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ESTIMATION OF PROTEIN-STARCH COMPLEX OF SELECTED WHEAT SPECIES DEPENDING ON PRODUCTION TECHNOLOGY INTENSITY*

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Summary. The aim of this study was to assess the effect of different levels of production technology on grain quality of 4 species of winter wheat: common wheat cultivar 'Tonacja', durum wheat cultivar 'Komnata', spelt wheat cultivar 'Schwabenkorn' and einkorn wheat – gene bank material PL 5003. The research material consisted of grain obtained from field experiments carried out in 2010−2013 at the Felin Experimental Farm, belonging to the University of Life Sciences in Lublin. The study showed that intensification of production technology increased water absorption and decreased amylolytic activity of wholemeal grain tested by mixolab, but had no effect on gluten content. Among the analysed species, spelt wheat was characterised by the highest gluten content and the longest resistance time of dough. Durum wheat was characterised by the highest amylolytic activity, tested both by the falling number method and using the mixolab, compared to the other wheat species.

Key words: common wheat, durum wheat, einkorn wheat, spelt wheat, mixolab, rheological properties of wheat dough

INTRODUCTION

Nowadays the acquisition of high and good quality yields is the fundamental task of contemporary agriculture. In the world more and more often note is taken of the need of broader utilisation of plant materials, valuable nutritionally and so far underestimated, such as e.g. the grain and products of somewhat forgotten wheat species. Diet impover-

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ishment is, next to environmental pollution and stress factors, one of the primary causes of many civilisation diseases. For this reason in agricultural practice we can encounter, on our fields and tables, raw materials not only from common wheat (*Triticum aestivum* ssp. *aestivum*) but also from durum wheat (*Triticum durum*), spelt wheat (*Triticum aestivum* ssp. *spelta*), emmer wheat (*Triticum dicoccum*) or einkorn wheat (*Triticum monococcum*) [Rachoń 2001, Cyrkler-Degulis, Bulinska-Radomska 2006, Rachoń et al. 2013]. Products obtained from hulled wheat have higher nutritional value compared to common wheat. In recent years the interest in hulled wheats is increasing also due to the return to extensive methods of production [Cyrkler-Degulis, Bulińska-Radomska 2006, Kohaydova, Karovicova 2008].

In the available literature there are relatively few publications concerning the estimation of grain quality of various wheat cultivars (except for common wheat) with the use of the mixolab. That, among other things, was the reason for undertaking research in this area. The objective of the study was the estimation of quality of the wholegrain flour from grain of 4 winter wheat genotypes under conditions of diversified production technology. The research hypothesis assumed that intensification of production technology can cause changes in rheological properties of wholegrain flour and varied responses of the genotypes studied.

MATERIALS AND METHODS

In the years 2010–2013, at the Felin Experimental Farm of the University of Life Sciences in Lublin, a two-factor field experiment was conducted with the method of randomised blocks, in 4 replicates. The experimental field was located on a soil developed from silts of loess origin, classified in the good wheat complex. The soil was rich in phosphorus and potassium (P – 78.9 and K – 180.1 $mg \cdot kg^{-1}$ of soil), while the content of magnesium in the soil was at a low level (39.5 $mg \cdot kg^{-1}$).

The first experimental factor was the wheat species. The study included winter forms of common wheat (*Triticum aestivum* ssp. *aestivum* L.) – cultivar Tonacja, durum wheat (*Triticum durum* Desf.) – cultivar Komnata, spelt wheat (*Triticum aestivum* ssp. *spelta* (L.) Thell.) – cultivar Schwabenkorn, and einkorn wheat (*Triticum monococcum* L.) – PL 5003 (sowing material acquired from the National Centre of Plant Gene Resources). The second variable in the experiments was the levels of production technology: the medium level: mineral fertilisation (N – 70, P – 30.5 and K – 99.6 $kg \cdot ha^{-1}$), seed priming and weed control; the high level: increased nitrogen fertilisation (N – 140, P – 30.5 and K – 99.6 $kg \cdot ha^{-1}$), seed priming, weed control, 2 treatments against diseases, insecticide and growth regulator.

