chamber type machine MULTIVAC C 300. Vacuum level was 99 %.

Control samples in air ambiance were also placed on the expanded polystyrene (EPS) trays (size 185 × 140 × 25 mm), just wrapped in polypropylene (PP) film (thickness 15 µm).

All samples, vacuum and MAP packed as well as control were stored in a commercial freezer/Cooler ELCOLD at two different temperatures, 0 ± 0.5 and +4 ± 0.5 °C (controlled by MINILog, Gresinger electronic), for 14 days under fluorescent lighting (OSRAM Lumilux De Luxe) with radiant fix at 100–800 lux (measured by Light meter LX-107). Throughout the storage period the samples were randomly interchanged to minimize unequal temperature fluctuations and light conditions.

Instrumental texture measurements

The textural properties of samples were determined before packaging (on 0 day) and after 2, 4, 6, 8, 11 and 14 storage days. Each textural measurement of three identical packages was carried out by Texture Analyzer TA.XT.plus (Stable Micro System Ltd., Surrey, England) using a compression and cutting test. Two different attachments were applied: a) spherical probe (Figure 1-a) and b) blade attachment (Figure 1-b). The results were reported as means of five determinations, based on application of the TA.XT.plus texture analyzer with a load cell of 50 kg. This instrument provides a rigid framework for tension compression cycling and texture test to generate true 3-dimensional product analysis of force, distance, and time. The results were expressed as maximum force in newtons (N). During analysis, the core temperature was +4 ± 1 °C.

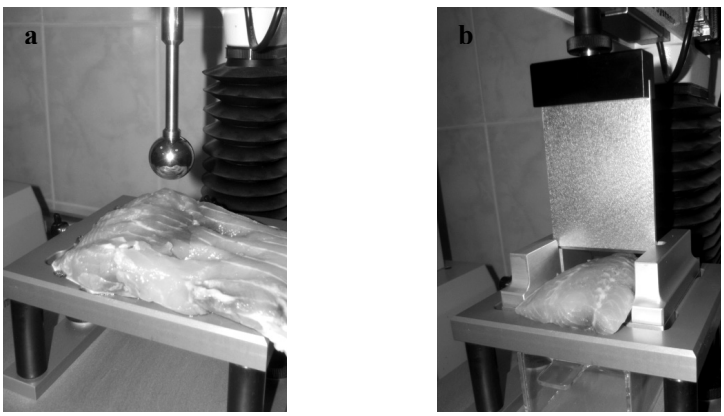

Figure 1. Attachments applied for textural measurements of carp fillets: (a) a sphere in diameter of 25.4 mm, and (b) blade set with a knife – thickness 3.0 mm, width 70 mm.

Spherical probe. A sphere was selected as the second probe to simulate further the human finger method. The sphere affected the fillet without breaking the muscle fibres and a 5 mm distance was chosen. The spherical probe was 25.4 mm in diameter (type P/1S). Pre-test speed, test speed and post-test speed were 1 mm sec^{-1}, and trigger force was 0.2 N. The typical compression curve, using the sphere, is shown in Figure 3-a. The location below the dorsal fin is the reliable for textural measurements (Figure 2).

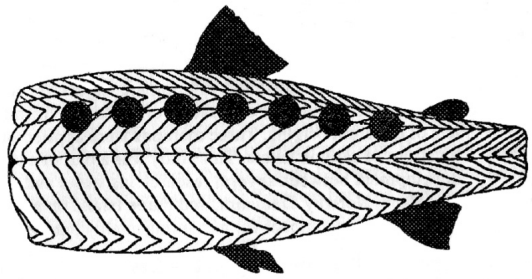

Figure 2. Locations of textural measurements on the carp fillet with a spherical probe.

Blade set with a knife. The blade (knife edge, 60º) had a thickness of 3.0 mm and width of 70 mm (type HDP/BSK) which cut through the sample at a speed of 1.0 mm sec^{-1} to 30 mm distance. The post-test speed was 10 mm sec^{-1} and trigger force was 0.2 N. The typical cutting curve, using the blade, is shown in Figure 3-b. The blade approach was applied by pressing the blade through the muscle vertical to the muscle fibres. Thickness of carp fillets varies from head to tail but is approximately 20 mm thick above the lateral line. The samples were prepared from fillet dorsal part, cut into pieces (size 70 x 65 mm, thickness 20 mm) without skin.

Texture parameters recorded from the force-time graphs included: force of compression and area (Figure 3).

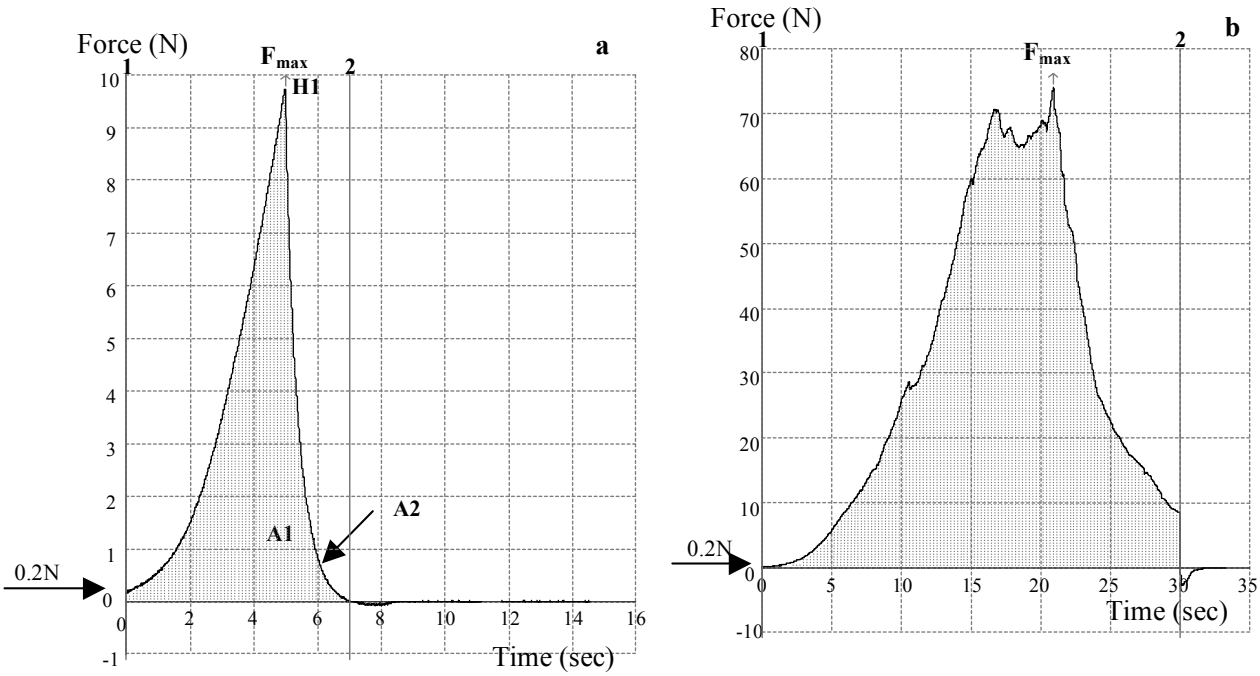

Figure 3. Typical force-time curves of the instrumental texture measurements of a carp sample: (a) for the spherical probe, and (b) for the blade set with a knife.

The F_{max} represents the force recorded at maximum compression and the force at complete cutting. Hardness = H1, resilience = A2/A1 equals the area under the curve from beginning of measurement until maximum force is reached, and A2 equals the area under the curve from maximum force until the force has reached zero again.

Statistical evaluation

The results were processed by mathematical and statistical methods. Data were subjected using one-way analysis of variance (ANOVA) using the statistical analysis software SPSS 13.0 for Windows, significance was defined at $P < 0.05$. Fitting of curves and charts was done by using spread-sheets MS Excel.

Results and discussion

Accordingly to the explanation of Stroud (2001), rigor or, to give it its full name, rigor mortis means the stiffening of the muscles of an animal shortly after death. The word "rigor" is used throughout this paper because it is shorter and easier to use than either death stiffening or rigor mortis.

Post mortem can to distribute three stages: 1) pre-rigor condition immediately after death the muscles of an animal are soft and limp, and can easily be flexed; 2) in rigor the muscles begin to stiffen and harden; 3) post-rigor condition after some hours or days the muscles gradually begin to soften and become limp again.

The fish remains rigid for a period which can vary from an hour or so to three days, then the muscles soften again. The time a fish takes to go into, and pass through, rigor depends on such factors: the species, its physical condition, the degree of exhaustion before death, its size, the amount of handling during rigor, and the temperature at which it is kept. Some species take longer than others to go into rigor, because of differences in their chemical composition. Whiting, for example, go into rigor very quickly and may be completely stiff one hour after death, whereas redfish stored under the same conditions may take as long as 22 hours to develop full rigor. Trawled codling, 18-22 inches long, gutted and stored in ice, usually take 2-8 hours to go into rigor. Small fish usually go into rigor faster than large fish of the same species (Stroud, 2001).

