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MILLING QUALITY OF SPRING TRITICALE GRAIN UNDER DIFFERENT NITROGEN FERTILIZATION

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Key words: milling, triticale, nitrogen fertilization, specific grinding energy, particle size distribution.

Abstract

This paper presents the milling parameters of spring triticale grain fertilized with nitrogen in doses of 80 and 120 kg ha^{-1}. The varied nitrogen fertilization level influenced the physical properties of triticale grain of significant importance during milling such as: test weight, thousand kernel weight, vitreousness and hardness expressed by the PSI index. Increasing the fertilization dose from 80 to 120 kg N ha^{-1} contributed to a decrease the energy demand for grain milling from 38.98 to 33.44 kJ kg^{-1} and a decrease in ash content in the grain. The use of the higher nitrogen dose caused an increase in the mean particle size of the milling product from 242 to 352 μm. The milling products of each of the studied cereals consisted of particles with sizes from 0.5 μm to 2000 μm. Each milling product was characterized by distribution with five modes. For sizes below 30 μm, the particle size distributions of all studied materials were comparable. The nitrogen fertilization level diversified the milling products with regard to the content of the other size fractions.

JAKOŚĆ PRZEMIAŁU ZIARNA PSZENŻYTA JAREGO NAWOŻONEGO RÓŻNYMI DAWKAMI AZOTU

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Słowa kluczowe: przemiał, pszenżyto, nawożenie azotem, energochłonność rozdrabniania, rozkład wielkości cząstek.

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Abstract

Przedstawiono wyniki badań procesu przemiału ziarna pszenżyta jarego nawożonego azotem w dawkach 80 i 120 kg ha^{-1}. Zróżnicowany poziom nawożenia azotem wpłynął na cechy fizyczne ziarna pszenżyta mające istotne znaczenie podczas przemiału, takie jak: gęstość usypowa, masa tysiąca ziaren, szklistość oraz twardość technologiczna wyrażona wskaźnikiem PSI. Zwiększenie dawki nawożenia z 80 na 120 kg N ha^{-1} przyczyniło się do zmniejszenia twardości ziarna, a wraz z nią do zmniejszenia zapotrzebowania na energię do przemiału ziarna z 38,98 do 33.44 kJ kg^{-1}. Zmniejszyła się również zawartość popiołu w ziarnie. Zastosowanie większej dawki azotu spowodowało zwiększenie średniego rozmiaru cząstek produktu przemiału z 242 do 352 μm. Produkty przemiału każdego z badanych zbóż składały się z cząstek o wielkościach od 0.5 μm do 2000 μm. Każdy z produktów przemiału charakteryzował się rozkładem o pięciu dominantach. W zakresie wielkości poniżej 30 μm rozkłady wielkości cząstek wszystkich badanych materiałów były porównywalne. Poziom nawożenia azotem różnicował produkty przemiału pod względem zawartości pozostałych frakcji rozmiarowych.

Introduction

Triticale (*Triticale*) is an interspecific hybrid obtained by crossing wheat (*Triticum*) and rye (*Secale*). This is a cereal with lower soil requirements than wheat which is more disease-resistant than wheat or rye. It is characterized by good winter hardiness and shows higher drought resistance than wheat (AMMAR et al. 2004). The physical properties and chemical composition of triticale grain take values intermediate between the values of the properties of the parental species. Triticale grain is a good source of protein with a favorable amino acid composition (PISULEWSKA et al. 2000). Triticale grain of spring varieties characterized by higher protein content compared to winter forms (PETKOV et al. 2000).

Triticale grain is used mainly for feed, although is a potential alternative to wheat in processed flour products such as bread, flat bread, cakes or pasta. Because of the nutritional benefits of triticale grain, undertaking research on improving its quality is still needed. Breeders are attempting to obtain new *Triticale* varieties with better grain properties, which will improve the milling and baking process (ZECEVIC et al. 2005).

