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FLOUR QUALITY, THE RHEOLOGICAL PROPERTIES OF DOUGH AND THE QUALITY OF BREAD MADE FROM THE GRAIN OF WINTER WHEAT GROWN IN A CONTINUOUS CROPPING SYSTEM

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Abstract. The aim of this study was to determine the quality of flour, dough and bread made from the grain of winter wheat grown in a continuous cropping system or after oil plants (winter rapeseed, spring rapeseed, white mustard, brown mustard) in production systems of different intensity. The above products, obtained from wheat grain harvested in three growing seasons (2006/2007, 2007/2008, 2008/2009), were analyzed to determine the whiteness, ash content and water absorption capacity of flour, the development time, stability, softening, resistance, extensibility and energy of dough, and the baking volume and yield of bread. The grain of winter wheat grown in a continuous cropping system produced whiter flour with a lower ash content than the grain of winter wheat plants grown after oil plants. The intensification of wheat grain production contributed to flour darkening and a decrease in flour ash content. Monoculture had no adverse effects on the water absorption capacity of flour, the development time, stability or softening of dough. Intensification of production improved water absorption of flour, the development time, stability and softening of dough. The extensibility and energy of dough made from flour obtained from wheat grown in a continuous cropping system were substantially lower, compared with wheat grown after winter rapeseed. Intensification of production also improved dough extensibility and energy. The resistance of dough made from wheat grain produced under medium-input technology was significantly lower, compared with grain produced under low-input technology. Intensification of wheat grain production contributed to a greater increase in the yield of bread made from winter wheat grown after oil plants (primarily winter rapeseed and brown mustard), compared with monoculture.

Key words: bread quality, flour quality, forecrop, production intensity, rheological properties of dough, winter wheat

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INTRODUCTION

The main goal of contemporary winter wheat breeding programs is to produce varieties with varied performance characteristics that meet the requirements of the food processing industry, including milling and baking [Biel and Maciorkowski 2012]. The chemical composition of wheat grain is genetically conditioned, but it is frequently modified by climate and habitat conditions [Daniel *et al.* 1998a,b, Smith and Gooding 1999, Woźniak 2007] as well as the intensity of the production process [Podolska and Sułek 2002, Guarda *et al.* 2004, Woźniak and Gontarz 2005, Woźniak 2006]. For this reason, seed material that meets the quality criteria set for bread wheat does not guarantee grain yields characterized by adequate processing suitability for milling and baking industries.

The biological diversity of agricultural ecosystems has been decreasing steadily since the mid-1980s. The loss of biodiversity not only reduces the number of cultivated plant groups, but also the number of cultivated species. In industrial agriculture, cereal polycultures are being gradually replaced with monocultures where a single crop or plant species are grown for a number of consecutive years (continuous cropping). Monoculture has numerous adverse effects. The yield of wheat grown in monoculture is reduced by 30% (if continuous cropping is practiced for several years) to more than 50% (if continuous cropping is practiced for more than 10 years) [Budzyński 2012]. In agricultural practice, attempts are made to minimize the negative effects of continuous cropping on yield by introducing intensive production techniques [Rozbicki 2002, Woźniak 2006, Budzyński 2012]. Growing wheat in continuous cropping systems, which results from the loss of biodiversity in agricultural ecosystems, can also affect the technological quality of flour. The appropriate selection of qualitative and quantitative technological parameters enables to fully exploit the potential of wheat varieties [Dubis 2012].

The objective of this study was to determine the effect of winter wheat monoculture on flour quality, the rheological properties of dough and bread quality. The results of the experiment were used to verify a working hypothesis that the negative effects of continuous cropping on the qualitative parameters of flour, dough and bread can be mitigated through the introduction of intensive production technology (nitrogen fertilization and fungicide treatments).

MATERIAL AND METHODS

We analyzed the quality of flour and the rheological properties of dough made from the grain of winter wheat grown in a split-plot field experiment with three replications. The experimental variables were:

(I) forecrop species: (Ia) winter rapeseed, (Ib) spring rapeseed, (Ic) white mustard, (Id) Indian mustard, (Ie) winter wheat;

(II) winter wheat production technology according to the below diagram:

Cultivation measures/date Operacja technologiczna/termin		Production technology – Technologia produkcji	
		low-input niskonakładowa	medium-input średnionakładowa
Top-dressing with N Nawożenie pogłówne N kg·ha^{-1}	BBCH 29	60	90
	BBCH 32	30	60
Disease control Ochrona przed chorobami	BBCH 00	seed dressing – zaprawianie 30 g triadimenol; 4 g imazalil; 3.6 g fuberidazole per 100 kg seeds	seed dressing – zaprawianie 30 g triadimenol; 4 g imazalil; 3.6 g fuberidazole per 100 kg seeds
	BBCH 32	—	picoxystrobin 150 g ha^{-1}; flusilazole 125 g ha^{-1}; carbendazim 62.5 g ha^{-1}; proquinazid 30 g ha^{-1}
	BBCH 39	—	picoxystrobin 100 g ha^{-1}; flusilazole 75 g ha^{-1}; carbendazim 37.5 g ha^{-1}; famoxate 50 g ha^{-1}; flusilazole 53.35 g ha^{-1}