In the medium level of production technology the winter wheat was fertilised with nitrogen in the amount of 70 $kg \cdot ha^{-1}$, in 3 doses: the first dose (20 $kg \cdot ha^{-1}$) was applied before sowing, the second (30 $kg \cdot ha^{-1}$) in spring, at the tillering stage (stage 23–25 in the BBCH scale), and the final dose (20 $kg \cdot ha^{-1}$) in the period preceding heading (BBCH 47–49). In the high level of production technology nitrogen fertilisation was applied in the amount of

140 kg·ha^{-1} (in 3 doses): the first dose was applied before sowing (20 kg·ha^{-1}), the second in spring, in the phase of tillering (BBCH 23–25) – 80 kg·ha^{-1}, and the final one at the start of heading (BBCH 51–53) – 40 kg·ha^{-1}. To provide protection against lodging, at the start of the stem elongation phase (BBCH 30–32) the liquid anti-lodging agent 675 SL was applied (2.0 dm^3·ha^{-1}). The treatment against fungal diseases consisted in the application of Tango Star 334 SE at the beginning of the stem elongation phase (BBCH 30–32) – 1.0 dm^3·ha^{-1}, and Artea 330 EC at the end of the heading phase (BBCH 58–59) – 0.5 dm^3·ha^{-1}. In the period of pests occurrence the insecticide Sumi-Alpha 050 EC was applied – 0.25 dm^3·ha^{-1}. In both levels of production technology the grain was primed pre-sowing with the preparation Baytan Universal 094 FS at the dose of 400 ml of the preparation with an addition of 200 ml of water per 100 kg of grain. Monocotyledonous and dicotyledonous weeds were destroyed chemically, using herbicides Attribut 70 WG (60 g·ha^{-1}, in spring, after the start of vegetation) and Sekator 125 OD (0,15 dm^3·ha^{-1}, in spring, after the start of vegetation), respectively.

The grain samples were ground into wholegrain flour using the Perten 3100 Laboratory Mill. Gluten content, gluten index (PN-A-74042) and falling number (PN-EN ISO 3093) were determined to assess the baking quality of tested wheat samples. Rheological properties of dough were studied using the Chopin mixolab [Dubat 2010]. The protocol (ChopinWheat+) had the following settings: mixing speed 80 rpm, total analysis time 45 min, dough weight 75 g, hydration water temperature 30°C. Wholegrain flour and water were added accordingly to obtain a dough with a maximum consistency of 1.10 Nm (±0.05) during the first test phase. Mixolab test was performed using standard protocol: 8 min at 30°C, heating at a rate 4°C·min^{-1} for 15 min, holding at 90°C for 7 min, cooling to 50°C at a rate 4°C·min^{-1} for 10 min and holding at 50°C for 5 min.

A typical mixolab curve is divided into five different phases: phase 1, initial kneading; phase 2, protein weakening; phase 3, starch gelatinisation; phase 4, cooking stability; phase 5, starch retrogradation [Dubat 2010]. The parameters that are obtained from the curve are water absorption (%), dough development time (time T1, min), dough stability (min), protein weakening (C2 and the difference between points C1 and C2, abbreviated C1-C2, N·m), starch gelatinisation (C3, N·m), amylolytic activity (C4, N·m), starch retrogradation (C5, N·m). Dough temperature for C2 (D2, °C) and for C3 (D3, °C), gelatinisation time (T3-T2, min) and curve slopes between C1 and C2 (slope α, N·m·min^{-1}), between C2 and C3 (slope β, N·m·min^{-1}), between C3 and C4 (slope γ, N·m·min^{-1}) were also recorded. For this study, also the torque in the 8th minute of mixolab analyses was checked from the curve (abbreviated C_{8min}), as well as the differences between C_{8min} and C2 (abbreviated C_{8min}–C2, N·m).

The results were statistically evaluated by the three-way analysis of variance (ANOVA) with subsequent Tukey's HSD test with Statgraphics Centurion XVI.I. Three main factors were: species of wheat, crop year and growing technology. Correlations between the mixolab parameters and wheat quality characteristics (gluten content and falling number) were determined with the statistical significance expression on the level $p = 0.05$ and $p = 0.01$.