The basic process in grain processing is milling, whose aim is first the separation of the endosperm, the pericarp and germs and the reduction of endosperm particles to a fraction, which passes through a sieve with an aperture of not larger than about 200 μm (POSNER 2003). The result of the milling process is affected by both the milling scheme used and the grain properties and the design and settings of the equipment. Cereal grain properties depend on genetic factors and environmental conditions and on agrotechnical practices – especially nitrogen fertilization (POMERANZ et al. 1985, DZIAMBA et al. 2001, YÜCEL et al. 2009, EDWARDS et al. 2010). The most important physical properties of grain affecting milling include grain hardness and vitreousness (GREFFEUILLE et al. 2007a, GREFFEUILLE et al. 2007b, DZIKI et al. 2011). During grinding of hard endosperm wheat grain, flour with thicker granulation and partly damaged starch grains is obtained (LETANG et al. 2001). Grain hardness significantly affects the energy consumption of grinding. Hard kernels require more energy during milling into flours than soft kernels (KILBORN et al. 1982, DZIKI and LASKOWSKI 2005, DZIKI and PRZYPEK-OCHAB 2009). Grain vitreousness is often interrelated with grain hardness. Kernels with more vitreous endosperm are most often harder (GLENN and JOHNSTON 1994) and increased endosperm vitreousness for hard wheats is associated with higher flour yields (DOBRASZCZYK 1994, HADDAD et al. 1999). According to MARSHALL et al. (1986), the geometric properties of grain such as length, width, thickness, sphericity and endosperm size also affect milling directly. Grain length, width and area have been associated with a 40% variation in the milling quality of winter wheat cultivars (BERMAN et al. 1996).

The milling value of grain, besides its physical properties, can also be evaluated on the basis of experimental milling (POSNER 2003). Based on experimental grain milling, among others, the amount and granulometric composition of semi-finished products and final products of the industrial process can be determined. Granulometric composition is of importance in subsequent processing stages. Depending on the raw material size reduction ratio, the course of such processes as: mixing, dough preparation and baking is different. The quality of the obtained products is also different (PARK et al. 2006). The energy consumption of the grinding process is directly associated with the product size reduction ratio. Energy inputs for the grinding process grow with an increasing size reduction ratio (LASKOWSKI et al. 2005).

In view of the increasing acreage of triticale cultivation in the world and the introduction of new varieties into cultivation (SALMON et al. 2004), it is necessary to evaluate the effect of triticale reaction to agrotechnical factors, especially nitrogen fertilization, in the aspect of the milling value of this grain, especially since many authors (BISKUPSKI 2000, JOHANSSON et al. 2001, MUT et al. 2005, STANKOWSKI et al. 2008, SOBCZYK et al. 2009) have indicated the possibility of influencing the quality of cereal grain by nitrogen fertilization. For these reasons, the aim of this paper was to study the physical properties of spring triticale grain fertilized with different nitrogen doses, influencing the milling process for grain and its milling.

Materials and Methods

Two modern spring triticale varieties, Andrus and Milewo, were selected for the research. A description of these cultivars can be found in the Common Catalogue of Varieties of Agricultural Plant Species (EU) in 2011. Grain came from a field experiment conducted at the Teaching and Research Centre in Tomaszkowo (53°73'N 20°41'E) in 2010–2011. The experiment was conducted using the method of random sub-blocks, in three replications. 30.2 kg P ha^{-1} in the form of 46% triple superphosphate and 83 kg K ha^{-1} as potash salt were applied in triticale fertilization. Nitrogen fertilization – was applied at two levels: 80 kg ha^{-1} (40 kg in the tillering phase and 40 kg in the shooting phase) and 120 kg ha^{-1} (40 kg pre-sowing, 40 kg in the tillering phase and 40 kg in the shooting phase). The pre-sowing fertilizer was ammonium nitrate and the fertilizer for top dressing 46% urea.

Grain samples in the quantity of 3 kg each were cleaned and the grain moisture content was then determined (ICC Standard No. 110/1). The moisture content of the grain was increased to 15%, by adding the appropriate amount of distilled water. The increase in the moisture content of grain was carried out in sealed containers during 24 h. The following physical properties of triticale grain were determined before the milling of each sample: test weight (TW), thousand kernel weight (TKW), particle size index (PSI) and grain vitreousness. TKW was measured for each sample with the use of an electronic kernel counter (Kernel Counter LN S 50A, UNITRA CEMI) and an electronic scale WPE 120. The particle size index (PSI) was determined in accordance with the AACC 55-30: 2000 method. The vitreousness of grain was evaluated on the basis of the analysis of cross-sections of kernels and expressed as the percentage of vitreous kernels in the sample of 50 elements (GREFFEUILLE et al. 2007b). The partially vitreous kernels were classified as semi-vitreous kernels and their number in the sample was multiplied by 0.5. The ash content in triticale grain and in the flours obtained after milling (*Determination of ash*... ICC Standard No. 104/1). The protein content in triticale grain was determined by the Kjeldahl method (*Determination of crude protein*... ICC Standard No. 105/2).