The following pre-sowing fertilization treatment was applied: 30 kg N·ha^{-1} (ammonium nitrate), 17 kg P·ha^{-1} (triple superphosphate) and 100 kg K·ha^{-1} (60% potash salt). In each year of the study, winter wheat cv. Olivin was sown in the second half of September with the density of 450 dressed kernels per m^2 of plot area. In spring, two nitrogen fertilization treatments (BBCH 29 and 32) were applied at 60 and 30 kg N·ha^{-1} (low-input production) or 90 and 50 kg N·ha^{-1} (medium-input production). Herbicide treatment was applied at the first leaf unfolded stage (BBCH 11) with 1 000 g·ha^{-1} of pendimethalin and 500 g·ha^{-1} of isoproturon in all production systems. In the low-input system, disease control was limited to seed dressing, whereas in the medium--input system, two chemical treatments were additionally applied at stages BBCH 32 and 39 (second-order factor in the experimental design). Each year, winter wheat was harvested in the first half of August. Flour quality was evaluated based on two analytical indicators: color [PN-A-74029:1999P] and ash content [PN-EN ISO 2171:2010E]. The rheological properties of dough were assessed in a farinograph and an extensograph. The farinographic evaluation involved the determination of the water absorption capacity of flour, the development time, stability and softening of dough [ICC-Standard 115/72, farinograph, 50 g sample]. Dough resistance, extensibility and energy were determined in an extensographic analysis [ICC-Standard 114/1, measured after 135 minutes of fermentation]. Wheat grain was ground according to the method proposed by Sitkowski [Klockiewicz-Kamińska and Brzeziński 1997]. A baking trial was conducted to determine bread baking volume and yield based on the method developed by Klockiewicz-Kamińska and Brzeziński [1997].

The results of laboratory analyses were processed by ANOVA in accordance with the experimental method. Mean values from every treatment were compared by Tukey's test. LSD values were calculated for 5% error rate. The results were processed in the Statistica 10.1 PL application.

RESULTS AND DISCUSSION

Weather conditions

The processing suitability of winter wheat grain is determined mainly by the variety's genotype. Genetically conditioned biosynthesis of nutrients, which is responsible for the performance characteristics of winter wheat, can also be highly influenced by environmental factors, such as moisture content and temperature during grain formation and ripening [Daniel *et. al*. 1998a,b, Goodling and Smith 1998], and anthropogenic factors (production intensity).

An analysis of the mean values of Sielianinov's hydrothermal index (K) measuring the effectiveness of water resources [Bac *et al*. 1998] for winter wheat during heading and ripening stages indicates that the first and third growing seasons were characterized by the most favorable precipitation profile (Fig. 1). Precipitation levels varied significantly across the three growing seasons analyzed in this study. In the 2006/2007 season, the first 20 days after heading were characterized by a drought (K<1), whereas favorable hydrothermal conditions were observed in the following 30 days. In the third growing season, a dry spell was noted only 40 days after heading. In the weeks preceding and following the above date, the value of the hydrothermal index ranged from 1.8 to 7.8. In the second growing season, a long-term drought was observed during heading and ripening stages (Fig. 1).

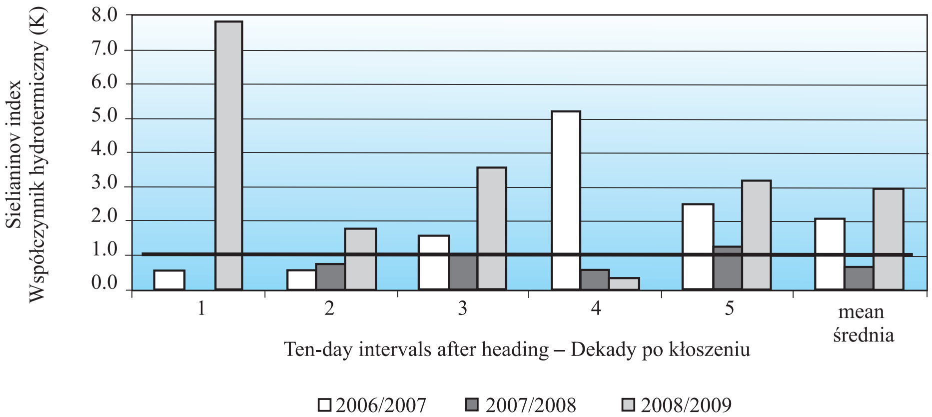

Fig. 1. Hydrothermal index of winter wheat after heading (Sielianinov index, K: 0-0.5 – extreme dry spell, 0.6-1.0 – dry spell, 1.1-2.0 – humid spell, >2.1 – wet spell)