RESULTS AND DISCUSSION

Gluten content is a common wheat specification required by end-users in the food industry and determines water absorption, dough stability, dough resistance and elasticity [Dhaka 2012]. The gluten content depended on wheat species and on the crop year (Tab. 1). The highest gluten content was noted in spelt wheat cultivar 'Schwabenkorn' and the lowest in einkorn wheat PL5003. These results agree with Abdel-Aal et al. [1995]. According to Rachoń et al. [2011] durum wheat was characterised by the highest gluten content, whereas common wheat was particularly low. Spelt wheat is usually characterised by higher gluten content than common wheat [Majewska et al. 2007].

Table 1. Qualitative features of tested winter wheat species

Tabela 1. Cechy jakościowe badanych gatunków pszenicy ozimej

	Gluten content Ilość glutenu [%]	Gluten Index Indeks glutenu	Falling number Liczba opadania [s]	Water absorption Wodochłonność [%]	Time T1 Czas T1 [min]	Stability Stałość [min]	Time T1 + + stability Czas T1 + + stałość [min]
Wheat species – Gatunek pszenicy (A)							
Common	30.5^{b}	48^{b}	198^{b}	62.6^{a}	3.2^{b}	6.2^{c}	9.4^{c}
Durum	26.9^{ab}	12^{a}	123^{a}	62.3^{a}	1.6^{a}	3.0^{b}	4.6^{b}
Spelt	40.6^{c}	17^{a}	223^{b}	62.9^{a}	4.4^{c}	6.8^{c}	11.2^{d}
Einkorn	22.4^{a}	23^{ab}	238^{b}	62.8^{a}	1.6^{a}	1.2^{a}	2.8^{a}
Growing technology – Technologia uprawy (B)							
Medium – Średnia	29.1^{a}	27^{a}	198^{a}	61.7^{a}	2.6^{a}	4.6^{b}	7.2^{a}
High – Wysoka	31.1^{a}	23^{a}	192^{a}	63.6^{b}	2.8^{a}	4.1^{a}	6.9^{a}
Crop year – Rok zbioru ziarna (C)							
2011	36.6^{c}	28^{a}	83^{a}	62.1^{a}	2.6^{a}	4.5^{b}	7.1^{b}
2012	31.6^{b}	28^{a}	281^{c}	64.1^{b}	3.3^{b}	5.3^{c}	8.6^{c}
2013	22.1^{a}	19^{a}	222^{b}	61.8^{a}	2.2^{a}	3.1^{a}	5.3^{a}
Interactions – Interkacje							
AB	–	–	–	–	–	–	+
AC	+	–	+	+	–	+	+
BC	–	–	–	–	–	+	+

a, b – values marked with the same letters do not differ significantly at p = 0.05 and p = 0.01, respectively/wartości oznaczone tą samą literą nie różnią się istotnie przy p = 0,05 i p = 0,01.

+ – interaction exists/interakcja występuje.

The higher level of growing technology did not cause any increase in gluten content (Tab. 1), in contrast to earlier studies by Woźniak [2006] and Rachoń et al. [2013]. A similar observation was noted by Nowak et al. [2004] who proved that different levels of growing technology exert equal influence on the quality of all wheat species. Gluten content of the wheat crop varies from year to year. The highest gluten content was determined in wheat samples from crop year 2011, and the lowest from crop year 2013. Falling number gives an indication of the amount of sprout damage that has occurred within a wheat sample. Falling number in tested wheat samples ranged from 62 to 351 s. Values below 200 s indicate a high level of enzyme activity. The highest alpha-amylase activity was noted in durum wheat cultivar 'Komnata' (Tab. 1). These results agree with Rachoń et al. [2011]. According to Abdel-Aal et al. [1997], common wheat and durum wheat flours had significantly higher falling number than spelt and einkorn wheat. Unfavourable weather conditions during vegetation period and harvest strongly influenced the quality of grain from 2011 crop which was characterised by the lowest falling number, which indicates sprout damage of grain [Szafrańska 2012]. The interaction of wheat species and crop year affected both gluten content and falling number.