The temperature is perhaps the most important factor governing the time a fish takes to go into, and pass through, rigor because the temperature at which the fish is kept can be controlled.

The instrumental hardness of fresh carp fillets decreased with storage time, indicating softening of the carp flesh.

The variation in textural parameters in vacuum, MAP and at air ambiance packaged fresh carp fillets during a 14 days storage period at temperature (0 ± 0.5 and +4 ± 0.5 °C) is shown in Figures 4 to 7.

The optimum defined shelf life of fresh carp fillets is as follows: at 0 ± 0.5 °C – 6 days at air ambiance, 8 days in vacuum, 14 days in MAP; at +4 ± 0.5 °C – 3 days at air ambiance, 6 days in vacuum, 14 days in MAP packaging (Kamolina and Dukalska, 2007).

Statistical analysis (ANOVA) of the data showed that all texture parameters – hardness and shear force – were found to be significantly decreased during the storage period ($P < 0.05$). The storage time and storage temperature has significant influence on the share force, which was measured by cutting test with a blade, whereas storage condition (vacuum, MAP and air ambiance) and storage time was significant for hardness, detected by compression test with a sphere ($P < 0.05$).

All texture variables determined with the 25.4 mm diameter spherical probe correlate significantly with storage time (days). The correlation was on a 0.01% significance level (r = -0.723). The texture parameters recorded the blade showed highest correlation with storage time (r = -0.748). Between the methods of instrumental texture measurements and texture values (force in newtons) a hard correlation exists (r = 0.872).

The experimental data expressed in Figure 4 clearly indicate that the values of hardness decreased at the storage time. The hardness value of the fresh carp samples was 26.84 N. The hardness of carp fillet's flesh decreased drastically 2-3 times already at the storage time from day 0 till day 2. The decrease in values at the first days of storage can be explained by 'post mortem' changes.

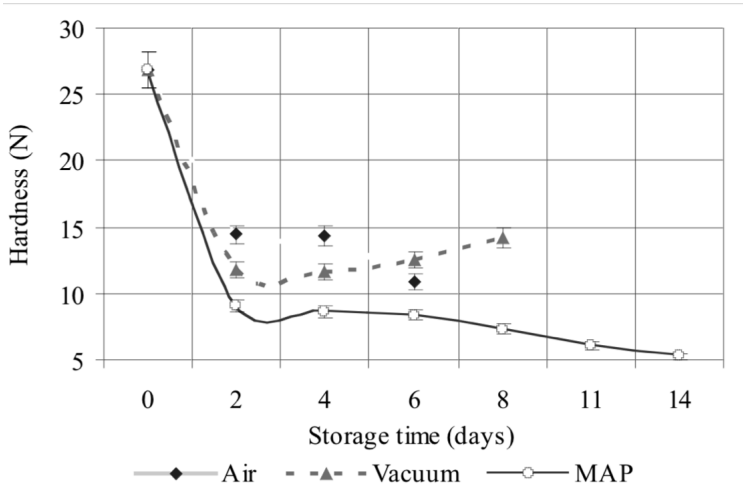

Figure 4. Hardness of vacuum, MAP and at air ambiance packaged fresh carp fillets stored at the temperature of 0 ± 0.5 °C, measured by compression with a spherical probe.

After 6 storage days (0 ± 0.5 °C) in air ambience, the hardness value of wrapped carp samples decreased from 26.84 N to 10.88 N, of vacuum packed – only to 12.5 N, while in MAP packed – even to 8.39 N; however, following 8 storage days – to 7.32 N. After 14 storage days in the MAP, the hardness diminished nearly 5 times – to 5.25 N. Whereas the hardness of fresh vacuum packed carp samples after 2 storage days (11.75 N) even slightly increased up to 14.2 N at day 8.

An important decrease in the hardness of carp samples was observed to those stored at +4 ± 0.5 °C (Figure 5): after 6 storage days in MAP, the hardness was 6.24 N. Similarly it was observed in samples stored at air ambiance – 6.65 N, whereas hardness of the vacuum packed carp sample at the same storage time was 12.32 N. Subsequently, at the next storage days the hardness values were invariable**.** During 14 storage days, the hardness of samples packed in MAP and stored at 0 ±0.5 °C decreased from 26.84 N (day 0) to 5.25 N (day 14); when stored at +4.0 ± 0.5 °C, respectively, to 6.75 N. During storage time in MAP at low temperature the solubility of carbon dioxide (CO_2) on the filet surface of the product increased; therefore the flesh texture properties in hardness as well as in the cutting forces considerably changed.

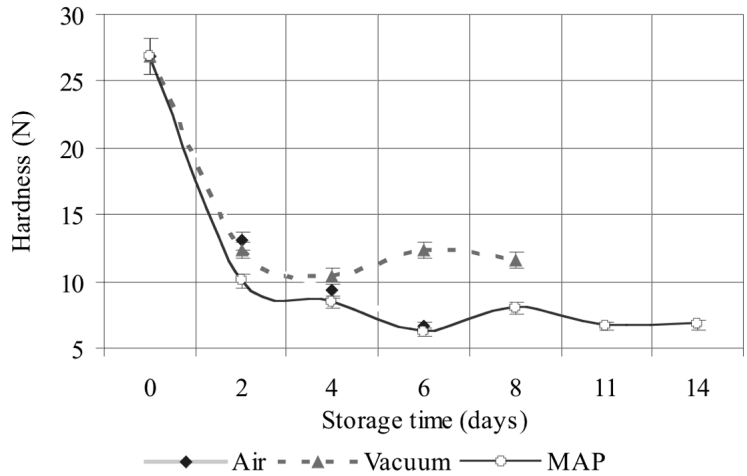

Figure 5. Hardness of vacuum, MAP and at air ambiance packaged fresh carp fillets stored at the temperature of +4 ± 0.5 °C, measured by compression with a spherical probe.

In all investigated samples stored at 0 ± 0.5 °C, a sharp shear force decrease was observed during first 2–4 storage days. The decrease in shear force value of fillets packed in air ambiance was slower (Figure 6) – from 193.44 N to 108.65 N (day 6); whereas in MAP packed, the shear force values decreased more notably – to 96.73 N (day 6) and 84.24 N (day 14), respectively. Similar changes in hardness were observed in vacuum packed carp filets stored for 8 days.

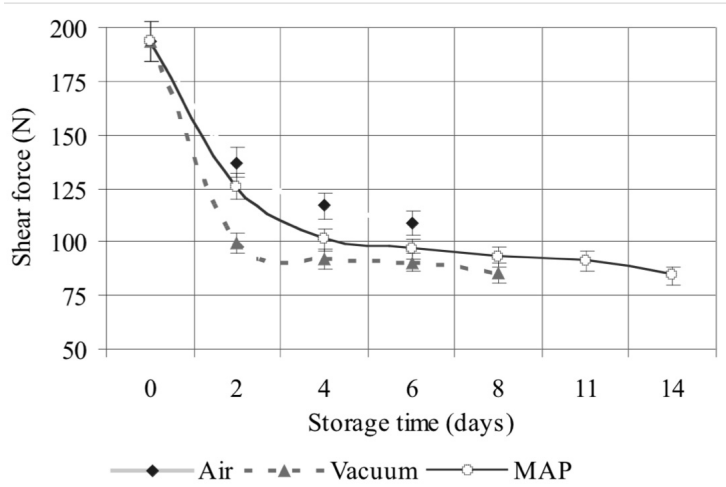

Figure 6. Shear force of vacuum, MAP and at air ambiance packaged fresh carp fillets stored at the temperature of 0 ±0.5 °C, measured by cutting with a blade.

The shear force value of wrapped carp filets stored at temperature of +4 °C in air ambiance diminished very sharply – from 193.44 N (day 0) to 65.40 N (day 6); compared to the same time in vacuum – to 98.56 N, and in MAP – to 87.29 N (Figure 7). The shear force value of MAP packed carp filets within the storage time of 14 days decreased more than 2 times.