Grain milling (100-gram samples) was carried out in a Brabender Quadrumat Junior laboratory mill, equipped with a cylindrical sifter fitted with a 70GG sieve (PE 236 μm). Six samples of each material were ground. The yields of the obtained flours and the milling efficiency factor K were determined (SITKOWSKI 2011):

$$K = \frac{Flour\ extract}{Ash\ content\ in\ flour} \qquad (1)$$

The mill was connected with the power source through the system measuring the consumption of electrical energy. The grinding time (t_r) was measured with a stop watch to an accuracy of ± 0.1 s. The power of idle running (P_s) of the mill was also determined (the average value of power consumed before the measurements and immediately after the milling of the last sample of each material). The energy necessary for putting the elements of the mill into motion (E_s – energy of idle running) was calculated by multiplying the active power of idle running and the time of grinding ($E_s = P_s \cdot t_r$). The work of grinding was determined assuming that the total energy consumed (E_c) by the mill equaled the sum of grinding energy and the energy needed for putting the elements of the mill into motion. The specific energy of grinding E_r [kJ kg^{-1}] was calculated with the following formula:

$$E_r = \frac{E_c - E_s}{m} \qquad (2)$$

where:
m – mass of the milled sample [kg]

The grinding index K_0 (energy required to produce 1 kg of flour) [kJ kg^{-1} of flour] was also determined acc. to Greffeuille et al. (2007b):

$$K_0 = \frac{E_c - E_s}{m_{\mathrm{Fl}}} \qquad (3)$$

where:
m_{Fl} – mass of flour [kg].

The particle size distribution (PSD) of ground grain particles (middlings) was determined quantitatively by the Laser Diffraction Analysis method in a Malvern Mastersizer 2000 analyzer. The measurement result was obtained as the mean of three successive replications. The analysis of the granulometric composition of the grist determined the mean particle size according to the formula (Velu et al. 2006):

$$d_p = \sum_{i=1}^{n} \varphi_i d_i \qquad (4)$$

where:
φ_i – share of the size fraction i in the studied sample [kg kg^{-1}],
d_i – mean size of fraction i particles [µm].

PSD measurements were performed after mixing of undersized and oversize particles, obtained from drum sieve mounted in mill.

The mean linear dimension of grain before grinding was determined as the arithmetic mean from the sizes of equivalent diameters of a representative sample of 30 kernels. The equivalent diameter was determined as the geometric mean from grain length (L), width (W) and thickness (T) (MOHSENIN 1986):

$$d_z = (LWT)^{1/3} \tag{5}$$

Geometric grain measurements were taken manually with an electronic caliper ($\Delta = \pm 0.05$ mm). The results are presented as the mean of the two years. Value of each of the quality of research in the following seasons were at the same level. A statistical analysis of the obtained results was conducted, including an analysis of variance using the software STATISTICA® for Windows v. 10 (StatSoft Inc.). The significance of differences between means was determined using Tukey's test. Statistical hypotheses were tested at the significance level of $\alpha = 0.05$.

Results

Significant variation in the studied physicochemical properties of grain under the influence of the applied fertilization levels was demonstrated (Table 1). The test weight ranged from 65.5 to 67.5 kg hl^{-1}. Fertilization with the higher nitrogen dose contributed to an increased TW as well as increased TKW. Higher TKW values were found for the Andrus variety. The studied triticale varieties were characterized by floury endosperm structure (the mean percentage of vitreous kernels was from 20% to 36%). Fertilization with a higher nitrogen dose contributed to decreased grain vitreousness.

Table 1

Selected physical and chemical properties of the triticale grains (average values from the years 2010–2011)

Variety	TW [kg hl^{-1}]	TKW [g]	Vitreousness [%]	Protein content [%]	PSI [%]	Ash content [%]
Andrus 80	$65.9^a \pm 0.03$	$36.0^c \pm 0.5$	$36^b \pm 2.1$	$11.62^a \pm 0.04$	$34^a \pm 0.5$	$2.20^d \pm 0.02$
Andrus 120	$66.8^b \pm 0.20$	$38.0^d \pm 0.3$	$24^a \pm 2.9$	$11.71^a \pm 0.25$	$38^c \pm 1.0$	$2.16^c \pm 0.03$
Milewo 80	$65.5^a \pm 0.10$	$33.6^a \pm 0.3$	$26^a \pm 2.3$	$12.70^b \pm 0.14$	$35^{a,b} \pm 2.0$	$2.12^b \pm 0.02$
Milewo 120	$67.5^c \pm 0.40$	$35.0^b \pm 0.7$	$20^a \pm 2.9$	$12.23^c \pm 0.20$	$37^{b,c} \pm 1.0$	$2.05^a \pm 0.02$
Fertilization						
80	$65.7^a \pm 0.20$	$34.8^a \pm 1.3$	$31^b \pm 6.1$	$12.16^a \pm 0.59$	$34.5^a \pm 1.0$	$2.16^b \pm 0.04$
120	$67.1^b \pm 0.40$	$36.5^b \pm 1.6$	$22^a \pm 3.5$	$11.97^a \pm 0.35$	$37.5^b \pm 1.0$	$2.10^a \pm 0.05$

