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EVALUATION THE BAKING VALUE OF PASSAGE FLOURS

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Abstract
The main direction of using wheat grains is grinding them into low-extraction flours. The flours collected from individual passages differ in terms of chemical composition and physical properties, which in turn differentiates their baking value. The aim of the study was to evaluate the baking value of passage flours obtained from the milling of spring and winter wheat grain. Wheat grain was milled in a 6-pass laboratory mill MLU-202 by Bühler. The baking value of the obtained passage flours was evaluated by an indirect method (protein content, gluten content and quality, falling number, farinograph analysis) and by a direct method (by baking and performing quality evaluation of the obtained bread). The research showed that the efficiency of flours from individual milling passages varied. The passages flours differed significantly in terms of chemical composition and baking value. The highest flour yields were obtained from the first and second grinding stages, while the smallest from the third grinding stage. Ash and total protein content, flour water absorption, and amylolytic enzymes activity increased together with the subsequent milling stage in both reduction-passage and grinding-passage. The gluten content increased with the next reduction stage, while it decreased with the subsequent grinding passage. The bread from the laboratory baking test was diversified in terms of sensory characteristics, loaf volume, and crumb porosity. The best quality bread was obtained from flour from the first two reduction passages. The lowest quality bread was obtained from flour from the final grinding passage.
Key words: wheat, flour from different grinding stages, protein, rheological properties, bread quality.

Introduction

Common wheat (*Triticum aestivum* L.), due to the chemical composition of the grain and its wide use, is the most popular cereal crop in the world. For the 2017/2018 season, the world wheat harvest has been estimated at 757 million tonnes (GUS, 2018). Approximately 60% of the wheat grain harvested each year is processed for consumption, mainly into various types of low-extraction (light) flour. The milling of wheat grain into low-extraction flours is a multi-stage process, as a result of which, the so-called passage flours are obtained, from which the final products – commercial flours are prepared. The baking value of commercial wheat flour, apart from the quality of the milled grain and the applied milling technology, is influenced by the selection of passage flour and its share in the final product. Among the components of wheat flour, the content and quality of protein substances play a particularly important role in shaping its baking value. In wheat grain endosperm, the higher protein concentration is in its external and internal parts, with gradual changes in protein content and no clear dividing zone between the endosperm richer and poorer in this component (Rothkaehl, 2006). The research conducted so far (Delcour *et al*., 1999; Prabhasankar *et al*., 2000; Rani *et al*., 2001; Rothkaehl, 2006; Banu *et al.*, 2010) shows that the flours collected from the individual mill passages differ in terms of protein content, including gluten proteins, as well as in terms of the content of starch, mineral substances, and enzymes. However, there are no reports indicating how differences in the chemical composition of passage flours affect the quality of bread obtained from them, so it was advisable to undertake such studies.

The aim of the study was to evaluate the baking value of passage flours obtained from laboratory milling of spring and winter wheat grains, on the basis of indirect indices and the direct method.

Materials and Methods

Samples of spring and winter wheat grain were used as a test material. Wheat grain was obtained from a field experiment carried out in 2014, in the Experimental Station Osiny, belonging to IUNG-PIB (Institute of Soil Science and Plant Cultivation – State Research Institute) in Puławy, in Poland. In the first stage of the study, a physicochemical evaluation of wheat grain was carried out. The weight of 1000 grains, plumpness, uniformity, glassiness, and hardness were determined using the Brabender farinograph attachment, according to Cacak-Pietrzak & Gondek (2010). Total ash content was determined using AACC Method 08-01.01 (AACC, 2010), while the total protein content was determined by Kjeldahl method in Kjel-Foss Automatic apparatus (N×5.83) according to AACC Method 46-11.02 (AACC, 2010). The grain was milled in a six-passage laboratory mill MLU-202 by Bühler (Cacak-Pietrzak & Gondek, 2010). Before milling, impurities on Brabender granite were removed from the grains and then they were subjected to two-stage moistening – 24 hours before milling to 13.0% moisture content, and 30 minutes before milling to 13.5% moisture content. The weight of the grain sample for milling was 30 kg. After milling, the obtained products, namely, flours from the reduction and grinding stages, as well as reduction and milling bran, were weighed. Next, their efficiency was calculated and the total ash content was determined according to AACC Method 08-01.01 (AACC, 2010).