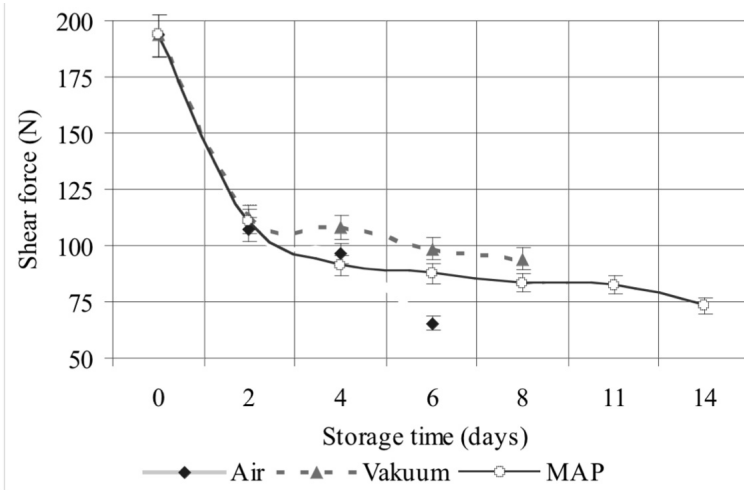

Figure 7. Shear force of vacuum, MAP and at air ambiance packaged fresh carp fillets stored at the temperature of +4 ±0.5 °C, measured by cutting with a blade.

The texture variation can be explained due to rigor mortis, describing the stiffness in muscle tissue after fish death. For all textural parameters, there was decrease in their values after first five storage days.

Rigor mortis of fish has technological significance since the process influences the quality of fillets. Ideally, fish should be filleted post-rigor (Venugopal, 2005).

Rigor results from a series of complicated chemical changes in the muscle of a fish after death; the process is not yet fully understood, and research is still going on, but it is known that factors like the physical condition of the fish at death, and

the temperature at which it is kept after death, can markedly affect the time a fish takes to go into, and pass through, rigor (Stroud, 2001).

In the literature (Jain et al., 2007) it is reported that the course of completion of rigor mortis for fish requires 5–24 h. The fish is considered as fresh and good for human consumption during rigor mortis. After rigor mortis stage, the decomposition of fish tissue occurs rapidly.

Carbon dioxide (CO_2) can be seen as most effective gas in reducing the growth of aerobic and gram-negative psychotropic bacteria, whereas negative affect of CO_2 has been observed on the color changes of fish tissues as well as on the texture and drip loss of fresh fish (Sivertsvik et al., 2002).

Significant differences ($P < 0.05$) were found between the data of textural measurements of different packed samples during 14 days of storage. Primarily, the storage time (days) has a significant influence ($P < 0.05$) on the textural parameters of vacuum and modified atmosphere packed fresh carp tissues. Also the packaging type and storage temperature had a significant effect ($P < 0.05$) on the textural parameters of carp.

The sampling technique is an important factor that can affect the final results of texture analysis. The difference in textural properties within one fillet can be higher in some instances than between fillets of different individuals. Mixing samples from different locations of a fillet may, therefore, be questionable. This can lead to difficulties in some cases in studying effects of processing or storage of fillets on texture (Sigurgisladottir et al., 1999).

Conclusion

Studies on the textural properties of common carp (*Cyprinus Carpio* L.) during storage in vacuum, MAP and at air ambiance indicated considerable changes in the compression characterising the hardness and cutting share forces, which could be influenced by post mortem textural changes. The highest changes in texture were found after rigor condition for first two days of storage. Primarily, the storage time with probability of 95% substantially influences the textural parameters of vacuum and modified atmosphere packed carp fillets ($P < 0.05$). Also temperature and packaging type has a significant effect on the textural parameters.

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THE APPLICATION OF ORGANIC TRACE MINERALS IN BEEF CATTLE NUTRITION

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Abstract

Understanding the efficacy of organic trace minerals has been increasingly important over the past few years as a result of increased customer awareness of their benefits and the increase in the number of commercial products available to the customer. Organically bound trace minerals of interest in animal nutrition specifically include iron, zinc, manganese, copper, cobalt, and selenium. These elements have been shown to improve reproductive efficiency as measured by conception rate, alleviated calving, and reduced placenta expulsion rate. Additional benefits include improved growth performance of calves.

The field trials in the period of 2005 – 2007 with Charolais breed beef cattle cows and calves verified efficacy of the premix PROTRACE G containing Fe, Zn, Cu, Mn, and Co helates, Se-amino acid (selenomethionine), potassium iodide, and vitamins A, D3 and E. Average calving rate of experimental group cows fed diet with added premix was 20 – 30 min, placenta expulsion time - 28 – 31 min, but in control group fed only basal diet - 2 h 21 min and 1 h 30 min – 2 h 09 min ($p < 0.05$) respectively. Live weight gain of calves and heifers of the experimental group was on 35 – 39% higher ($p < 0.05$) than that in the control group.

Key words: organic trace minerals, chelates, reproductive efficiency, growth performance.

Introduction

Trace minerals play a vital and important role in nutrition, being part of structural materials, constituents of the soft tissues and cells, and regulate many of the vital biological processes. They occur naturally in most feed ingredients but the amount and bioavailability varies considerably. Although trace minerals are traditionally included in the diet at a very small amount in the form of premix of inorganic salts such as sulphates, chlorides, carbonates and oxides, there are several factors that may reduce their availability when ingested by the animal. The poor retention and high excretion rates of inorganic minerals led to environmental concerns during the 1980s and 1990s, especially in Europe. The EU is concerned about possible detrimental effects of excess supplementation with trace minerals on the environment or human and animal health, and so in 2003 legislated a reduction in permitted feed concentration of several trace metals – Co, Cu, Fe, Mn, and Zn (Commission Regulation (EC) No, 1334/2003 of 25 July 2003).

Fortunately, research in trace element nutrition has led to the development of more bioavailable organic minerals by binding them to organic ligands, usually a mixture of amino acids or small peptides and thus, the so-called organic trace minerals.

A ligand is a molecule containing an atom, which has an ion pair of electrons. In the process of chelation, the ligand acts as a chelating agent and encircles the metal atom to form a heterocyclic ring structure. That is, the metal atom is bonded to the ligand through donor atoms such as the oxygen of the carboxyl group, nitrogen or sulphur of the amino acid or peptide (Hynes et al., 1995). When such ligands bond to a metal ion via two or more donor atoms, the complex formed contains one or more heterocyclic rings and such species are called 'chelates'. There are various categories of organic trace minerals as defined by the Association of American Feed Control Officials (AAFCO, 1998), such as: a) metal amino acid helate – is a product resulting from the reaction of a soluble metal salt with amino acids with the mole of metal to one to three (preferably two) moles of amino acids to form coordinate covalent bonds; b) metal amino acid complex – is a product resulting from complexing

of a soluble metal salt with amino acid(s); c) metal polysaccharide complex – is a product resulting from complexing of a soluble metal salt with a polysaccharide solution, and d) metal proteinate – is a product resulting from the chelation of a soluble metal salt with amino acids and/or partially hydrolyzed protein.

Absorption of inorganic trace minerals is often a major limitation of their utilization. During digestion, the mineral ions from inorganic sources are released and may re-combine with other digesta components in the intestine forming insoluble complexes and thereby excreted, whereas the organic minerals utilize peptide and/or amino acid uptake mechanisms in the intestine (Ashmead, 1993). The mineral within the complex or chelate is protected from physiochemical factors or from negative interaction with dietary components such as phytate, which binds cations making them unavailable for absorption (Fairweather-Tait, 1996). In addition, the organic trace minerals remain to be electrically neutral at certain pH conditions. Thus, the mineral chelate complex is absorbed intact through intestinal mucosa, traversing the mucosal cell membrane into the plasma. Organic trace minerals have stability constants at such magnitude as to allow the metal ions to be released and transferred to the host's biological systems (Ashmed, 1993). Chelates allow a lower supplementation rate of trace minerals with an equivalent or improved effect on animal health, growth and productivity.

The purpose of the trial was to prove efficacy of organic trace minerals on beef cattle cows and calves performance indices – calving and placenta expulsion rate, suckling stimulus of newborn calf, female calves live weight changes before and after weaning and in period of breeding.

Materials and methods

The field trials took place at the farm 'Jaunrubeni' of Riga district in the period of 2005 – 2007. Twelve Charolais breed beef cattle cows with calves were split into two groups and randomly assigned to one of the experimental diets. In each group there were three cows with suckler male calves and three suckler female calves. Cows of both groups were being fed basal diet *ad libidum* consisting of grass silage and meadow hay; only in the diet of the experimental group premix PROTRACE G proposed by experts of the Proventus Farms Pluss Ltd. was added. The premix contained Fe, Zn, Cu, Mn, and Co helates, Se-amino acid (selenomethionine), potassium iodide, and vitamins A, D_3 and E. Daily dose per cow – 100 g of premix – was mixed in 1 kg of barley meal. Cows of control group got 1 kg meal without premix. All animals – cows and calves – were weighed at the beginning of the trial period, on 02.09.05, and subsequently on 02.10.05, 02.11.05, and 25.11.05. After the first weighing experimental group cows and calves were fed diet with added premix. After the weighing on 02.11.05 calves were weaned from cows and separated in 4 pens: a) 3 female calves which were fed and continued to be fed added premix; b) 3 male calves which were fed and continued to be fed added premix; c) 3 female-calves and d) 3 male calves from the control group were fed only basal diet and continued to be fed basal diet. In a separate pen, 6 cows (mothers of the male and female calves) were kept; they were fed and continued to be fed the added premix. And the cows of the control group were placed in the second pen – they were fed and continued to be fed only basal diet. Each of these groups of cows increased to 10 animals.