Explanations: data are average values ± standard deviation, *a, b, c, d* – differences of values in columns (for the given variety) marked with the same letters are insignificant at $\alpha = 0.05$

The particle size index (PSI) ranged from 34% to 38%. Increasing the nitrogen fertilization of the studied triticale varieties contributed to increases in the PSI index. Triticale grains obtained from plots fertilized with nitrogen in the amount of 80 kg N ha^{-1} were classified as very soft grains and from the plot fertilized with a dose of 120 kg N ha^{-1} were classified as extra soft grains. The mean ash content in grain ranged from 2.05% to 2.2%. Increased nitrogen fertilization caused decreased ash content in grain.

Results of the evaluation of triticale grain geometrical properties are shown in Table 2. Triticale fertilization with the higher nitrogen dose contributed to increased grain length and decreased width but did not affected the grain thickness and geometric mean diameter. Flour extracts obtained from grain milling ranged from 59.3 (Andrus variety) to 63.7% (Milewo variety) – Table 3. No significant effect of nitrogen fertilization on this property was found. No significant effect of nitrogen fertilization on the ash content in flours obtained from milling was demonstrated either. The different nitrogen fertilization had no effect on the ash content of the flour. This variety was also distinguished by higher milling efficiency factor K, with the highest value of the K factor (112) recorded for fertilization with the higher nitrogen dose. The amount of energy consumed for triticale grain grinding depended on the level of applied nitrogen fertilization. The higher nitrogen dose caused a decrease in energy spent during grain milling, favorable in terms of milling into flour. The grain grinding index K_0, corresponding to the energy necessary to obtain the appropriate quantity of flour, similar to the energy consumed for grain grinding, depended on the applied nitrogen fertilization. The dose of 120 kg N ha^{-1} contributed to decreased K_0 and energy used for grain grinding.

Table 2

Geometrical properties of the triticale grains (average values from the years 2010–2011)

Variety	Length [mm]	Width [mm]	Thickness [mm]	Geometric mean diameter (d_z) [mm]
Andrus 80	$8.28^{a,b} \pm 0.51$	$3.26^{a} \pm 0.25$	$3.18^{a} \pm 0.19$	$4.41^{a} \pm 0.24$
Andrus 120	$8.23^{a,b} \pm 0.37$	$3.08^{a} \pm 0.29$	$3.08^{a} \pm 0.23$	$4.27^{a} \pm 0.23$
Milewo 80	$8.09^{a} \pm 0.39$	$3.16^{a} \pm 0.29$	$3.06^{a} \pm 0.27$	$4.27^{a} \pm 0.29$
Milewo 120	$8.51^{b} \pm 0.56$	$3.14^{a} \pm 0.28$	$3.14^{a} \pm 0.19$	$4.37^{a} \pm 0.25$
Fertilization				
80	$8.18^{a} \pm 0.46$	$3.21^{b} \pm 0.27$	$3.12^{a} \pm 0.24$	$4.34^{a} \pm 0.27$
120	$8.37^{b} \pm 0.49$	$3.11^{a} \pm 0.28$	$3.11^{a} \pm 0.21$	$4.32^{a} \pm 0.24$

Explanations as in Table 1

Table 3

Assessment of the milling value of triticale grain (average values from the years 2010–2011)