The baking value of passage flours was evaluated by direct and indirect methods. Total protein content was determined using Kjeldahl method in apparatus Kjel-Foss Automatic (N×5.83) according to AACC Method 46-11.02 (AACC, 2010), gluten content and quality in Glutomatic 2200 apparatus according to Method 38-12.02 (AACC, 2010), while the falling number with Hagberg-Pertenin in apparatus Falling Number 1400 according to AACC Method 56-81.03 (AACC, 2010). A farinograph analysis was also performed using Brabender's farinograph with a 50 g flour mixer according to AACC Method 54-21.02 (AACC, 2010). Dough for baking was prepared using the direct method, from 400 g flour (14.0% moisture content), water in the amount needed to obtain dough of 350 FU consistency, 12 g of baker's yeast, and 6 g of kitchen salt. The dough was kneaded in the Stephan mixer for 2 min at a speed of 1400 revolution min^{-1}. The fermentation time was 90 min; after 60 min of fermentation, the dough was pierced. Next, the dough pieces with a mass of 250 g were weighed, which, after shaping, were placed in moulds and subjected to final fermentation. Baking was carried out in the Sveba Dahlen furnace at 230 °C for 30 min. The evaluation of bread was carried out 24 hours after baking. Bread output, loaf volume, and crumb porosity were determined by the Dallman method (Romankiewicz *et al.*, 2017). Sensory evaluation of bread was carried out by means of scaling, by a 10-person trained team of evaluators. The following were assessed: external appearance of the loaf, properties of the crust and crumbs, as well as taste and smell. Each quality distinction was awarded from 0 to 5 points. All of analysis were done in three replications. The results were developed statistically in the Statgraphics Centurion XVI program. A one-way analysis of variance was carried out, with the significance of differences between the averages being determined by Tukey's test at the level of α=0.05.

Results and Discussion

Grains of spring and winter wheat were significantly diversified in terms of physicochemical characteristics (Table 1). Winter wheat grain was more fertile and even in terms of size. It was characterized by a floury endosperm structure and lower ash content than spring wheat grain, which was finer, glassy, harder, and contained more total protein. The obtained results are confirmed by literature data (Cacak-Pietrzak, Ceglińska, & Torba, 2005; Cacak-Pietrzak & Gondek, 2010; Marzec, Cacak-Pietrzak, & Gondek, 2011; Dziki *et al.*, 2014; 2017), which indicate differences in physical properties and chemical composition of winter grain and spring wheat cultivars, which is reflected in its milling properties – energy consumption in the grain grinding process, total flour and bran yield, as well as flour yield from particular milling passages and their ash content.

The total efficiency of passage flours obtained from the milling of spring and winter wheat grain in the laboratory mill was high, comparable to the yield of low-extraction flours obtained in the industrial mill (Delcour, Van Win, & Grobet, 1999; Prabhasankar, Sudha, & Rao, 2000; Sutton & Simmons, 2006; Banu *et al.*, 2010). The total flour efficiency obtained from winter wheat grain milling was significantly higher than the efficiency of spring wheat flour, respectively: 78.8 and 74.4% (Table 2). This can be explained by the higher ripeness of winter wheat grain, and the resulting higher share of endosperm grain from which low-extraction flours are obtained, as well as a lower share of fruit and seed coats, which are sieved during grain milling and becomes a waste product – bran. The results of earlier studies (Cacak-Pietrzak, Ceglińska, & Torba, 2005; Dziki *et al.*, 2014) indicate higher flour efficiency obtained from winter wheat grain milling than spring wheat. The flour efficiency from reduction passages were about twice as low as from grinding passages, which resulted from high flour efficiency from the first (29.4 and 32.9%) and the second grinding passages (18.8 and 19.3%). This indicates good grindability of porridges and fines. This trait is of great practical importance, as it allows to reduce the number of porridge and grinding passages

Table 1

Physicochemical characteristics of spring and winter wheat grains

Wheat grain	1000 grain weight (g)	Selectness (%)	Uniformity (%)	Glassines (%)	Hardness (j.B)	Protein content (% s.s.)	Ash content (% s.s.)
Spring	32.7^{b*}	42^{b}	62^{b}	65^{a}	650^{a}	12.8^{a}	1.96^{a}
Winter	48.0^{a}	85^{a}	85^{a}	6^{b}	515^{b}	10.4^{b}	1.64^{b}

* average values marked with the same letter indices within the column do not differ significantly statistically at the level of α=0.05

j.B – conventional units in Brabender scale, % of s.s. – the percentage calculated from the dry mass of grain.