During spring of 2006, all processes of parturition were recorded: length of parturition, placenta separation rate, the time when the calves started to suckle, weight of the newborn calves was registered and afterwards the weight of the calves continued to be registered each month. Cows and weaned calves in both groups were fed basal diet, adding premix PROTRACE G only to the diet of the experimental group of cows and calves. The same field trial activities were continued in 2007.

Results and Discussion

During the first three months of the trial period and in the subsequent period no remarkable changes in the live weight of cows in both groups was observed. For female-calves changes were significant and the mentioned difference increased (Table 1). The male calves were sold after weaning and are not included in the study.

Table 1

Live weight changes in female calves and heifers born in the spring of 2005 during the period of 02.09.05 – 02.11.07

Groups	Weighing dates before and after weaning			Weighing dates of breeding period	
	02.09.05	02.11.05	25.11.05	01.10.06	02.11.07
Control group Female calves/heifers, kg	199	242	270	469	631
Daily weight gain, kg (02.09. – 25.11, 84 days)	0.845			–	–
Daily weight gain, kg (02.11. – 25.11, 23 days)	1.217			–	–
Daily weight gain, kg (25.11.05 – 01.10.06 and 01.10.06 – 02.11.07)	–			0.603	0.444
Experimental group Female calves/heifers, kg	252	334	373	581	851
Daily weight gain, kg (02.09. – 25.11, 84 days)	1.440			–	–
Daily weight gain, kg (02.11. – 25.11, 23 days)	1.696			–	–
Daily weight gain, kg (25.11.05 – 01.10.06 and 01.10.06 – 02.11.07)	–			0.630	0.740

Female calves of the control group in the autumn period of 84 days in 2005 provided a daily weight gain of 0.845 kg, whereas the experimental group provided 1.440 kg or more than 70%. The weaning period is very important and at least one month after weaning a decrease of growth rate is possible. During 23 days after weaning the calves of the experimental group had a 1.696 kg daily weight gain, whereas the control group calves had a 1.217 kg daily weight gain. Weight gain in the experimental group was by 39% higher than that of the control group.

The mentioned tendency was expressed within all the subsequent period until the end of the trial period in November 2007 when the average live weight of the heifers in the control group was 631 kg, whereas from the experimental group 851 kg – by 220 kg or 35% heavier in the experimental group. Although it is not possible to support these indices by statistical analysis, the tendency of a favourable effect of the premix PROTRACE G on the performance of calves and heifers is very notable.

Essentially different was the process of calving between the trial groups (Table 2). As to each of the trial groups 12 cows were assigned by calving data it was numerically enough for statistical analysis.

Table 2

Average indices of calving rate between trial groups in the spring 2006

Groups	Average calf live weight at birth	Calving rate in hours and minutes		
		Calving	Placenta expulsion	Calf starts sucking
Experimental group cows with basal diet plus premix PROTRACE G	45. 6	30 min[a]	31 min[a]	57 min[a]
Control group, basal diet	44.9	2 h 21min[b]	2 h 09min[b]	1 h 32min[b]
+ longer time period in Control group	–	+ 1 h 51 min	+ 1 h 38 min	+ 35 min

a, b – significantly different (p < 0.05)

It is important to mention that cows from the experimental group after calving were undisturbed and peaceful and subsequent postpartum reproduction activities were expressed – heat determination and insemination. Cows from the control group after calving looked exhausted, aggressive, and nervous, the udders seemed not to be full, postpartum reproduction activities were less expressed.

The potential significant role of minerals in herd fertility is indisputable. The minerals that affect reproduction in cattle are generally found within the trace element group, although deficiencies of calcium and phosphorus can also affect fertility (Butler, 2000).

It is extremely necessary to feed a balanced level of organic selenium to activate the expulsion of the placenta. The positive effect of selenium involves the release of the prostaglandins. Prostaglandins may induce the release of the placenta by stimulating the production of the enzyme collagenase. The organic selenium can activate the enzyme collagenase to help break down the collagen, which is the material that cements the cell of the uterus and the placenta together. Reproductive problems are frequently reported in association with trace mineral deficiency, particularly copper and manganese. All these elements were in adequate level in the experimental group diet.

Table 3

Live weight changes in female calves and heifers born in spring of 2006 during the period of 01.06.06 – 01.11.07

Groups	Weighing dates					
	at birth	01.06.06	01.10.06	04.01.07	02.06.07	01.11.07
Control group Female-calves/heifers, kg	43	120[a]	254[a]	278[a]	378[a]	517[a]
Experimental group Female-calves/heifers, kg	44	158[b]	303[b]	373[b]	518[b]	702[b]

a, - b significantly different (p < 0.05)

From the calves born in the spring of 2006 it was possible to group 6 female calves in the control group and 5 in the experimental group. It provided an opportunity to apply statistical analysis to the weighing data. Within the period from 01.06.06 to the end of the trial on 01.11.07, live weight of the calves and heifers of the experimental group was significantly higher than that of the control group (Table 3). The same tendency, which was found with female calves and heifers born in the spring of 2005 (Table 1), was observed.

Table 4

Average indices of calving rate between trial groups in the spring of 2007

Groups	Average calf live weight at birth	Calving rate in hours and minutes		
		Calving	Placenta expulsion	Calf starts sucking
Experimental group cows with basal diet plus premix PROTRACE G	45.0	20 min[a]	28 min[a]	51 min[a]
Control group, basal diet	44.9	2 h 22min[b]	1 h 30min[b]	1 h 29min[b]
+ longer time period in Control group	–	+ 1 h 02 min	+ 1 h 02 min	+ 38 min

a, - b significantly different (p < 0.05)

According to Close (1998), iron linked to amino acid increased the transfer of Fe across the placenta and into the embryos. Thus, when organic Fe was provided in the gestation diet, significant quantities crossed the placenta and were incorporated into the foetus. This resulted in significantly more vital newborns with a very high suckling stimulus. This indicates that more iron crossed the placenta and transferred into foetuses, which then had higher blood haemoglobin and immunoglobulin levels at birth. This higher immune status and viability resulted in stronger calves consuming more milk and hence displaying a better performance.

The calving process in the spring of 2007 was similar to the one during the spring of 2006 (Table 4).

Data from table 4 confirm the same findings during the calving process as the data of the spring of 2006 (Table 2). The calving process for cows of the experimental group was very short and after calving the cows were undisturbed and peaceful. Cows from the control group after calving looked exhausted, aggressive and nervous.

Conclusions

1. Premix PROTRACE G added to the diet of the experimental group cows substantially improved the calving process – in experimental group the calving was easy and rapid (20 – 30 min versus 2 h 22 min), placenta expulsion was quick (28 – 31 min versus 1 h 30 min), and the calves started suckling the cows sooner (51 – 57 min versus 1 h 29 min) in comparison to the same processes in the control group.

2. Newborn calves from the experimental group were more vital with very high suckling stimulus. It reflects on the further performance – during all the trial period the live weight growth was significantly higher. The live weight of heifer in experimental group at the end of experiment was 702 kg versus 517 kg in comparison to control group.

3. The performance indices of all the mentioned cows and calves in the experimental group were certainly better and higher than those in the control group.

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GRAIN CHEMICAL COMPOSITION OF SPRING BARLEY GENOTYPES

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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.

Key words: 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.

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)

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}.

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 130C° 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 Discussions

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.

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

Constituent	Mean value	Standard deviation	min value	max value	Coefficient of variation, %
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 $p < 0.05$*

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, 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.

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

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 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.

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BAKING QUALITY AND PROTEIN COMPOSITION OF EMMER WHEAT LANDRACES

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Abstract

Emmer wheat, *Triticum dicoccum* SCHRANK (SCHUEBL), is an old species of cereal which has been traditionally grown in aride areas. The renewed interest in this variety has its origin in favourable quality parametres of emmer wheat grain and a beneficial effect on human organism. This article deals with a study of quality parametres and storage protein composition of 6 varieties of emmer wheat (which have been chosen from the collection of gene bank at the Research institute of Crop Production in Prague-Ruzyně and in České Budějovice). High crude protein content in grain was proved during the trials. Nevertheless, such a characteristic is not suitable for the classical bakery processing (production of leavened products). The analysed genotypes contain more than 10% of high molecular weight glutenins (HMW glutenins), approximately 70% of low molecular weight glutenins + gliadins (LMW glutenins + gliadins), and almost 20% of residual albumins and globulins. Thanks to high share of albumins and globulins, emmer wheat grain is very valuable raw material for the production of healthy diet. The level of stability of storage proteins composition destine the suitability of emmer wheat for organic and low input farming in Less Favoured Areas.