Water absorption is an indicator of baking quality. Protein content and starch damage are the main factors that influence the water absorption capacity of the flours. Water absorption in tested wheat wholegrain samples ranged from 57.0 to 67.2%. These results agree with the observation of Szafrańska [2012] for water absorption of common wheat. There were no significant differences in water absorption between tested wheat species (Tab. 1). According to Rachoń et al. [2011], durum wheat was characterised by the highest farinograph water absorption, whereas spelt wheat was particularly low. The highest mixolab water absorption was noted for wholegrain common wheat (69.1%), whereas a lower value was determined for durum wheat (67.6%) and the lowest for spelt wheat (58.0%) [Anonymous 2012]. Wheat samples cultivated with the high growing technology were characterised by higher water absorption (Tab. 1). The highest water absorption was determined in wheat samples from crop year 2012.

The strength of a wheat cultivar could be determined from the mixolab curve on the basis of dough development time (time T1), dough stability during mixing, C2 and slope α [Caffe-Treml et al. 2010, Dhaka et al. 2012]. Time T1 and dough stability were significantly dependent on the tested wheat species and crop year (Tab. 1). Long development time (time T1) and stability indicate that wholegrain wheat is strong. Spelt wheat cultivar 'Schwabenkorn' exhibited the characteristics of good quality wheat cultivars with the longest time T1 (4.4 min) and higher dough stability (6.8 min), whereas einkorn wheat PL 5003 had shorter time T1 and dough stability (1.6 and 1.2 min, respectively) (Tab. 1). According to Rachoń et al. [2011], there is no significant difference between farinograph stability time of common wheat and durum wheat, whereas spelt wheat has the highest value of this parameter. According to the criterion of Dhaka et al. [2012], tested durum wheat cultivar 'Komnata' and einkorn wheat PL 5003 are weak cultivars characterised by low dough stability (≤ 4 min) and C2 values below 0.4 N·m (Tab. 2), indicating that these doughs are less tolerant to mixing as compared to the other wheat cultivars. Poor rheological properties of einkorn doughs were shown also by Abdel-Aal et al. [1997].

The slope α is related to proteins thermal weakening and is also indicative of dough strength [Koksel et al. 2009, Caffe-Treml et al. 2010]. The slope α was significantly dependent on the cultivar and the crop year (Tab. 2). Wholegrain flour dough from einkorn wheat PL 5003 was characterised by the highest value of slope α. The difference between mixolab values C1 and C2 is related to gluten quality – higher values indicate weaker gluten properties [Koksel et al. 2009]. Wholegrain flour dough from durum wheat cultivar 'Komnata' had the highest values of C1–C2 which means that this cultivar has the lowest proteolytic activity (Tab. 2).

Table 2. Rheological properties of wholegrain dough from winter wheat in terms of protein characteristics significant

Tabela 2. Właściwości reologiczne ciasta ze śruty całoziarnowej z ziarna pszenicy ozimej charakteryzujące cechy białka

	C2 [N·m]	α [N·m·min^{-1}]	C1–C2 [N·m]	C_{8min} [N·m]	C_{8min}–C2 [N·m]
Wheat species – Gatunek pszenicy (A)					
Common	0.35^{d}	-0.067^{ab}	0.75^{a}	0.64^{a}	0.57^{c}
Durum	0.16^{a}	-0.057^{b}	0.96^{c}	0.92^{b}	0.48^{b}
Spelt	0.32^{c}	-0.072^{a}	0.78^{ab}	0.98^{b}	0.66^{d}
Einkorn	0.28^{b}	-0.039^{c}	0.82^{b}	0.62^{a}	0.34^{a}
Growing technology – Technologia uprawy (B)					
Medium – Średnia	0.28^{a}	-0.060^{a}	0.84^{a}	0.80^{a}	0.52^{a}
High – Wysoka	0.28^{a}	-0.057^{a}	0.82^{a}	0.78^{a}	0.50^{a}
Crop year – Rok zbioru ziarna (C)					
2011	0.24^{a}	-0.057^{b}	0.86^{b}	0.77^{b}	0.53^{b}
2012	0.33^{b}	-0.067^{a}	0.78^{a}	0.88^{c}	0.55^{b}
2013	0.26^{a}	-0.052^{b}	0.84^{b}	0.72^{a}	0.46^{a}
Interactions – Interakcje					
AB	–	–	–	–	–
AC	+	+	+	+	+
BC	–	–	–	–	–