Variety	Flour extract [%]	Ash content in flour [%]	Milling efficiency factor (K) [–]	Specific grinding energy (E_r) [kJ kg^{-1}]	Grinding index (K_0) [kJ kg^{-1} flour]	Average particle size of milling product (d_p) [μm]
Andrus 80	59.3^a ± 1.5	0.60^a ± 0.05	99^a ± 6.7	41.44^b ± 2.92	68.32^b ± 6.19	266^{a,b} ± 37
Andrus 120	60.9^a ± 0.9	0.62^a ± 0.04	98^a ± 4.8	33.80^a ± 1.78	54.91^a ± 3.29	396^c ± 7
Milewo 80	63.4^a ± 3.1	0.58^a ± 0.02	109^{a,b} ± 7.0	36.52^b ± 1.55	57.76^b ± 2.97	219^a ± 10
Milewo 120	63.7^a ± 1.7	0.57^a ± 0.03	112^b ± 2.8	33.08^a ± 4.84	51.32^a ± 7.28	310^b ± 26
Fertilization						
80	61.3^a ± 3.1	0.59^a ± 0.03	104^a ± 8.3	38.98^b ± 3.4	63.04^b ± 7.21	242^a ± 35
120	62.3^a ± 1.9	0.59^a ± 0.04	105^a ± 7.5	33.44^a ± 3.4	53.11^a ± 5.57	352^b ± 50

Explanations as in Table 1

An important parameter of the milling value is the granulometric composition of the milling product. The analysis of particle size distribution indicates that the nitrogen fertilization level clearly diversified the milling products with regard to the content of individual size fractions. The granulometric composition of the milling product of each of the studied cereal was characterized by a very wide particle size range, from 0.5 μm to 2000 μm (Figure 1).

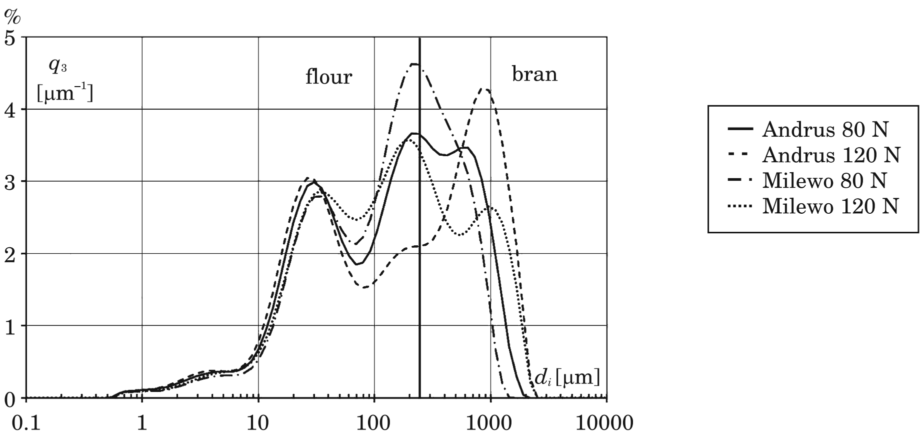

Fig. 1. Granulometric composition of middlings obtained from triticale grains (average values from the years 2010–2011)

The percentage of the fraction under 30 μm was comparable in all of the studied materials, although differences were found in thicker fractions. The percentage of the 200 μm fraction diminished noticeably with increased nitrogen fertilization in both studied varieties (from 3.6% to 2.1% for a change in the fertilization level from 80 to 120 kg N ha^{-1} for the Andrus variety). A similar change in the content of the 200 μm fraction occurred in the milling product of the Milewo variety. An analogous increase in the fertilization level caused a decrease in the percentage of the 200 μm fraction from 4.6% to 3.5%. The opposite tendency found in the content of the largest size fraction. Increasing the fertilization level from 80 kg N ha^{-1} to 120 kg N ha^{-1} caused an increase in its percentage from 3.5% to 4.2% (Andrus) and from an almost zero to 2.7%.

Flour extract was inversely correlated with the ash content in grain (r = -0.677) and the ash content in flour increased with a rising ash content in grain (r = 0.769) (Table 4). The amount of energy consumed for grain milling increased with rising grain vitreousness (r = 0.785) and diminished with increasing test weight (r = -0.649) and the value of the PSI index (r = -0.676).

Table 4

Significant value of linear correlation for physicochemical properties of grain and characteristic milling properties

Trait	Flour extract	Ash content in flour	Milling efficiency factor	Specific grinding energy	Grinding index	Average particle size of milling product
TW	–	–	–	–0.649	–0.624	0.587
TKW	–	–	–0.593	–	–	0.783
Ash content in grain	–0.677	0.769	–0.672	0.612	0.646	–
Vitreousness	–	–	–	0.785	0.815	–
PSI	–	–	–	–0.676	–0.624	0.694

Discussion

Variation of triticale nitrogen fertilization affects most of the studied qualitative grain characteristics. TKW indicating the endosperm size and its filling increased along with the increased nitrogen fertilization dose. According to SLAUGHTER et al. (1992), the higher the wheat TKW, the higher the flour extract is obtained. No such relationship for the studied triticale grain was found in own research, but it was found that higher TKW values were accompanied by a higher mean particle size in the milling product (r = 0.783). Differences in the mean particle size of the milled material may result from differences in the mechanical properties of small and large caryopses.