Key words: emmer wheat, quality, storage protein composition.

Introduction

Emmer wheat (*Triticum dicoccum* SCHRANK (SCHUEBL), tetraploid species 2n=28, AABB genom), which is divided into 99 botanic varieties (Michalová *et al*., 2002), belongs to glumeous varieties of wheat that have a long tradition of growing and use as human diet (Marconi and Cubadda, 2005). Considering increasing requirements for richness, diversity and good-quality of foodstuff products, the interest in this species of wheat has been still increasing (Hammer and Perinno, 1995; Olsen, 1998; Nielsen and Mortensen, 1998). Such a renewed interest in emmer wheat varieties has its origin in countries with well-developed intensive agriculture. On the other hand, the surface of areas of emmer wheat has been decreasing in countries with less developped farming sector (Marconi and Cubadda, 2005).

Wheat storage (gluten) proteins create up to 80% from a total amount of wheat grain (Shewry *et al*., 2000). Technologically, glutenins and gliadins are the most important wheat storage proteins. Their proportion and amount in wheat grain is variable and changes with the total protein content, growing conditions, genetic disposition of variety, and process of grain maturing (Branlard *et al*., 2000; Shewry *et al*., 2000). The gluten quality for the specific final utilization is determined especially by the optimal storage proteins combination. Each of them affects rheology in a unique way dough viscosity and tensibility are affected by gliadins, elasticity – by glutenins (Bushuk and Bekes, 2002).

Gliadins create heterogeneous mixture of onechain polypeptides; they are proteins with the lowest nutritional value in the way of amino-acid composition. Glutenins are divided into two groups: the HMW and LMW (High and Low Molecular Weight) (Thompson *et al*., 1994; Shewry *et al*., 2000). Most studies of bread-making wheat focus on HMW glutenins, performing as key factors in the bread-making process, and they are easily identifiable by the electrophoresis (Krejčířová *et al*., 2007). Albumins and globulins are usually ranged to the so-called protoplasmatic proteins. As to the amino-acid composition, these proteins have the highest nutritional quality. Generally, albumins and globulins are not considered as proteins critical for the flour quality, even though a small significance was noticed (Schofield and Booth, 1983). According

to some autors, they decrease the quality of gluten (Paine *et al*., 1987; Bushuk, 1989).

Several authors state the favourable quality indicators for the human diet. They mention the high crude protein content in the first place; nevertheless, it is not suitable for the bakery processing. The literature may contain the results of the quality analysis contrary to each other. Therefore, this study is focused on the quality parametres of the varieties of emmer wheat which are part of the collection of the gene bank at Research institute in Prague-Ruzyně (RI). The second part evaluates protein composition and determines the nutrition value of emmer wheat grain.

Materials and methods

On the basis of the previous screening, 6 genotypes of emmer (Table 1), 4 landraces (Kundan, Jara, Praga, Rosamova česká přesívka), and 2 modern (M6 - Vanek, M10 – SW Kadrij) controlling cultivars of bread wheat were choosen. In the experimental year 2007, small plot trials with two replications were performed in two locations (Research institute in Prague-Ruzyně = RI, and University of South Bohemia in České Budějovice = USB). 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}; and Ca 4360 mg.kg^{-1}. USB – 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}; and Ca - 1557 mg.kg^{-1}. The climatic and soil conditions were favorable for emmer growing et both locations. The experiments were carried out in low input growing system (practically not certificied organic farming system), without mineral fertilizers and pesticides at both locations. For seeding we used trial seed machine and for harvesting the Wintersteiger machine. The trials were weeded after tillering.

The quality analyse were carried out in the laboratories of the Czech Agricultural University in Prague. The following methods were used to carry out the laboratory analysis: crude protein content - (Kjeldahl - ICC No. 105); wet gluten content and gluten index ČSN ISO 5531, Glutomatic 2200, Zeleny sedimentation – value - ICC No. 116/1, enzyme (α-amylase) activity – Falling number ICC No. 107; and starch content (according Ewers, ČSN ISO 56 0512-16, Polamat A).

For the classification of wheat grain storage protein composition, the polyacrylamide gel electrophoresis in sodium dodecyl sulphate (SDS-PAGE) was used, according to the method of Wrigley (1992). Percentage of individual protein subunits HMW, LMW glutenins a gliadins, and residual albumins and globulins was calculated on the basis of denzitometric evaluation of electreograms using the Bio 1D software from Vilber-Lourmat firm.

Table 1

List of varieties

Code of variety	ECN[1]	BCHAR[2]	Name	SP[3]	*Triticum dicoccum* (SCHRANK) SCHUEBL:
D1	01C0200117	412064	Horny Tisovnik	CZ	var. *rufum* SCHUEBL
D2	01C0200947	412048	Ruzyne	-	var. *rufum* SCHUEBL
D3	01C0201262	412051	Tapioszele 1	-	var. *serbicum* A. SCHULZ
D4	01C0201282	412017	Tapioszele 2	-	var. *rufum* SCHUEBL.
D7	01C0203989	412013	Kahler Emmer	D	var. *dicoccum*
D10	01C0204501	412013	No. 8909	-	var. *dicoccum*
Note: [1] ECN = identificator ; [2] BCHAR = taxonomical code ; [3] SP = origin					

Results and discussion

The obtained results document crude protein content, wet gluten content, gluten index, sedimentation value, starch content, starch content and grain storage proteins composition of emmer landraces in comparison with landraces and modern cultivars of bread wheat.

Evaluated varieties provide higher crude protein content than controlling ones. At location RI is difference 3.5% and CB 2.6% on behalf emmer (Table 2). The higher protein content provide D4 (Tapioszele 2) – 20.1%. According to standartd ČSN 46 1100-2 is possible to include all emmer varieties in quality group elite. Coeficient of variation (CV) is 8.9% (RI) and 12.4% (USB). The higher protein content of emmer with comparison of soft wheat grown in the same conditions acknowledges e.g. (Marconi *et al*., 2005; Michalová *et al*., 2002).

At the location RI emmer provide the higher wet gluten content than controlling varieties about 9%, at USB was the same. CV attained 20%, relativelly stable at both location. Crude protein content, quality and content of gluten provide negative relation. Varieties with high gluten content but its low quality aren´t usefull for making proofing dought from backery point of view (Zimolka *et al*., 2006).

Gluten index have possitive corelation with quality of gluten. High value of gluten index showed strong gluten which is very difficult working. Low value is characterised by weak gluten which isn´t suitable for backery processing. In case of RI location provide 30 (CV 85.1%) at CB it is 36 (CV 37.9) (Table 2). This trait is very unstable. Gluten index provide double value in case of controlling varieties. Gluten of emmer is weak and isn´t good for backery processing.

Sedimentation value determine viscosoelastic character of gluten albumines and theire quality which provide fermentative processes in dought (proofing) for. With crude protein content and bread volume corelate in positivelly way. The value are low at both locations. Varieties aren´t able to surmount value (ČSN 46 1100-2) as minimum for submission into quality category B (bread). Controlling varieties provide high value (RI – 63 ml, USB – 54 ml) (Table 3). According to (Stehno, 2001) are sedimentation value at half with comparison of modern varieties.

Table 2

Quality parametres I

Variety	Crude protein content (%)			Wet gluten content (%)			Gluten index		
	location		mean	location		mean	location		mean
	RI	CB		RI	CB		RI	CB	
D1	18.0	15.6	16.8	44.5	30.0	37.3	4	43	24
D2	20.4	18.6	19.5	55.8	42.9	49.4	51	43	47
D3	15.9	14.4	15.2	34.9	33.0	34.0	5	15	10
D4	20.2	20.0	20.1	53.4	45.2	49.3	11	17	14
D7	19.6	19.2	19.4	40.2	49.7	45.0	55	24	40
D10	19.0	18.3	18.7	57.2	44.5	50.9	53	43	48
mean	**18.9**	**17.7**	**-**	**47.7**	**40.9**	**-**	**30**	**36**	**-**
SD	**1.7**	**2.2**	-	9.2	7.7	-	25.5	13.7	-
CV	**8.9**	**12.4**	**-**	**19.2**	**18.8**	**-**	**85.1**	**37.9**	**-**
M6	1.8	14.8	15.3	38.2	41.1	39.7	83	90	87
M10	15.0	15.3	15.2	39.2	41.8	40.5	79	55	67

Starch content is the same in case of all varieties and is very fixed. The lower starch content provide varieties D2 (Ruzyně) a D4 (Tapioszele2) at both location. The higher content provide variety D3 (Tapioszele 1) (65.9% RI and 64.8% CB) at both locations. (Galterio *et al*., 1994) features the lower value of starch content (52.7-56.8%).