Table 2

Yields of flour and bran from the milling of spring and winter wheat grains

Wheat grain	Efficiency of reduction flours (%)			Efficiency of grinding stage flours (%)			Flour efficiency (%)	Bran efficiency (%)	
	SI	SII	SIII	W1	W2	W3		ΣS	ΣW
Spring	7.1[a*]	10.8[b]	2.3[a]	32.9[a]	19.3[a]	2.0[a]	74.4[a]	14.9[a]	10.7[a]
Winter	11.7[b]	14.2[a]	2.8[a]	29.4[b]	18.8[a]	1.9[a]	78.8[b]	11.5[b]	9.7[a]

* average values marked with the same letter indices within the column do not differ significantly statistically at the level of α=0.05
S, SI, SII, SIII – reduction passages W, W1, W2, W3 – grinding passages.

in the mill, and thus reduce the cost of the grain milling process. The grindability of porridge and pellets is influenced by the structure of wheat endosperm. The studies of Cacak-Pietrzak, Ceglińska & Torba (2005) and Cacak-Pietrzak & Gondek (2010) show that with the increase in glassiness and hardness of grains, the grinding efficiency of porridge increases, and more flour is obtained from the grinding passages, which has been confirmed by the results of the study. The lowest flour efficiency was obtained from the final reduction (2.3 and 2.8%) and dimensional grinding passages (1.9 and 2.0%).

Passage flours differed significantly among each other in terms of chemical composition (Table 3). In spring wheat flour, the ash content ranged from 0.52% (W1) to 1.97% (W3), while in winter wheat flour, it was lower and ranged from 0.44% (W1) to 1.80% (W3). Ash content increased with the subsequent passage, both for flours from the reduction and grinding passages. Similar relationships were also found in the total protein content in passage flours. The lowest content of this component was found in flours from the first reduction passages (8.9 and 10.1%), as well as in grinding passages (9.4 and 11.2%), while the highest content was found in flours from the final grinding passages (12.7 and 15.5%). The results of studies carried out by Rani *et al.* (2001), Rothkaehl (2006) and Gómez, Ruiz-Paris & Bonastre (2010) show similar differences in ash and total protein content in wheat passage flours taken from the industrial mill. The ash content of the industrial mill flours tested by Delcour, Van Wine & Grobet (1999) ranged from 0.35 to 3.18% and increased with the subsequent milling passages. In this study, gluten content increased with the subsequent reduction passages, while it decreased with the subsequent grinding passages. The

Table 3

Chemical characteristics of passage flours

Passage flour	Ash content (% s.s.)	Protein content (% s.s.)	Gluten content (%)	Gluten index	Falling numer (s)
Spring wheat					
SI	0.65[c*]	10.1[e]	26.7[b]	95[b]	301[b]
SII	0.73[b]	13.4[b]	31.3[a]	94[b]	290[bc]
SIII	0.74[b]	15.2[a]	31.7[a]	95[b]	253[d]
W1	0.52[d]	11.2[d]	25.9[b]	98[a]	315[a]
W2	0.72[b]	12.6[c]	25.2[b]	100[a]	289[c]
W3	1.97[a]	15.5[a]	21.6[c]	99[a]	251[d]
Winter wheat					
SI	0.56[d]	8.9[d]	22.4[b]	99[a]	212[a]
SII	0.58[d]	10.6[b]	28.6[a]	99[a]	198[b]
SIII	0,67[c]	10.8[b]	29.5[a]	99[a]	168[c]
W1	0.44[e]	9.4[c]	23.4[b]	100[a]	207[ab]
W2	0.87[b]	10.2[bc]	22.6[b]	100[a]	204[ab]
W3	1.80[a]	12.7[a]	17.7[c]	100[a]	167[c]

* average values marked with the same letter indices within the column (spring wheat, winter wheat separately) do not differ significantly statistically at the level of α=0.05
SI, SII, SIII – reduction-stage flours; W1, W2, W3 – grinding-stage flours
% s.s. – the percentage calculated from the dry matter of flour.

most gluten was washed from flours of the second (28.6 and 31.3%) and third reduction passages (29.5 and 31.7%), and the least from the final reduction passages (17.7 and 21.6%). Gluten isolated from all passage flours was of good quality (gluten index – IG >90). The activity of amylolytic enzymes in the flour increased with the subsequent milling passage, both in the reduction and grinding passages. The lowest amylolytic activity was observed for flours from the first reduction passages (falling numbers of 301 and 212 s), while the highest for flours from the final grinding passages (falling numbers of 251 and 167 s). The high activity of flour from the industrial mill's final grinding passages is also indicated by the results of Rani *et al.* (2001) and Rothkaehl (2006) studies, whereas in the studies of Prabhasankara, Sudha & Rao (2000) and Banu *et al.* (2010), the changes in the amylolytic activity of flour from subsequent industrial mill passages were irregular.