Fertilization with the higher nitrogen dose contributed to increased test weight. A positive correlation was found between TW and the mean ground grain particle size (r = 0.587). This relationship may be caused by a higher percentage of endosperm in grain (relative to bran) for grains with higher test weight (DZIKI and LASKOWSKI 2005).

The effect of milling largely depends on grain hardness. Increasing the nitrogen fertilization of the studied triticale varieties contributed to increases in the PSI index (i.e. it decreased grain hardness). Hard kernels require higher energy during grinding than soft kernels (KILBORN et al. 1982, DZIKI and LASKOWSKI 2005, DZIKI and PRZYPEK-OCHAB 2009). This relationship was also confirmed in own study. It was also found that grain with higher hardness was characterized by higher vitreousness. Positive correlations between wheat grain vitreousness and hardness and the energy consumption of the grinding process was confirmed by CACAK-PIETRZAK et al. (2009). Vitreous kernels are more resistant and require more energy input for grinding. The reason is the internal grain structure, because in a vitreous kernel starch grains are deeply embedded in the protein matrix as opposed to the structure of a floury grain, which is marked by loose endosperm structure (starch grains are set apart from each other).

The obtained amounts of ash in the grain of the studied triticale considerably exceeded the ash contents in triticale grain in the studies by SOBCZYK et al. (2009) and WARECHOWSKA and DOMSKA (2006). The high ash content in triticale grain is an unfavorable property with regard to the use of this cereal for flour. High ash content in triticale compared to wheat is due to grain morphology (PEÑA 2004). According to SOBCZYK et al. (2009), the most favorable ash level in grain for the milling value of triticale is ensured by a dose of 36 kg N ha^{-1} or 98 kg N ha^{-1}. A dose of 120 kg N ha^{-1} proved more favorable in own study.

Research conducted by CEGLIŃSKA et al. (2005) and SOBCZYK et al. (2009) indicates that flour extract obtained from milling triticale grain varies widely. In the current study, the extraction rate for flour acquired from milling triticale grain was relatively low and ranged from 59.3 to 63.7% (from 15% tempering moisture). Similar results in triticale for tempering moisture at 15% were obtained by DENNETT and TRETHOWAN (2013). Fertilization with a higher nitrogen dose contributed to a small extent to an increase in flour extract, yet this was not confirmed statistically. According to SOBCZYK et al. (2009), a rise in the nitrogen dose in triticale fertilization causes increased triticale flour extract, although according to BISKUPSKI (2000), fertilization with a higher nitrogen dose contributes to decreased triticale flour extract.

The ash content in the obtained flour is an important index of the milling value of grain. The ash content in triticale flours can vary widely depending on the obtained extract (BISKUPSKI 2000, CEGLIŃSKA et al. 2005, SOBCZYK et al. 2009). In the conducted study, the mean ash contents ranged from

0.57% to 0.62%. The varied nitrogen fertilization had no effect on the flour ash content.

In commercial milling of grain into flour, flour production takes place according to the classification of a particular flour type (with particular ash content). The milling value of grain relates to the potential possibility of obtaining the highest possible flour extract of a particular type from commercial milling in an industrial mill (SITKOWSKI 2011). The milling efficiency coefficient (*K*) applied to demonstrate the difference in the milling of the studied triticale grain. The milling efficiency coefficient includes flour extract in connection with its ash content. Nitrogen fertilization had no effect on milling efficiency coefficient. Andrus triticale showed a worse milling value than Milewo triticale.

Conclusions

Summing up, the different nitrogen fertilization levels influenced the physical properties of triticale grain of significant importance during milling such as: test weight, thousand kernel weight, vitreousness and hardness expressed by the PSI. Increasing the fertilization dose from 80 to 120 kg N ha^{-1} contributed to a subsequent decrease in energy demand for grain milling and a decrease in ash content in the grain. The use of the higher nitrogen dose caused an increase in the mean particle size of the milling product.

Further investigation is required into the role of nitrogen fertilization of triticale on milling quality. Milling quality of grain triticale with wider range at nitrogen fertilization will be the subject of our next study.