Falling number detect damage of storage matter of grain wheat endosperm by hydrolytic enzymes, which are syntetised in consequence of start germination before harvest in grain. For insertion into quality group elita is minimum value 240 s according to ČSN 46 1100-2. This value didn´t get only one variety D3 (Tapioszele 1) at RI location

(Table 3). At the same location is higher level of CV 20%. This fact could be explained by later harvest some of varieties (came after rainy time), it is conformed by (Zimolka *et al*., 2006). This author note that falling number is very sensitive to rainy time during harvest. At CB location there was harvested in time and varieties provide the high value with low variability.

Table 3

Quality parametres II

Variety	Zeleny test (ml)			Starch content (%)			Falling number (s)		
	location		mean	location		mean	location		mean
	RI	CB		RI	CB		RI	CB	
D1	10	15	13	62.7	64.6	63.7	399	380	390
D2	12	17	15	59.1	61.8	60.5	367	369	368
D3	12	14	13	65.9	64.8	65.4	221	387	304
D4	14	17	16	58.6	60.3	59.5	363	352	358
D7	10	16	13	60.5	61.4	61.0	426	359	393
D10	14	15	15	60.4	62.4	61.4	355	403	379
mean	**12**	**16**	**-**	**61.2**	**62.6**	**-**	**355**	**375**	**-**
SD	1.8	1.2	-	2.7	1.8	-	70.9	18.8	-
CV	**14.9**	**7.6**	**-**	**4.4**	**2.9**	**-**	**20.0**	**5.0**	-
M6	59	50	55	62.7	61.7	62.2	339	269	304
M10	66	57	62	62.7	60.4	61.6	329	289	309
mean	**63**	**54**	**-**	**62.7**	**61.1**	**-**	**334**	**279**	**-**

In accordance with the results stated in Table 4, storage proteins composition of emmer wheat does not differ too much from storage proteins composition of bread wheat in low input farming system. Therefore, the statement of Marconi and Cubadda (2005) may not be confirmed. They state that emmer wheat grain is not so toxic for people suffering from digestive allergies as bread wheat grain (because of storage proteins composition). On the other hand, a comparison of the proportion of valuable albumine and globuline fractions could be very interesting aspect. The fractions of emmer wheat genotypes, grown on more fertile station (RI), achieve lower level (16.9%) than the fractions of bread wheat ones (17.5%). The proportion of these fractions in emmer wheat grain is higher (17.2%) in case of less fertile station (USB).

When comparing the stability of storage proteins composition from the point of view of the coefficient variability, we may generalize the results of the studies for the analysed groups of the varieties. HMW glutenins are the most fluctuating group CV = 7.3 – 36.2, the percentage of LMW albumins and glubulins is more stable feature CV = 0.2 – 4.6. The percentage of HMW glutenins is very versatile factor in case of emmer wheat and bread wheat too; it is supposed to be influenced by land and climatic conditions of the station (Krejčířová *et al*., 2006, 2007). The diversity of albumins and glubulins in emmer wheat genotypes is also very interesting characteristics CV = 15.6% - RI and 21% - USB; the proportion of these two types of elements is fixed in bread wheat genotypes CV = 3.1% - RI and 2.8% - USB.

Table 4

Storage proteins composition

Genotype	Parametre	Location					
		RI			USB		
		HMW[1]	LMW[2]	A+G[3]	HMW[1]	LMW[2]	A+G[3]
Emmer	**Mean (%)**	**10.2**	**72.9**	**16.9**	**13.6**	**69.2**	**17.2**
	SD	2.2	1.5	2.6	2.0	2.6	3.6
	CV (%)	**21.5**	**2.0**	**15.6**	**14.5**	**3.7**	**21.0**
Bread wheat	Mean (%)	**9.6**	**72.4**	**18.0**	**14.3**	**70.6**	**15.1**
(landraces)	SD	3.45	3.3	1.3	1.0	1.4	1.6
	CV (%)	**36.2**	**4.6**	**7.0**	**7.3**	**2.0**	**10.3**

Genotype	Parametre	Location					
		RI			USB		
		HMW[1]	LMW[2]	A+G[3]	HMW[1]	LMW[2]	A+G[3]
Bread wheat (modern varieties)	Mean (%)	**10.1**	**72.5**	**17.5**	**11.6**	**71.6**	**16.8**
	SD	1.4	0.9	0.5	0.6	0.2	0.5
	CV(%)	**14**	**1.2**	**3.1**	**18.4**	**0.2**	**2.8**
Notes: [1]HMW glutenins; [2]LMW glutenins + gliadins; [3]albumins + globulins							

According to Table 5, the effect of the species (emmer wheat, bread wheat) on the composition of storage proteins has not been confirmed by statistics. On the contrary, the effect of the station (intensity of the farming) has been registered in both cases (HMW glutenins and LMW glutenins and gliadins). Krejčířová *et al*. (2006, 2007) confirms these statements in her paper works; she points out the fact that the availability of nitrogen during the growing season is a limiting factor of the dislocation of the assimilated nutrients into each protein fraction. The proportion of albumins and globulins was not influenced by the station.

Table 5

ANOVA, values of the test criterion *F* for storage proteins composition

Factor	Quality parameter		
	HMW glutenins	LMW glutenins + gliadins	Albumins + globulins
Genotype	0.16^{n}	0.60^{n}	0.10^{n}
Location	15.80^{*}	9.85^{*}	0.82^{n}
Notes: *statistically significant α = 0.01; n – statistically insignificant			

Conclusions

High proportion of crude protein in grain was affirmed by the quality analysis (in several cases, it exceeded 20% in small-parcel trials). Its quality (from the point of view of its use in bakery sector) seems to be quite problematic factor. It proves negative values of gluten index and Zeleny test. In case of emmer wheat, it is better not to use it in the bakery sector, but in the other sectors and branches. Bread made of emmer wheat is flat but it has perfect sensoric qualities and features.

Emmer wheat, grown in low-input farming system, does contain similar storage proteins to bread wheat; the fact that emmer wheat grain is suitable for people suffering from celicalia cannot be approved. The evaluated genotypes contain more than 10% of HMW glutenins, about 70 % of LMW glutenins and gliadins and almost 20% of albumins and globulins in grain. The high percentage of the last group mentioned above causes the valuability of emmer wheat as a raw material for the production of healthy diet. The stability of storage proteins composition predestines the suitability of emmer wheat for organic and low-input farming systems in Less Favoured Areas. Emmer is not able to compete with modern varieties from the point of view of the level of yield, nevertheless it provides very good-quality grains.

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INVESTIGATION OF POLYPLOIDY IN THE BREEDING OF LILIES (*LILIUM SPP.*)

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Abstract

Some of best varieties of plants, especially ornamentals and fruits, were polyploid. Polyploids have larger flowers and stems than diploids. In the production of polyploid forms, different types of crosses were made. In present study a cross of diploid (2n = 2x = 24) and tetraploid (4n = 4x = 48) varieties resulted in the production of highly viable seeds 89.3% on average, but a cross of tetraploids and diploids – of 39.5% on average, with fluctuating results between cross combinations. Treating seeds and bulb scales with colchicine solutions can change chromosome number of 9 varieties. These results demonstrated that optimal concentration of colchicine was 1 g kg^{-1} for chromosome doubling of seeds. A high concentration (2 g kg^{-1}) showed phytotoxicity that is detrimental for plant regeneration. The scales of bulbs treated with 1 g kg^{-1} colchicine have resulted in the production of lily polyploid forms. The polyploid plants regenerated after pre-treatment by colchicine may be selected in early stage by phenotype of young bulblets. Broad, fleshy bulb scales setting right angle to growth axis were characteristic for regenerated tetraploids. The produced polyploid plants, in comparison with diploids, had a larger diameter of the flower (+2 up to 2.5 cm), more extended plant height (+10 up to 20 cm), increased flower count (+2) and was coming into bloom 4-10 days later than diploids of the same variety.

Key words: Breeding, chromosome doubling, colchicine

Introduction

The genus *Lilium* spp. includes about 100 species distributed throughout the cold and temperate parts of the Northern Hemisphere (McRae, 1998). The wild species are divided in seven different sections (Comber, 1949). Among them, three sections are the most commonly used for breeding cultivars, e.g. Asiatic hybrids of the *Sinomartagon* section (Okazaki and Hane, 2005), Trumpet hybrids and Easter lily (*L. longiflorum* Thunb.) of the *Leucolirion* section and Oriental hybrids of the *Archelirion* section (Van Tuyl et.al., 1990). The species and cultivars are mainly diploid (2n = 2x = 24) but polyploid forms exist including triploids and tetraploids, which are either induced for breeding purposes or spontaneously found during interspecific breeding programs. Therefore, cultivars include both diploids as well as polyploids of which the latter became more important in recent years.