The farinographical evaluation makes it possible to examine the dough under conditions similar to those of bakery production, which makes it possible to determine the baking value of the flour and its suitability for mechanical processing more fully than using the evaluation of the quantity and quality of protein substances. It also provides information on the water absorption of flour – a parameter that affects the yield of dough and bakery products (Szafrańska, 2017). Passage flours differed significantly among each other in terms of water absorption (Table 4). Flours of spring wheat grain were characterized by higher water absorption (from 60.8 to 79.4%) than those of winter wheat (from 54.8 to 71.2%). The water absorption of flours increased with the subsequent stages, both in the reduction and grinding passages. Rothkaehl (2006) showed similar relationships in relation to the water absorption of passenger flours taken from the industrial mill, whereas in the study of Banu *et al*. (2010), the changes in the water absorption of flours from the subsequent milling passages were irregular.

In our research, the highest water absorption was observed in the flour from the final passages, which contained the largest number of particles of ground fruit and seed coats. Doughs obtained from spring wheat flour were characterized by longer development and stability times and lower softening than dough from winter wheat flour. Studies conducted by Abramczyk & Rothkaehl (2002) showed that dough made of flour with high gluten protein content and low amylolytic enzymes activity, is characterized by good rheological properties. This has been confirmed by the results of this study.

The output of bread obtained from the tested passage flours was statistically diversified (Table 5). Bread of a higher efficiency was obtained from flour from reduction passages than from grinding passages, which resulted from higher water absorption of flour from reduction stages. Significant differences were also found in loaf volume and crumb porosity. Bread made of flour from reduction passages (372 – 432 cm^3) was characterized by a larger volume than bread from grinding passages (206 – 409 cm^3). It was also characterized by crumbs of a more uniform porosity.

Table 4

Water absorption of passage flours and rheological properties of the dough

Passage flour	Water absorption (%)	Development time (min)	Stability time (min)	Softness (FU)
Spring wheat				
SI	60.8^{d}	2.8^{b}	3.3^{b}	68^{b}
SII	62.5^{c}	3.8^{a}	4.4^{a}	55^{c}
SIII	65.5^{c}	3.7^{a}	3.1^{b}	52^{c}
W1	64.3^{c}	2.8^{b}	2.7^{c}	74^{b}
W2	71.6^{b}	2.2^{c}	2.1^{d}	82^{a}
W3	79.4^{a}	2.5^{bc}	1.5^{e}	88^{a}
Winter wheat				
SI	54.8^{e}	2.2^{c}	3.0^{ab}	74^{c}
SII	55.8^{d}	2.7^{b}	3.2^{a}	70^{c}
SIII	57.4^{c}	2.5^{c}	2.6^{bc}	62^{d}
W1	56.4^{cd}	3.0^{a}	2.8^{b}	84^{b}
W2	61.2^{b}	2.6^{b}	2.6^{bc}	92^{a}
W3	71.2^{a}	2.3^{c}	1.4^{d}	95^{a}

* average values marked with the same letter indices within the column (spring wheat, winter wheat separately) do not differ significantly statistically at the level of α=0.05
SI, SII, SIII – reduction passages; W1, W2, W3 – grinding passages.