Rys. 1. Wskaźniki zabezpieczenia w wodę pszenicy ozimej po wykłoszeniu (współczynniki hydrotermiczne Sielianinowa, K: 0-0,5 – susza, 0,6-1,0 – posucha, 1,1-2,0 – wilgotny, >2,1 – bardzo wilgotny)

Flour quality parameters

The experimental variables significantly affected flour color (Table 1). Significantly whiter flour was obtained from the grain of winter wheat grown after spring oil crops (Table 1). Intensified production of winter wheat grain led to minor, but significantly statistical, darkening of wheat flour. The reduction in flour whiteness resulting from higher production intensity was not correlated with the choice of forecrop (Table 1).

Table 1. Flour color (% whiteness)
Tabela 1. Barwa mąki (% wzorca bieli)

Growing season Sezon wegetacyjny	Production technology Technologia produkcji	Forecrop – Przedplon					Mean Średnia
		rapeseed – rzepak		mustard – gorczyca		winter wheat pszenica ozima	
		winter ozimy	spring jary	white biała	brown sarepska		
2006/2007	low-input niskonakładowa	81.25	82.49	81.93	81.87	81.33	81.25
	medium-input średnionakładowa	80.56	80.88	81.17	81.01	80.93	80.56
2007/2008	low-input niskonakładowa	80.57	81.56	80.19	81.5	80.92	80.95
	medium-input średnionakładowa	80.42	79.49	80.35	79.63	79.52	79.88
2008/2009	low-input niskonakładowa	79.45	79.33	79.90	80.18	78.83	79.54
	medium-input średnionakładowa	79.52	80.15	80.00	79.65	80.16	79.90
2006/2007	–	80.91	81.69	81.55	81.44	81.13	81.34
2007/2008		80.50	80.53	80.27	80.57	80.22	80.42
2008/2009		79.49	79.74	79.95	79.92	79.50	79.92
–	low-input niskonakładowa	80.42	81.13	80.67	81.18	80.36	80.75
	medium-input średnionakładowa	80.17	80.17	80.51	80.10	80.20	80.23
Mean – Średnia		80.30	80.65	80.59	80.64	80.28	–

LSD – NIR
forecrop – przedplon 0.27
production technology – technologia produkcji 0.32

A clear, but not statistically significant, decrease in ash content was observed in the flour made from the grain of winter wheat grown after winter wheat in comparison with the flour made from winter wheat grown after winter rapeseed. Intensification of the production process also lowered the ash content of winter wheat flour. The above trend was more pronounced in the flour made from winter wheat grown after winter rapeseed than in flour made from winter wheat grown after winter wheat (Table 2). Contrary results were reported by Woźniak [2007] in whose study wheat monoculture contributed to a higher ash content of flour. In the work of Dubis [2012], intensified nitrogen fertilization was weakly correlated with the color and ash content of spring wheat flour. In the above study, higher nitrogen fertilization rates led to a minor improvement in flour whiteness and a decrease in the ash content of flour. The differences in the ash content of flour resulting from various nitrogen fertilization rates did not exceed 0.6%.

Table 2. Ash content of flour ($g \cdot kg^{-1}$ DM)
Tabela 2. Zawartość popiołu w mące ($g \cdot kg^{-1}$ sm)

Growing season Sezon wegetacyjny	Production technology Technologia produkcji	Forecrop – Przedplon					Mean Średnia
		rapeseed – rzepak		mustard – gorczyca		winter wheat pszenica ozima	
		winter ozimy	spring jary	white biała	brown sarepska		
2006/2007	low-input niskonakładowa	5.8	5.7	5.5	5.0	5.4	5.5
	medium-input średnionakładowa	5.7	5.9	5.7	5.5	5.4	5.6
2007/2008	low-input niskonakładowa	5.2	4.9	4.9	4.9	5.1	5.0
	medium-input średnionakładowa	5.0	4.7	4.6	4.8	5.0	4.8
2008/2009	low-input niskonakładowa	5.4	5.6	5.2	5.1	5.2	5.3
	medium-input średnionakładowa	4.9	4.8	4.9	4.8	5.0	4.9
2006/2007	–	5.8	5.8	5.6	5.3	5.4	5.6
2007/2008		5.1	4.8	4.8	4.9	5.1	4.9
2008/2009		5.2	5.2	5.1	5.0	5.1	5.1
–	low-input niskonakładowa	5.5	5.4	5.2	5.0	5.2	5.3
	medium-input średnionakładowa	5.2	5.1	5.1	5.0	5.1	5.1
Mean – Średnia		5.4	5.3	5.2	5.1	5.2	–
LSD – NIR	ns – ni						