[a,b] – values marked with the same letters do not differ significantly at p = 0.05 and p = 0.01, respectively/wartości oznaczone tą samą literą nie różnią się istotnie przy p = 0,05 i p = 0,01.

+ – interaction exists/interakcja występuje.

During mixolab test the dough and the mixer are kept at 30°C for 8 min. After this time there is a gradual temperature rise with a gradient of 4°C·min^{-1}. As the temperature increases the consistency of the dough decreases with excessive mixing, which is an indication of protein weakening [Dubat 2010]. The greater the decrease in consistency, the lower the protein quality.

Mixolab allows to characterise wheat and flours in terms of protein quality as well as starch behaviour during gelatinisation and retrogradation. Wholegrain flour from durum wheat cultivar 'Komnata', which was characterised by the highest alpha-amylase activity tested by the falling number method, had the lowest consistency of a dough after starch gelatinisation (C3), the lowest stability during heating (C4) and retrogradation (Tab. 3). Wheat samples cultivated with the high level of growing technology were characterised by the lowest values of torque in points C3, C4 and C5. Rains during harvest of grain from 2011 crop strongly influenced the amylolyitc activity measured by mixolab and caused the lowest values of torque in points C3, C4 and C5.

Slope β is an indicator of pasting speed [Koksel et al. 2009]. Wholegrain flour from durum wheat cultivar 'Komnata' has the lowest β slope which indicates a slow gelatinisation processes [Caffe-Treml et al. 2010].

Table 3. Rheological properties of wholegrain dough from winter wheat in terms of starch characteristics

Tabela 3. Właściwości reologiczne ciasta ze śruty całoziarnowej z ziarna pszenicy ozimej charakteryzujące właściwości skrobi

	C3 [N·m]	C4 [N·m]	C5 [N·m]	β [N·m·min⁻¹]	γ [N·m·min⁻¹]	D2 [°C]	D3 [°C]	T3 – T2 [min]
Wheat species – Gatunek pszenicy (A)								
Common	1.58^{b}	0.69^{b}	1.16^{b}	0.511^{b}	–0.093^{a}	55.0^{a}	72.6^{b}	4.7^{c}
Durum	0.71^{a}	0.24^{a}	0.37^{a}	0.187^{a}	–0.141^{a}	55.3^{a}	69.9^{a}	4.0^{a}
Spelt	1.56^{b}	0.88^{c}	1.47^{c}	0.589^{b}	–0.071^{a}	55.5^{a}	72.7^{b}	4.5^{bc}
Einkorn	1.57^{b}	1.22^{d}	2.14^{d}	0.577^{b}	–0.052^{a}	57.8^{b}	74.0^{c}	4.3^{ab}
Growing technology – Technologia uprawy (B)								
Medium – Średnia	1.38^{b}	0.80^{b}	1.35^{b}	0.471^{a}	–0.123^{a}	56.0^{a}	72.7^{b}	4.4^{a}
High – Wysoka	1.32^{a}	0.72^{a}	1.22^{a}	0.461^{a}	–0.056^{a}	55.8^{a}	72.0^{a}	4.3^{a}
Crop year – Rok zbioru ziarna (C)								
2011	1.24^{a}	0.38^{a}	0.64^{a}	0.445^{a}	–0.050^{a}	55.7^{a}	69.8^{a}	3.8^{a}
2012	1.50^{c}	1.07^{c}	1.82^{c}	0.503^{a}	–0.067^{a}	56.7^{b}	75.3^{c}	4.9^{c}
2013	1.32^{b}	0.82^{b}	1.39^{b}	0.450^{a}	–0.150^{a}	55.4^{a}	71.8^{b}	4.4^{b}
Interactions – Interakcje								
AB	+	+	+	–	–	–	+	+
AC	–	–	–	–	–	–	+	–
BC	–	–	–	–	–	–	–	–

$^{a, b}$ – values marked with the same letters do not differ significantly at p = 0.05 and p = 0.01, respectively/wartości oznaczone tą samą literą nie różnią się istotnie przy p = 0,05 i p = 0,01.