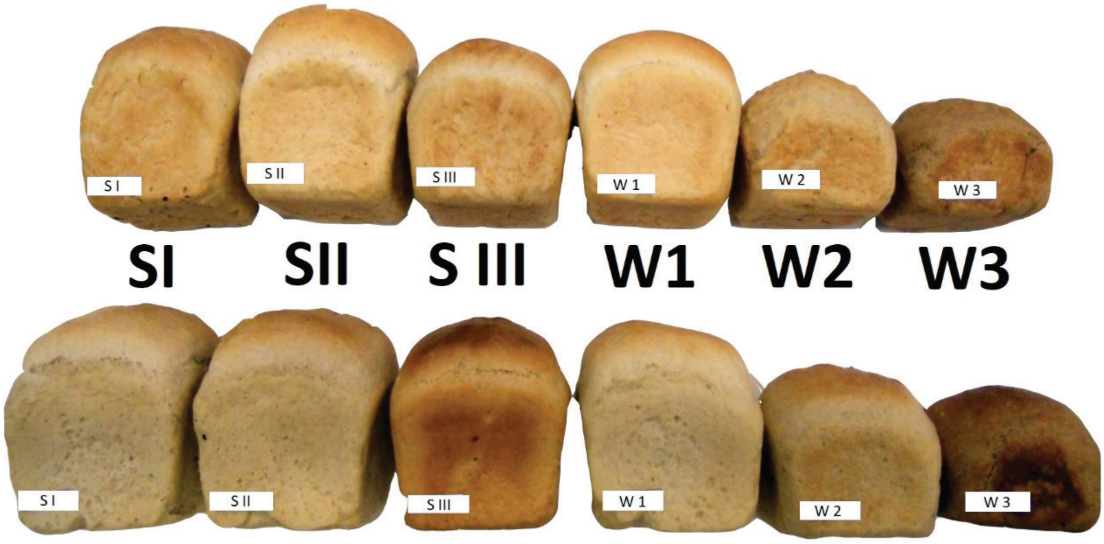

Figure 1. Appearance of bread from passage flours from the grains of winter wheat grain (upper row) and spring wheat grain (lower row).
SI, SII, SIII – reduction passages; W1, W2, W3 – grinding passages.

Table 5

Yield and quality of bread made from passage flours

Passage flour	Bread output (%)	Bread volume (cm^3)	Porosity index of the crumb	Sensory assessment (Σ pkt.)
		Spring wheat		
SI	138.4[a]	423[a]	90[a]	24.0[a]
SII	137.9[a]	420[a]	90[a]	24.0[a]
SIII	134.2[b]	389[a]	85[a]	21.5[b]
W1	138.6[a]	380[ab]	85[a]	20.0[b]
W2	140.4[a]	316[b]	50[b]	16.0[c]
W3	140.7[a]	217[c]	30[c]	7.0[d]
		Winter wheat		
SI	135.8[c]	418[ab]	80[a]	23.5[a]
SII	137.6[c]	432[a]	85[a]	24.5[a]
SIII	137.7[c]	372[c]	90[a]	22.0[b]
W1	137.7[c]	409[b]	85[a]	24.0[a]
W2	144.1[b]	288[bc]	45[b]	18.0[c]
W3	146.4[a]	206[d]	30[c]	8.0[d]

* average values marked with the same letter indices within the column (spring wheat, winter wheat separately) do not differ significantly statistically at the level of α=0.05
SI, SII, SIII – reduction passages; W1, W2, W3 – grinding passages.

Similarly, as in the research carried out by Every *et al.* (2006), bread from flours from the final grinding passages had the smallest volume.

The differences in loaf volume and porosity of bread crumbs from flours from individual milling passages were confirmed by sensory evaluation results. The sum of points awarded by the team conducting sensory evaluation of bread ranged from 7.0 to 24.5 (Table 5). Taking into account the external appearance of loaves, bread made of reduction-stage flour was rated higher than of grinding-stage flours (Figure 1). Reservations concerned in particular bread made from flour from the final grinding passage, which was very poorly grown, with crumbs too compact and not very porous. The majority of bread loaves were characterized by an appropriate skin colour, but the evaluators pointed to the colour of bread skin from flour from the final grinding passages as too dark. Additionally, the skin of this bread was cracked and wrinkled. The bread crumbs were dry, elastic, and with the exception of bread made from flour from the final grinding passages, evenly coloured. The taste and smell were characteristic to wheat bread. No significant differences in the taste and smell of bread from particular passage flours were found.

Conclusions

Flours from the same batch of grain taken from individual passages of the laboratory mill were significantly diversified in terms of chemical composition and baking value, which allows the composition of final flour of defined quality parameters. However, flour from the final grinding passages should be absolutely rejected, as during milling they were contaminated with shredded particles of the fruit and seed coats, which significantly increased their ash content. Flours from these passages, despite the high total protein content, contained the least gluten proteins and were characterized by the highest activity of amylolytic enzymes. The bread obtained from these flours had a deformed shape, was poorly grown, with a compact crumb and too dark skin colour. The remaining passage flours have proper baking properties and can be used to make flour for baking purposes.

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