Rheological properties of dough

The water absorption capacity of flour is one of the key parameters determining the quality of winter wheat grain. Satisfactory water absorption values were reported only in the first and third growing season in the medium-input production system (Table 3). In the second growing season, the water absorption capacity of flour did not exceed 53.5% regardless of production intensity. Throughout the 3-year study, the average water absorption of flour made from the grain of winter wheat grown in 2-year continuous cropping system was statistically similar to that of the flour made from winter wheat grown after oil plants. Intensification of the production process significantly increased the water absorption capacity of flour (by approximately 1.6%). The highest increase of 2% was noted in intensified continuous cropping systems. In a study by Ellmann [2011], intensive production of winter wheat increased water absorption of flour by 1% in comparison with extensive production. Podolska and Sułek [2002] and Dubis [2012] also demonstrated that higher nitrogen fertilization rates improved the water absorption capacity of flour.

Table 3. Water absorption capacity of flour (%)
Tabela 3. Wodochłonność mąki (%)

Growing season Sezon wegetacyjny	Production technology Technologia produkcji	Forecrop – Przedplon					Mean Średnia
		rapeseed – rzepak		mustard – gorczyca		winter wheat pszenica ozima	
		winter ozimy	spring jary	white biała	brown sarepska		
2006/2007	low-input niskonakładowa	53.7	52.3	51.7	51.9	52.3	52.4
	medium-input średnionakładowa	55.1	53.3	53.5	53.8	54.1	54.0
2007/2008	low-input niskonakładowa	51.3	51.2	51.5	50.4	51.7	51.2
	medium-input średnionakładowa	52.2	53.3	53.1	53.3	53.5	53.1
2008/2009	low-input niskonakładowa	54.7	53.6	54.0	54.8	53.2	54.1
	medium-input średnionakładowa	55.4	56.1	55.2	55.6	55.6	55.6
2006/2007	–	54.4	52.8	52.6	52.9	53.2	53.2
2007/2008		51.8	52.3	52.3	51.9	52.6	52.2
2008/2009		55.1	54.9	54.6	55.2	54.4	54.8
–	low-input niskonakładowa	53.2	52.4	52.4	52.4	52.4	52.6
	medium-input średnionakładowa	54.2	54.2	53.9	54.2	54.4	54.2
Mean – Średnia		53.8	53.3	53.2	53.3	53.4	–
LSD – NIR production technology – technologia produkcji 0.2							

The rheological properties of dough, which reflect changes in dough consistency during formation, development and mixing, were strongly influenced by weather conditions throughout the study. Despite the noted variations, the annual values describing dough development time, stability and softening were above the minimum levels set for bread wheat. Continuous cropping did not exert a negative effect on the above rheological properties of dough (Tables 4-6). The stability of dough made from winter wheat grown in a continuous cropping system was approximately 28% lower (decrease from approximately 4.6 to 3.3 minutes) than that of winter wheat grown after winter rapeseed, but the observed difference was not statistically significant (Table 5).

Table 4. Dough development (min)
Tabela 4. Rozwój ciasta (min)

Growing season Sezon wegetacyjny	Production technology Technologia produkcji	Forecrop – Przedplon					Mean Średnia
		rapeseed – rzepak		mustard – gorczyca		winter wheat	
		winter ozimy	spring jary	white biała	brown sarepska	pszenica ozima	
2006/2007	low-input niskonakładowa	1.5	1.2	1.3	1.2	1.4	1.3
	medium-input średnionakładowa	2.0	1.7	1.7	1.5	1.7	1.7
2007/2008	low-input niskonakładowa	1.4	1.0	1.0	1.0	0.9	1.1
	medium-input średnionakładowa	1.8	1.7	1.8	2.0	2.0	1.9
2008/2009	low-input niskonakładowa	1.8	1.3	0.9	1.4	1.5	1.4
	medium-input średnionakładowa	2.0	1.9	1.9	1.9	2.0	1.9
2006/2007	–	1.8	1.5	1.5	1.4	1.6	1.6
2007/2008		1.6	1.4	1.4	1.5	1.5	1.5
2008/2009		1.9	1.6	1.4	1.7	1.8	1.7
–	low-input niskonakładowa	1.6	1.2	1.1	1.2	1.3	1.3
	medium-input średnionakładowa	1.9	1.8	1.8	1.8	1.9	1.8
Mean – Średnia		1.8	1.5	1.4	1.5	1.6	–
LSD – NIR	production technology – technologia produkcji					0.1	

Table 5. Dough stability (min)
Tabela 5. Stałość ciasta (min)