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References

AACC International 2000. *Approved methods of the American Association of Cereal Chemists.* Methods 55–30, *10th Ed.,* The Association: St. Paul, MN.

AMMAR K., MERGOUM M., RAJARAM S. 2004. *The history and evolution of triticale.* [In:] *Triticale improvement and production.* Eds. M. Mergoum, H Gómez-Macpherson. FAO Plant Production And Protection Paper Vol. 179, Food And Agriculture Organization Of The United Nations, Rome pp. 1–9.

BISKUPSKI A. 2000. *The influence of two levels of nitrogen fertilization on physical, milling and biochemical properties as well as baking quality of triticale cultivars*. Fol. Univ. Agric. Stetin., Agric., 206(82): 19–24.

BERMAN M., BASON M.L., ELLISON R., PEDEN G., WRIGLEY C.W. 1996. *Image analysis of whole grain to screen for flour milling yield in wheat breeding.* Cereal Chem., 73: 323–327.

CACAK-PIETRZAK G., CEGLIŃSKA A., GONDEK E., JAKUBCZYK E. 2009. *Influence of the structure of the wheat grain on the grinding process.* Postępy Tech. Przetw. Spoż., 2: 53–56.

Ceglińska A., Samborski S., Rozbicki J., Cacak-Pietrzak G., Haber T. 2005. *Estimation of milling and baking value for grain of winter triticale varieties depending on nitrogen fertilization*. Pamięt. Puł., 139: 39–46.

Dennett A.L., Trethowan R.M., 2013. *Milling efficiency of triticale grain for commercial flour production*. J. Cereal Sci., 57: 527– 530.

Determination of ash in cereals and cereal products. ICC Standard No. 104/1.

Determination of crude protein in cereals and cereal products for food and for feed. ICC Standard No. 105/2.

Determination of moisture content of cereals and cereal products (practical method). ICC Standard No. 110/1.

Dobraszczyk B.J. 1994. *Fracture-mechanics of vitreous and mealy wheat endosperm.* J. Cereal Sci., 19: 273–282.

Dziamba J., Dziki D., Laskowski J. 2001. *Effect of nitrogen fertilization on selected properties of wheat.* Inż. Rol., 10: 121–127.

Dziki D., Laskowski J. 2005. *Wheat kernel physical properties and milling process.* Acta Agrophys., 6: 59–71.

Dziki D., Przypek-Ochab D. 2009. *Evaluation of energy consumption for crushing wheat seed with diversified hardness.* Inż. Rol., 5: 61–67.

Dziki D., Rożyło R., Laskowski J. 2011. *Wheat flour milling and the influence of grain hardness on the process.* Acta Agrophys., 18: 33–43.

Edwards M.A., Osborne B.G., Henry R.J. 2010. *Puroindoline genotype, starch granule size distribution and milling quality of wheat.* J. Cereal Sci., 52: 14–320.

Glenn G.M., Johnston R.K. 1994. W*ater vapor diffusivity in vitreous and mealy wheat endosperm.* J. Cereal Sci., 20: 275–282.

Greffeuille V., Mabille F., Rousset M., Oury F.X., Abecassis J., Lullien-Pellerin V. 2007a. *Mechanical properties of outer layers from near-isogenic lines of common wheat differing in hardness.* J. Cereal Sci., 45: 227–235.

Greffeuille V., Abecassis J., Barouh N., Villeneuve P., Mabille F., Bar L'helgouac'h C., Lullien-Pellerin V. 2007b. *Analysis of the milling reduction of bread wheat farina, physical and biochemical characterization*. J. Cereal Sci., 45: 97–105.

Haddad Y., Mabille F., Mermet A., Abecassis J., Benet J.C. 1999. *Rheological properties of wheat endosperm with a view on grinding behaviour.* Powder Technol., 105: 89–94.

Johansson E., Prieto-Linde M.L., Jönsson J.Ö. 2001. *Effects of wheat cultivar and nitrogen application on storage protein composition and breadmaking quality.* Cereal Chem., 78: 19–25.

Kilborn R.H., Black H.C., Dexter J.E., Martin D.G. 1982. *Energy consumption during flour milling: description of two measuring systems and the influence of wheat hardness on energy requirements.* Cereal Chem., 59: 284–288.

Laskowski J., Łysiak G., Skonecki S. 2005. *Mechanical properties of granular agro-materials and food powders for industrial practice.* II. Material properties for grinding and agglomeration. Institute of Agrophysics PAS, Lublin, pp. 29–30.