+ – interaction exists/interakcja występuje.

Initial temperature of starch gelatinisation (D2) was in the range of 54.1–59.6°C and final temperature of starch gelatinisation (D3) in the range of 65.2–75.8°C. Significantly higher temperature D2 and D3 was noted for the wholegrain flour dough from einkorn wheat PL 5003 (Tab. 3). Initial and final temperature of gelatinisation was strongly influenced by the weather conditions during vegetation period and harvest of the crop year. A similar observation was also noted by Szafrańska [2012]. Significantly lower gelatinisation time (T3–T2) was noted for wholegrain flour dough from durum wheat cultivar 'Komnata' (mean 4.0 min) and for crop year 2011 (mean 3.8 min). The highest correlation coefficient was obtained between falling number and amylase activity C4 and temperature D3.

Correlation between wholegrain flour quality parameters shows that gluten content has the positive influence on mixolab water absorption (r = 0.630) and time T1(r = 0.631) whereas negative influence on slope α (r = –0.610) (Tab. 4). The gluten content was found to be correlated with C_{8min} (r = 0.461) and the difference C_{8min} and C2 (r = 0.569), whereas there was no significant correlation between gluten content and C2. Falling number was positively correlated with the torque in points C2, C3, C4 and C5, final temperature of gelatinization D3 and gelatinization time T3–T2 (Tab. 5). The positive correlation between the β slope and falling number (0.540) (Tab. 5) gives indications about the hydrolytic activity of alpha-amylase during the heating period.

Table 4. Correlation coefficient between gluten content and selected mixolab parameters significant at p = 0.05 and p = 0.01*

Tabela 4. Współczynniki korelacji między ilością glutenu a wybranymi parametrami z mixolabu istotne przy p = 0,05 i p = 0,01*

	Water absorption Wodochłonność	Stability Stałość	α	Time T1 Czas T1	Time T1+ + stability Czas T1+ + stałość	C_{8min}	C_{8min}–C2
Gluten content Ilość glutenu	0.630*	0.529*	–0.610*	0.631*	0.576*	0.461	0.569*

Table 5. Correlation coefficient between falling number and selected mixolab parameters significant at p = 0.05 and p = 0.01*

Tabela 5. Współczynniki korelacji między liczbą opadania a wybranymi parametrami z mixolabu istotne przy p = 0,05 i p = 0,01*

	C2	C3	C4	C5	β	D3	T3–T2
Falling number Liczba opadania	0.489	0.535*	0.810*	0.786*	0.540*	0.812*	0.624*

CONCLUSIONS

1. Analysed winter wheat species were differentiated in terms of protein and starch properties. Spelt wheat cultivar ‘Schwabenkorn’ was characterised by the highest gluten content and the highest sum of time T1 and stability. The highest alpha-amylase activity determined both by falling number method and mixolab test was found for durum wheat cultivar ‘Komnata’.

2. Analysed winter wheat species cultivated at the high level of growing technology were characterised by significantly higher water absorption, lower stability of dough, starch gelatinisation C3, amylase activity C4 and retrogradation C5 than wheat cultivated at the medium growing technology.

3. Crop year had a significant effect on wet gluten content, water absorption, resistance time of dough (Time T1+ stability) and starch characteristics such as starch gelatinisation C3, amylase activity C4 and retrogradation C5.