Growing season Sezon wegetacyjny	Production technology Technologia produkcji	Forecrop – Przedplon					Mean Średnia
		rapeseed – rzepak		mustard – gorczyca		winter wheat	
		winter ozimy	spring jary	white biała	brown sarepska	pszenica ozima	
2006/2007	low-input niskonakładowa	1.8	1.0	1.6	1.4	1.4	1.4
	medium-input średnionakładowa	3.7	2.0	2.5	1.5	1.8	2.3
2007/2008	low-input niskonakładowa	2.0	1.3	1.6	1.4	1.3	1.5
	medium-input średnionakładowa	4.0	2.8	5.5	4.0	5.5	4.4
2008/2009	low-input niskonakładowa	2.7	2.7	2.3	2.4	2.1	2.4
	medium-input średnionakładowa	13.3	9.0	7.5	4.7	7.8	8.5
2006/2007	–	2.8	1.5	2.1	1.5	1.6	1.9
2007/2008		3.0	2.1	3.6	2.7	3.4	3.0
2008/2009		8.0	5.9	4.9	3.6	5.0	5.5
–	low-input niskonakładowa	2.2	1.7	1.8	1.7	1.6	1.8
	medium-input średnionakładowa	7.0	4.6	5.2	3.4	5.0	5.1
Mean – Średnia		4.6	3.2	3.5	2.6	3.3	–
LSD – NIR	production technology – technologia produkcji					1.1	

Production intensity significantly differentiated dough development time, stability and softening (Tables 4, 5 and 6). Dough development time and dough stability were significantly higher (by 38% and nearly 3-fold, respectively) for winter wheat subjected to intensive nitrogen fertilization and full antifungal protection (medium-input production system) (Tables 4 and 5). Higher nitrogen fertilization rates and two fungicide treatments had a clearly beneficial influence on dough softening, which decreased by 28 units, i.e. by 27% (Table 6). In a study by Dubis [2012], dough development time and dough stability were also significantly differentiated and higher for spring wheat subjected to intensive nitrogen fertilization (164 kg $N \cdot ha^{-1}$).

Table 6. Dough softening (j.Br)
Tabela 6. Rozmiękczenie ciasta (j.Br)

Growing season Sezon wegetacyjny	Production technology Technologia produkcji	Forecrop – Przedplon					Mean Średnia
		rapeseed – rzepak		mustard – gorczyca		winter wheat	
		winter ozimy	spring jary	white biała	brown sarepska	pszenica ozima	
2006/2007	low-input niskonakładowa	99	125	105	104	104	107
	medium-input średnionakładowa	88	93	83	104	77	89
2007/2008	low-input niskonakładowa	117	126	124	131	128	125
	medium-input średnionakładowa	87	96	71	95	76	85
2008/2009	low-input niskonakładowa	73	82	79	78	92	81
	medium-input średnionakładowa	34	56	57	67	53	53
2006/2007	–	94	109	94	104	91	98
2007/2008		102	111	98	113	102	105
2008/2009		54	69	68	73	73	67
–	low-input niskonakładowa	96	111	103	104	108	104
	medium-input średnionakładowa	70	82	70	89	69	76
Mean – Średnia		83	96	87	97	89	–
LSD – NIR	production technology – technologia produkcji				5		

An extensographic evaluation revealed that the extensibility and energy of dough made from winter wheat grown in a continuous cropping system were significantly lower (by 7% and 9%, respectively) in comparison with the dough made from winter wheat grown after rapeseed, in particular winter rapeseed (Tables 8 and 9). Higher nitrogen fertilization rates and antifungal protection also improved dough extensibility and energy. Intensification of the production process increased the analyzed parameters by 10% and 12%, respectively (Tables 8 and 9). The resistance of dough made from the grain of winter wheat grown in a medium-input system was significantly lower (by approximately 5%) than that of dough produced from the grain of winter wheat grown in a low-input system (Table 7).

In numerous studies, higher rates of nitrogen fertilizer improved the rheological properties of dough [Cacak-Pietrzak *et al*. 1999, Stankowski *et al*. 2004, Szafrańska *et al*. 2008, Dubis 2012, Bepirszcz 2013], whereas fungicide use was weakly correlated with the above parameter [Cacak-Pietrzak *et al*. 2008, 2009, Dubis 2012, Bepirszcz 2013]. Al.-Mashhadi *et al*. [1989] observed that intensified nitrogen fertilization increased dough extensibility, but had no effect on dough resistance, development time or stability.

Table 7. Dough resistance (j.Br)
Tabela 7. Opór ciasta (j.Br.)