Polyploidization plays an important role in the interspecific breeding of lilies. Among ornamental plants, a large number of polyploidy cultivars have been developed because they display horticultural desirable characteristics such as extension of flowering longevity, deep flower colour, and larger flowers (Okazaki and Hane, 2005). In the Easter lily successful induction of polyploids by colchicine was reported (Emsweller, 1949; Emsweller, 1988). Polyploid lilies have thicker leaves, stronger stems (especially important for forcing under low light conditions during winter period) and in interspecific hybridization the restoration of F1-sterility at the tetraploid level (Van Holsteijn, 1994; Van Tuyl et.al., 1990).

Polyploidization is useful for improving genetic constitution and broadening genetic variation and commercial tetraploid Asiatic hybrid lilies recently have been distributed to markets (McRae, 1987). Production of polyploid plants is one of the current issues in lily breeding (Van Tuyl et.al., 1990).

Polyploids are obtained through artificial chromosome doubling by treatment of vegetative tissue with spindle inhibitors such as colchicine (Blakeslee and Avery, 1937; Emsweller, 1988). Colchicine has been used for doubling the number of chromosomes of many crop plants over a period of more than 50 years. Colchicine is a natural

alkaloid with an antimitotic activity, obtained from the plant *Colchicum autumnale* L. (Emsweller, 1988). To be effective colchicine must be present in the cell when the chromosomes divide. Colchicine is very harmful to humans and in some cases shows undesirable mutagenetic activity on plants (Van Tuyl et al., 1990).

The objective of this study was to determine which crossing of different ploidity of lilies have highest viability of seeds and what concentration of colchicine is more effective for producing polyploid forms.

Materials and Methods

The pollination of various ploidity crosses of Asiatic hybrids were made in 2002 at the experimental place in the Riga region, Saulkrasti in the greenhouse. Greenhouse temperatures varied from 15-18 °C at night to 25-28 °C during the day. Obtained seeds were germinated in the Petri dishes in the sterile sand at 20 °C for 15 days. The seed germination was determined in percentage (Kalnina and Serzane, 1959).

Colchicine treatment was carried out in 2004 year in the Department of Horticulture of the Latvia University of Agriculture. The polyploid forms were produced utilizing the seeds and bulb scales of diploid lilies (2n = 2x = 24). The seed material obtained from crossings of different lily groups are: Asiatic hybrids ('My Joann' x 'New Age'), Oriental hybrids ('Liesma' x 'Casa Blanca'), Trumpet hybrids (*L. regale* Wils. x 'Zemgale') and *L. monadelphum* Bieb. from the section *Liriotypus*. The seeds were soaked in water at 20 °C for 4 days. In a control variant, untreated seed material was put in Petri dishes on filter paper and kept in the refrigerator at 5 °C for 4 weeks. Cool-treated seeds were soaked in 1 g kg^{-1} and 2 g kg^{-1} colchicine solution at 26 °C for 10 hours and then washed three times with distilled water. Both the treated and the untreated seeds were planted in boxes in a mixture of peat and washed river sand at the ratio 5:1. Until bulblets had developed, the seeds were kept at 20 – 25 °C. The chemicals colchicine has been used in chromosome doubling. Bulb scales were treated with 0.1, 0.5 and 1 g kg^{-1} colchicine solution.

For chromosome number determination, the bulbs were kept in washed river sand medium at 25 °C for 3 weeks – until clean, white root tips had developed. Prior to chromosome counting, these bulbs were kept for 24 hours at 4 °C. After this treatment, undamaged healthy root tips were cut off – about 5 to 7 mm long, and washed under running water. Because the process of cell division can be stopped by colchicine before chromosomes multiply, all dividing cells are allowed to proceed up to this stage. The cut root tips were put into 50 ml beakers filled with 0.7 g kg^{-1} colchicine solution and kept for 2 h; then washed three times in running water and transferred to a modified Clarke's Fluid (750 g kg^{-1} ethyl alcohol, 250 g kg^{-1} ethanol glacial acetic acid) for 30 min at 20 °C. The acetic acid effect was neutralized by keeping the tips of the rootlets for 45 minutes in distilled water and 24 hours in 700 g kg^{-1} ethyl alcohol. For chromosome counting, the root tips were left for 48 hours in colouring solution of 5 g kg^{-1} carmine in 450 g kg^{-1} propionic acid. The root tips were cut to about 1-2 mm and, in a drop of stain, mashed with a steel needle. The preparation was then covered. Under microscope, the chromosomes were counted and cells of five rootlets inspected for each genotype. Selection of polyploid plants was done visually, by measuring the size of plant height and the size of the flowers and by counting the chromosomes in root tips.

Data were analyzed using ANOVA and Microsoft Excel 97.

Results and Discussion

The meiotic polyploidization, in contrast to the mitotic, produces polyploids through the fusion of two gametes (pollen or egg cells), one or both was having the double number of chromosomes. Meiotic polyploidization has a great potential and it is a natural method to obtain polyploids (Van Tuyl et al., 1990). In the production of lily polyploid forms, crosses of diverse ploidity resulted in the production total of 3082 seeds 1037 of which were viable (Table 1).

Table 1

The germination of seeds of various ploidity crosses of Asiatic hybrids

Cross	Number of obtained seeds	Number of viable seeds	Germination of seeds, %
Diploid x tetraploid			
'Baltais Lācis' x 'LA Tetra'	27	24	88.9
'Mona' x 'Avignon'	109	95	87.2
'Venta' x 'Gran Paradiso'	129	123	95.4
'New Age' x 'Jumprava'	27	20	74.1
'Baltais Lācis' x 'Avignon'	125	115	92.0
'New Age' x 'Skrīveri'	95	80	84.2
Total:	**512**	**457**	**Average 89.3**
Tetraploid x diploid			
'Apricot Supreme' x 'My Joann'	178	63	35.4
'Aristo' x 'Honey Pink'	119	55	46.2
'Gran Paradiso' x 'Ča-Ča-Ča'	127	71	55.9
'Gran Paradiso' x 'Nakts Tango'	104	22	21.2
'Jumprava' x 'Venta'	98	29	29.6
'Jumprava' x 'New Age'	76	37	48.7
Total:	**702**	**277**	**Average 39.5**
Tetraploid x tetraploid			
'Apricot Supreme' x 'Jumprava'	198	20	10.1
'Avignon' x 'Jumprava'	126	13	10.3
'Gran Paradiso' x 'Apricot Supreme'	138	76	55.1
'Jumprava' x 'Apricot Supreme'	146	68	46.6
'Jumprava' x 'Gran Paradiso'	189	47	24.9
'Jumprava' x 'LA Tetra'	97	10	10.3
Total:	**894**	**234**	**Average 26.2**
Triploid x tetraploid			
'Saule' x 'Jumprava'	187	12	6.3
'Saule' x 'Gran Paradiso'	112	13	11.6
'Saule' x 'Chanson'	159	10	6.3
'Compass' x 'Gran Paradiso'	164	14	8.5
'Compass' x 'Aristo'	161	9	5.6
'Alkestios' x 'Avignon'	191	11	5.7
Total:	**974**	**69**	**Average 7.1**
Whole:	**3082**	**1037**	

A cross of diploid (2n = 2x = 24) and tetraploid (4n = 4x = 48) varieties resulted in the production of highly viable seeds, 89.3% on average. A cross of tetraploid and diploid varieties resulted in the production of viable seeds, 39.5% on average with fluctuating results between combinations. Higher seed viability (48.7 - 55.9%) was obtained in cross combinations by using high in pollen viability male parents: 'Ča-Ča-Ča' (82.9%), 'My Joann' (76.3%), 'New Age' (70.2%). Because of its low pollen viability (14.8%), if 'Nakts Tango' was used as a male parent, the seed viability was proportionally lower. Reciprocal crossing of tetraploid varieties resulted in the production of moderately viable seed - 26.2%. 'Apricot Supreme' used as male parent contributed to the count of more viable seeds (46.6 - 55.1%). Non-significant amount of viable seeds (10.3%) was obtained in cross combinations with 'Jumprava' and 'LA Tetra' used as male parents. A cross combination of triploid (3n = 3x = 36) and tetraploid cultivars produced low viability seeds (7.1% on average).

Polyploids were obtained by colchicine

treatment of mitotic cells (mitotic polyploidization). Chromosome count of the varieties can be changed when treating seeds, bulb scales or bulblets with colchicine solutions. Selections of polyploid plants in biennial seedlings were made according to their morphological traits, and the degree of ploidity was being determined cytologically. The reasons for using polyploidy in lily breeding are the larger flowers and the stronger stems of polyploidy plants (Van Tuyl et al., 1990). As pointed out by Emsweller (1988) polyploids usually bloom later and thus extend the flowering season. In our study the produced polyploid plants, in comparison with diploids, had a larger diameter of the flower (+2 up to 2.5 cm), more extended plant height (+10 up to 20 cm), increased flower count (+2) and was coming into bloom 4-10 days later than diploids of the same variety.