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OCENA KOMPLEKSU BIAŁKOWO-SKROBIOWEGO WYBRANYCH GATUNKÓW PSZENICY W ZALEŻNOŚCI OD INTENSYFIKACJI UPRAWY

Streszczenie. Celem badań była ocena jakości ziarna czterech gatunków pszenicy ozimej w zależności od zróżnicowanego poziomu agrotechniki. W badaniach uwzględniono: pszenicę zwyczajną (*Triticum aestivum* ssp. *aestivum* L.) odmiany 'Tonacja', pszenicę twardą (*Triticum durum* Desf.) odmiany 'Komnata', pszenicę orkisz (*Triticum aestivum* ssp. *spelta* (L.)) odmiany 'Schwabenkorn' i pszenicę jednoziarnistą (*Triticum monococcum* L.) – materiał z banku genów PL 5003. Materiał badawczy stanowiło ziarno pszenicy otrzymane z doświadczeń polowych prowadzonych w latach 2010–2013 na terenie Gospodarstwa Doświadczalnego Felin, należącego do Uniwersytetu Przyrodniczego w Lublinie. Zastosowano dwa poziomy agrotechniki: przeciętny poziom agrotechniki – nawożenie mineralne (N – 70, P – 30,5 i K – 99,6 $kg \cdot ha^{-1}$), zaprawianie ziarna i zwalczanie chwastów, wysoki poziom agrotechniki – zwiększone nawożenie azotowe (N – 140, P – 30,5 i K – 99,6 kg·ha^{-1}), zaprawianie ziarna, zwalczanie chwastów, dwa zabiegi przeciw chorobom, insektycyd i regulator wzrostu. Ziarno rozdrobniono za pomocą rozdrabniacza laboratoryjnego FN3100 (Perten), a następnie oznaczono ilość i indeks glutenu (PN-A-74042) oraz liczbę opadania (PN-EN ISO 3093). Właściwości reologiczne ciasta ze śruty całoziarnowej określono za pomocą aparatu mixolab firmy Chopin (protokół ChopinWheat+). Uzyskane wyniki badań śruty całoziarnowej opracowano statystycznie, wykonując trzyczynnikową analizę wariancji, gdzie źródłem zmienności były: gatunek pszenicy, zastosowany poziom agrotechniki, rok zbioru ziarna oraz interakcje między wymienionymi czynnikami. Istotność różnic wartości średnich wykonano testem t-Tukeya przy poziomie istotności p = 0,05 i p = 0,01. W celu określenia zależności między badanymi wyróżnikami jakościowymi wyznaczono współczynniki korelacji liniowej Pearsona. Do obliczeń wykorzystano program Statgrafics Centurion XVI.I.

Przeprowadzone badania wykazały, że na właściwości reologiczne ciasta ze śruty całoziarnowej istotny wpływ miały zastosowane czynniki doświadczenia oraz ich interakcje. Śruta całoziarnowa uzyskana z ziarna uprawianego w wysokim poziomie agrotechniki charakteryzowała się większą wodochłonnością oraz krótszym czasem stałości ciasta, a także niższą aktywnością enzymów amylolitycznych określoną za pomocą mixolabu w porównaniu do ziarna uprawianego w przeciętnym poziomie agrotechniki. Zastosowany wysoki poziom agrotechniki nie miał natomiast wpływu na ilość glutenu. Warunki pogodowe panujące w trakcie wegetacji i zbioru ziarna wpłynęły istotnie na ilość glutenu, wodochłonność śruty całoziarnowej, oporność ciasta na mieszenie (suma czasu T1 i stałości) oraz na właściwości skrobi, takie jak: kleikowanie skrobi (C3), aktywność enzymów amylolotycznych (C4) oraz retrogradacja skrobi (C5). Spośród analizowanych gatunków pszenica orkisz charakteryzowała się największą ilością glutenu i największą tolerancją ciasta na miesienie. Największą aktywnością enzymów amylolitycznych określanych liczbą opadania i za pomocą mixolabu cechowała się pszenica durum w porównaniu do śruty całoziarnowej pozostałych badanych gatunków pszenicy.

Słowa kluczowe: pszenica zwyczajna, pszenica twarda, pszenica jednoziarnista, pszenica orkisz, mixolab, właściwości reologiczne ciasta pszennego