Growing season Sezon wegetacyjny	Production technology Technologia produkcji	Forecrop – Przedplon					Mean Średnia
		rapeseed – rzepak		mustard – gorczyca		winter wheat	
		winter ozimy	spring jary	white biała	brown sarepska	pszenica ozima	
2006/2007	low-input niskonakładowa	198	208	223	228	230	217
	medium-input średnionakładowa	165	173	213	213	200	193
2007/2008	low-input niskonakładowa	213	271	163	188	196	206
	medium-input średnionakładowa	243	189	244	215	192	217
2008/2009	low-input niskonakładowa	293	323	350	300	323	318
	medium-input średnionakładowa	312	273	284	306	284	292
2006/2007	–	182	191	218	221	215	205
2007/2008		228	230	204	202	194	212
2008/2009		303	298	317	303	304	305
–	low-input niskonakładowa	235	267	245	239	250	247
	medium-input średnionakładowa	240	212	247	245	225	234
Mean – Średnia		238	240	246	242	238	–
LSD – NIR	production technology – technologia produkcji				5		

Table 8. Dough extensibility (mm)
Tabela 8. Rozciągliwość ciasta (mm)

Growing season Sezon wegetacyjny	Production technology Technologia produkcji	Forecrop – Przedplon					Mean Średnia
		rapeseed – rzepak		mustard – gorczyca		winter wheat	
		winter ozimy	spring jary	white biała	brown sarepska	pszenica ozima	
2006/2007	low-input niskonakładowa	179	145	155	165	156	160
	medium-input średnionakładowa	190	187	181	156	176	178
2007/2008	low-input niskonakładowa	166	151	168	155	151	158
	medium-input średnionakładowa	167	176	157	171	165	167
2008/2009	low-input niskonakładowa	170	169	160	163	157	164
	medium-input średnionakładowa	192	192	182	187	182	187
2006/2007	–	185	166	168	161	166	169
2007/2008		167	164	163	163	158	163
2008/2009		181	181	171	175	170	176
–	low-input niskonakładowa	172	155	161	161	155	161
	medium-input średnionakładowa	183	185	173	171	174	177
Mean – Średnia		178	170	167	166	165	–
LSD – NIR	production technology – technologia produkcji				4		

Table 9. Dough energy (cm^2)
Tabela 9. Energia ciasta (cm^2)

Growing season Sezon wegetacyjny	Production technology Technologia produkcji	Forecrop – Przedplon					Mean Średnia
		rapeseed – rzepak		mustard – gorczyca		winter wheat	
		winter ozimy	spring jary	white biała	brown sarepska	pszenica ozima	
2006/2007	low-input niskonakładowa	55.2	48.3	56.2	65.4	58.5	56.7
	medium-input średnionakładowa	54.3	55.0	59.3	57.1	61.2	57.4
2007/2008	low-input niskonakładowa	58.6	66.0	44.2	47.7	46.7	52.6
	medium-input średnionakładowa	71.3	57.4	66.2	65.7	54.8	63.1
2008/2009	low-input niskonakładowa	93.7	102.4	99.6	90.1	89.3	95.0
	medium-input średnionakładowa	120.1	104.4	102.2	108.4	103.0	107.6
2006/2007	–	54.8	51.7	57.8	61.3	59.9	57.1
2007/2008		65.0	61.7	55.2	56.7	50.8	57.9
2008/2009		106.9	103.4	100.9	99.3	96.2	101.3
–	low-input niskonakładowa	69.2	72.2	66.7	67.7	64.8	68.1
	medium-input średnionakładowa	81.9	72.3	75.9	77.1	73.0	76.0
Mean – Średnia		75.6	72.3	71.3	72.4	69.0	–
LSD – NIR forecrop – przedplon 5.4 production technology – technologia produkcji 3.8							

Bread baking volume and yield

In the flour analysis, baking properties were evaluated directly in a baking trial. It was assumed that the baking trial would reveal specific properties of flour that cannot be predicted with the involvement of indirect analytical methods. The baking trial demonstrated that the flour obtained from grain harvested in the first and second years of the study (which largely failed to meet the quality requirements set for bread wheat) produced satisfactory (characteristic of bread wheat) bread yield and baking volume (Tables 10 and 11).

In this study, bread made from winter wheat flour was characterized by average baking volume of approximately 572-585 cm^3. The investigated parameter was not significantly differentiated by any of the analyzed experimental variables (Table 10). In other studies, production technology was also weakly correlated with baking volume in baking trials [Dubis 2012, Cacak-Pietrzak *et al*. 1999, 2008, 2009, Ellmann 2011].

The choice of forecrops had no significant influence on bread yield (Table 11). The flour obtained from grain grown in a medium-input production system (150 kg $N \cdot ha^{-1}$ and two fungicide treatments) was characterized by a higher bread yield. In the low-input production system (90 kg $N \cdot ha^{-1}$ and no fungicide treatment), bread yield was approximately 1.9% lower. Intensification of the production process had a more beneficial effect on bread yield when winter wheat was grown after oil plants (mostly winter rapeseed and brown mustard) than in a continuous cropping system (Table 11).