When compared to diploids, roots of polyploids were shorter, rather stout, stumpy, smaller in numbers, and bulb scales were wider, more swollen with the outer scales curved in a 90 degree angle.

A total of 534 seeds produced in crosses with cultivars of Asiatic, Oriental and Trumpet hybrid lilies as well as seeds of the species *L. monadelphum* were treated with colchicine solution (Table 2).

Table 2

Influence of colchicine solution to production of polyploids by treated lily seeds

Group of crosses	Concentration of colchicine solution, g kg^{-1}	Number of treated seeds and obtained bublets				
		Treated seeds	int.al.			
			diploids	%	polyploids	%
Asiatic hybrids	1	67	62	92.5	5	7.5
'My Joann' x 'New Age'	2	63	13	20.6	1	1.6
Oriental hybrids	1	37	10	20.0	2	5.4
'Liesma' x 'Casa Blanca'	2	40	0	0	0	0
Trumpet hybrids	1	78	54	69.2	3	3.8
L. regale x 'Zemgale'	2	64	0	0	0	0
Liriotypus	1	98	77	78.6	2	2.0
L. monadelphum	2	87	0	0	0	0
	Total:	**534**	**216**	**40.5**	**13**	**2.4**

To determine the most effective treatment, plants should be exposed to several concentrations. Treatment of 280 seeds with 1 g kg-1 colchicine solution resulted in the production of 215 (81.7%) plants among which there were 12 polyploid plants. Germination of seeds treated with 1 g kg^{-1} colchicine solution was similar to that of untreated seeds.

Treatment of 254 seeds with 2 g kg^{-1} colchicine solution resulted in the production of 14 (15.5%) plants among, which there was one polyploid plant. All these plants were the result of a cross combination of the Asiatic hybrid lilies 'My Joann' x 'New Age'. The concentration of this solution was toxic to seeds. Before the seedlings developed, part of the seeds perished, or the cotyledon of the seedlings failed to develop properly and the primary rootlet and seedlings perished. The concentration of colchicine solution and timing of seed exposure to treatment should be adjusted according to each classification group.

The bulb scales were treated with 0.1, 0.5 and 1 g kg^{-1} colchicine solutions. The treatment with 0.1 g kg^{-1} colchicine solution resulted in the production of 1.1 bulblets per scale on average (min - 0.1; max - 2.8) (Fig 1).

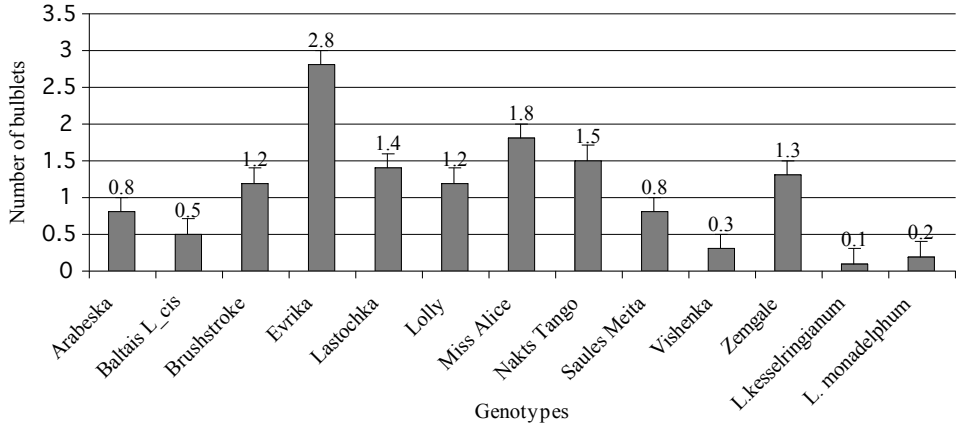

Figure 1. The results of the production of bulblets by treated bulb scales with 0.1 g kg^{-1} colchicine.

The treatment with 0.5 g kg^{-1} colchicine solution resulted in 0.97 bulblet on average (min - 0.1; max - 1.9) (Fig 2).

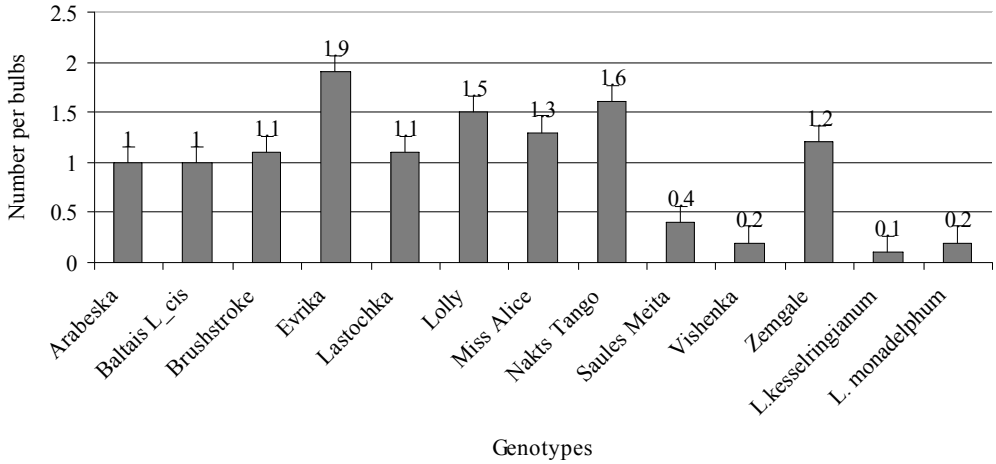

Figure 2. The results of the production of bulblets by treated bulb scales with 0.5 g kg^{-1} colchicine.

Bulb scales treated with 1 g kg^{-1} colchicine solution produced 0.2 bulblets per scale on average (Fig 3). This concentration turned out to be toxic. The use of this concentration resulted in the production of 10 polyploid plants. The results by Emsweller (1988) obtained from treatments of lily bulb scales with concentration of 1 g kg^{-1} were optimum in comparison with concentrations of 0.2 and 1.6 g kg^{-1}.

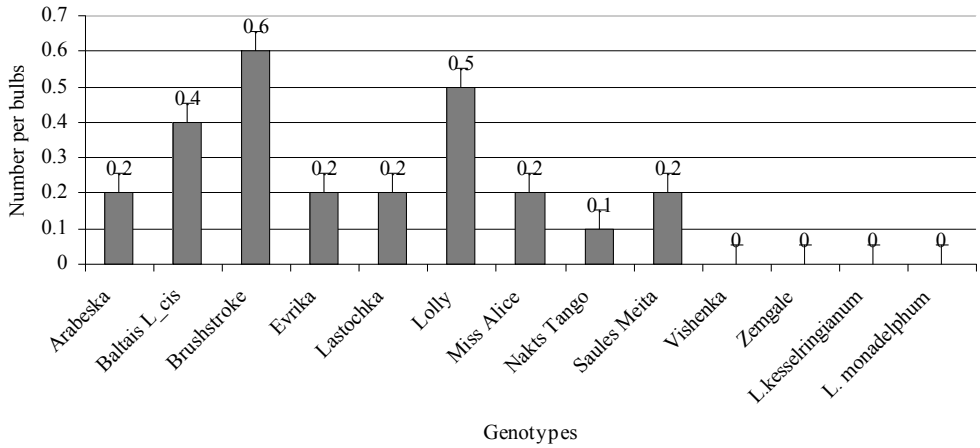

Figure 3. The results of the production of bulblets by treated bulb scales with 1 g kg-1 colchicine.

The cultivars that excelled with a greater amount of min and max bulblets were: 'Evrika' (1.9 and 2.8), 'Miss Alice' (1.3 and 1.8), 'Nakts Tango' (1.5 and 1.6), 'Lolly' (1.2 and 1.5). On average, less than one bulblet was obtained with 'Višenka' (0.2 and 0.3) and 'Saules Meita' (0.4 and 0.8). The species *L. monadelphum* produced 0.2 and 0.2 bulblets on average, and *L. kesselringianum* P. Miscz. - 0.1 and 0.1 bulblets on average. These results may be traced to the sensitivity of the species to concentrations of colchicine solution. Polyploid plants were not produced.

Conclusions

1. The viability of hybrid seeds is dependent on the level of ploidity of initial material. High viability (89% on average) of hybrid seeds has been obtained in a cross between a diploid and a tetraploid, and 39% on average in case of reciprocal crossing. Comparatively low seed viability has been recorded in hybrids between tetraploid form (26%) and between triploid and tetraploid form (7%) of crosses.
2. In the production of polyploid forms, 1 g kg^{-1} colchicine solution is considered optimal in the treatment of seeds; 2 g kg^{-1} colchicine solution proved to be toxic to seeds.
3. The concentration of colchicine solution and exposure time must be adjusted experimentally by taking into consideration individual lily groups. The scales of bulbs treated with 1 g kg^{-1} colchicine have successfully produced polyploid forms.

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