Letang C., Samson M.F., Lasserre T.M., Chaurand M., Abecassis J. 2001. *Production of starch with very low protein content from soft and hard wheat flours by jet milling and air classification*. Cereal Chem., 79: 535–543.

Marshall D.R., Mares D.J., Moss H.J., Ellsion F.W. 1986. *Effects of grain shape and size on milling yield in wheat.* II. Experimental Studies. Aust. J. Agr. Res., 37: 331–342.

Mohsenin N.N. 1986. *Physical Properties of Plant and Animal Materials.* Gordon and Breach Science Publisher, New York, USA.

Mut Z., Sezer I., Gülümser A. 2005. *Effect of different sowing rates and nitrogen levels on grain yield, yield components and some quality traits of triticale.* Asian J. Plant Sci., 4: 533–539.

Park S., Chung O.K., Seib P.A. 2006. *Hard winter wheat and flour properties in relation to breadmaking quality of straight-dough bread: flour particle size and bread crumb grain.* Food Sci. Technol. Int., 11: 164–170.

Peña R.J. 2004. *Food uses of triticale.* In: *Triticale improvement and production*. Eds. M. Mergoum, H. Gómez-Macpherson, Food and Agriculture Organisation of the United Nations, Rome, Italy, pp. 37–48.

PETKOV K., KOWIESKA A., JASKOWSKA I. 2000. *Nutrition value of the structural easy hydrolysing carbohydrates in some cultivars triticale.* Fol. Univ. Agric. Stetin., Agric., 206: 215–218.

PISULEWSKA E., ŚCIGALSKA B., SZYMCZYK B. 2000. *Comparison of nutritive value of Polish cultivars of spring triticale.* Fol. Univ. Agric. Stetin., Agric., 206: 219–224.

POMERANZ Y., PETERSON C.J., MATTERN P.J. 1985. *Hardness of winter wheats grown under widely different climatic conditions.* Cereal Chem., 62: 463–467.

POSNER E.S. 2003. *Principles of milling. Encyclopedia of food science, food technology and nutrition.* Book Chapter. Academic Press, Harcourt Brace Jovanovich Publishers. London, pp. 3980–3986.

SALMON D.F., MERGOUM M., GÓMEZ MACPHERSON H. 2004. *Triticale production and management.* In: *Triticale improvement and production*. Eds. M Mergoum, H Gómez-Macpherson, FAO Plant Production And Protection Paper, Food And Agriculture Organization Of The United Nations, Rome, 179: 27–34.

SITKOWSKI T. 2011. *Methods of assessment of milling of grain on the basis of the results of laboratory grinding*. Prz. Zboż.-Młyn., 2: 35–36.

SLAUGHTER D.C., NORRIS K.H., HRUSCHKA W.R. 1992. *Quality and classification of hard red wheat.* Cereal Chem., 69: 428–432.

SOBCZYK A., KOGUT B., SURDEL M. 2009. *Changes in the milling value of some winter triticale cultivars under the influence of nitrogen fertilization.* Zeszyty Naukowe Południowo-Wschodniego Oddziału Polskiego Towarzystwa Inżynierii Ekologicznej z siedzibą w Rzeszowie. Polskie Towarzystwo Gleboznawcze, Oddział w Rzeszowie, 11: 243–249.

STANKOWSKI S., SMAGACZ J., HURY G., UŁASIK S. 2008. *Effect of nitrogen fertilization intensity on grain and flour quality of winter wheat cultivars.* Acta Sci. Pol., Agric., 7: 105–114.

VELU V., NAGENDER A., PRABHAKARA RAO P.G., RAO D.G. 2006. *Dry milling characteristic of microwave dried maize grains.* J. Food Eng., 74: 30–36.

WARECHOWSKA M., DOMSKA D. 2006. *Comparison of technological usefulness indices and macroelement contents in the grain of some winter triticale cultivars.* Fol. Univ. Agric. Stetin., Agric., 247: 211–216.

YÜCEL C., BALOCH F.S., ÖZKAN H. 2009. *Genetic analysis of some physical properties of bread wheat grain* (*Triticum aestivum* L. em Thell). Turk. J. Agric. For., 32: 249–258.

ZECEVIC V., KNEŽEVIC D., MICANOVIC D. 2005. *Technological quality of wheat-triticale flour blends.* Tractors and Power Machines, 10: 448–453.