Table 10. Baking volume of bread (cm^3)
Tabela 10. Objętość chleba (cm^3)

Growing season Sezon wegetacyjny	Production technology Technologia produkcji	Forecrop – Przedplon					Mean Średnia
		rapeseed – rzepak		mustard – gorczyca		winter wheat	
		winter ozimy	spring jary	white biała	brown sarepska	pszenica ozima	
2006/2007	low-input niskonakładowa	590.6	577.3	577.4	564.0	587.4	579.0
	medium-input średnionakładowa	580.0	577.4	592.0	560.0	586.0	579.0
2007/2008	low-input niskonakładowa	578.0	602.0	598.6	598.0	595.4	594.4
	medium-input średnionakładowa	584.0	590.6	594.0	574.6	592.0	587.0
2008/2009	low-input niskonakładowa	561.4	572.6	558.0	569.9	580.6	568.5
	medium-input średnionakładowa	568.0	553.4	558.6	564.0	570.6	562.9
2006/2007	–	585.3	577.4	584.7	562.0	586.7	579.2
2007/2008		581.0	596.3	596.3	586.3	593.7	590.7
2008/2009		564.7	563.0	558.3	567.0	575.6	565.7
–	low-input niskonakładowa	576.7	584.0	578.0	577.3	587.8	580.7
	medium-input średnionakładowa	577.3	573.8	581.5	566.2	582.9	576.3
Mean – Średnia		577.0	578.9	579.8	571.8	585.3	–
LSD – NIR	ns – ni						

Table 11. Bread yield (%)
Tabela 11. Wydajność chleba (%)

Growing season Sezon wegetacyjny	Production technology Technologia produkcji	Forecrop – Przedplon					Mean Średnia
		rapeseed – rzepak		mustard – gorczyca		winter wheat	
		winter ozimy	spring jary	white biała	brown sarepska	pszenica ozima	
2006/2007	low-input niskonakładowa	136.4	138.8	140.6	134.7	139.2	137.9
	medium-input średnionakładowa	141.8	137.4	140.0	141.2	138.2	139.7
2007/2008	low-input niskonakładowa	140.9	140.6	139.8	139.2	141.4	140.4
	medium-input średnionakładowa	141.7	139.7	140.2	141.0	142.2	141.0
2008/2009	low-input niskonakładowa	145.7	142.3	147.1	145.5	143.4	144.8
	medium-input średnionakładowa	146.7	146.2	145.3	156.3	145.2	147.9
2006/2007	–	139.1	138.1	140.3	138.0	138.7	138.8
2007/2008		141.3	140.2	140.0	140.1	141.8	140.7
2008/2009		146.2	144.3	146.2	150.9	144.3	146.4
–	low-input niskonakładowa	141.0	140.6	142.5	139.8	141.3	141.0
	medium-input średnionakładowa	143.4	141.1	141.8	146.2	141.9	142.9
Mean – Średnia		142.2	140.9	142.2	143.0	141.6	–
LSD – NIR	production technology – technologia produkcji 0.8						

General assessment (quality class of winter wheat)

There are two different climate zones in Poland that lead to significant variations in weather conditions between years. In years characterized by favorable weather, the processing suitability of high-quality varieties of spring and winter wheat grain grown with the application of suitable cultivation measures can exceed grain purchasing standards. In less supportive years, even grain with the most favorable genetic traits may not conform to the above standards [Rozbicki 2002, Dubis 2012, Bebirszcz 2013]. The influence of the analyzed variables on the processing suitability of winter wheat grain was quantified by comparison with absolute values in accordance the methods developed by the Research Center for Cultivar Testing (COBORU) for the Assessment of Variety Value for Cultivation and Use. Grain harvested in the third year of the study was characterized by the highest quality (quality class B) (Table 12). Grain produced in the first and second years of the study generally did not meet the required quality standards (quality class C).

Not all grain harvested in the last year of the study (2008/2009) conformed to industrial quality standards, which were met only by the grain from the medium-input production system (quality class B) regardless of the applied forecrop. Grain harvested from the low-input production system conformed to quality standards (quality class B) only when winter wheat was grown after winter rapeseed (Table 12). In a study by Bepirszcz [2013], satisfactory quality of common wheat grain was achieved only in a high-input production system (nitrogen fertilization at 160-200 kg $N \cdot ha^{-1}$ and full disease control). The quality of grain harvested from low-input and medium-input production systems did not conform to industrial requirements, mainly due to a low protein and gluten content.

Table 12. Quality class of winter wheat
Tabela 12. Grupa jakościowa pszenicy ozimej

Growing season Sezon wegetacyjny	Production technology Technologia produkcji	Forecrop — Przedplon				
		rapeseed — rzepak		mustard — gorczyca		winter wheat pszenica ozima
		winter ozimy	spring jary	white biała	brown sarepska	
2006/2007	low-input niskonakładowa	C	C	C	C	C
	medium-input średnionakładowa	C	C	C	C	C
2007/2008	low-input niskonakładowa	C	C	C	C	C
	medium-input średnionakładowa	C	C	C	C	C
2008/2009	low-input niskonakładowa	B	C	C	C	C
	medium-input średnionakładowa	B	B	B	B	B

CONCLUSIONS

The grain of winter wheat grown in a continuous cropping system produced whiter flour with a lower ash content than the grain of winter wheat grown after oil plants. Intensification of the production process contributed to flour darkening (regardless of the choice of forecrop) and a decrease in flour ash content (a greater decrease was noted in the grain of winter wheat grown after winter rapeseed than in monoculture). Winter wheat monoculture had no adverse effects on the water absorption capacity of flour, the development time, stability or softening of dough. Intensified production significantly increased the water absorption of flour, in particular in treatments where winter wheat was grown in a continuous cropping system. Intensified production also had a beneficial effect on the development time, stability and softening of dough. The extensibility and energy of dough made from winter wheat grown in a continuous cropping system was significantly lower in comparison with winter wheat grown after rapeseed, in particular winter rapeseed. Higher nitrogen fertilization rates and full fungicide protection significantly improved dough extensibility and energy. The resistance of dough made from winter wheat grain produced under medium-input technology was significantly lower, compared with grain produced under low-input technology. The choice of forecrops had no significant influence on bread baking volume or yield. The flour obtained from grain grown in a medium-input production system (150 kg $N \cdot ha^{-1}$ and two fungicide treatments) was characterized by a higher bread yield. Intensification of the production process had a more beneficial effect on bread yield when winter wheat was grown after oil plants (mostly winter rapeseed and brown mustard) than in a continuous cropping system. Grain harvested from the low-input production system conformed to quality standards (quality class B) only when winter wheat was grown after winter rapeseed. Grain harvested from wheat plants grown in a continuous cropping system (or after spring oil plants) was characterized by satisfactory quality (quality class B) only in more intensive production systems. Wheat grain harvested in growing seasons characterized by unfavorable weather conditions did not meet industrial quality standards regardless of the applied of forecrop or production system intensity.

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JAKOŚĆ MĄKI, WŁAŚCIWOŚCI REOLOGICZNE CIASTA ORAZ JAKOŚĆ PIECZYWA OTRZYMANEGO Z ZIARNA PSZENICY OZIMEJ UPRAWIANEJ PO SOBIE

Streszczenie. W badaniach oceniono jakość mąki, ciasta oraz pieczywa uzyskanego z ziarna pszenicy ozimej uprawianej po sobie lub po roślinach oleistych (rzepak ozimy, rzepak jary, gorczyca biała, gorczyca sarepska) w technologiach o różnym stopniu intensywności nakładów. Ocenie poddano ww. produkty uzyskane z ziarna pszenicy ozimej zebranego w 3 sezonach wegetacyjnych (2006/2007, 2007/2008, 2008/2009). W analizie uwzględniono: biel mąki i zawartość w niej popiołu, wodochłonność mąki, czas rozwoju, stałość oraz rozmiękczenie ciasta, opór, rozciągliwość i energię ciasta, wydajność i objętość chleba. Mąkę o większej bieli oraz o mniejszej zawartości popiołu uzyskano z ziarna pszenicy uprawianej po sobie niż po roślinach oleistych. Intensyfikacja procesu produkcji ziarna pszenicy ozimej powodowała ciemnienie mąki oraz obniżenie w niej zawartości popiołu. Nie udowodniono, aby uprawa pszenicy po sobie negatywnie oddziaływała na wodochłonność mąki, rozwój i stałości oraz rozmiękczenie ciasta. Wpływ intensyfikacji technologii uprawy na wodochłonność mąki, czas rozwoju ciasta, jego stałość i rozmiękczenie był wyraźnie pozytywny. Rozciągliwość oraz energia ciasta uzyskanego z mąki pszenicy uprawianej po sobie były zdecydowanie mniejsze niż uprawianej po rzepaku ozimym. Wykazano zdecydowanie pozytywne oddziaływanie wzrastającej intensywności procesu uprawy pszenicy na rozciągliwość i energię ciasta. Z kolei opór ciasta uzyskanego z ziarna pszenicy wyprodukowanego w technologii średnio intensywnej był istotnie mniejszy niż w oszczędnej. Intensyfikacja technologii uprawy silniej zwiększała wydajność chleba uzyskanego z ziarna pszenicy uprawianej po roślinach oleistych (głównie rzepaku ozimym i gorczyca sarepskiej) niż po sobie.

Słowa kluczowe: intensywność produkcji, jakość pieczywa, jakość mąki, przedplon, pszenica ozima, właściwości reologiczne ciasta

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