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INFLUENCE OF NITROGEN FERTILISATION ON THE TECHNOLOGICAL VALUE OF SEMI-DWARF GRAIN WINTER TRITICALE VARIETIES ALEKTO AND GNIEWKO

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K e y w o r d s: semi-dwarf winter triticale, varieties, nitrogen fertilisation, quality features, test baking.

A b s t r a c t

This paper examines the milling value of grain and baking quality of flour from two semi-dwarf varieties of winter triticale (Alekto and Gniewko) grown at different nitrogen fertilisation doses (60, 90 (60+30), 120 (90+30), 150 (90+60) kg N·ha^{-1}. Grain harvested in two seasons: 2008/2009 and 2010/2011, was subjected to evaluation. The nitrogen fertilisation was significant influence on test weight, flour extract, protein content, sedimentation value, dough development and dough stability. Tested varieties were differ in flour extract, sedimentation value and flour colour. It has been demonstrated that the grain obtained from semi-dwarf triticale cultivars cultivated at different levels of nitrogen supply did not meet the requirements regarding the baking value set for grains used to bake good quality bread. The main reasons were a low falling number and low content as well as poor quality of wet gluten in grain, which precluded the production of dough with good farinographic properties or achievement of sufficiently high bread yield and bread volume. The correlation analysis showed significant positive relationships between the nitrogen fertilisation versus the content of protein or wet gluten in winter triticale grain as well as the development and stability of dough.

WPŁYW NAWOŻENIA AZOTEM NA JAKOŚĆ TECHNOLOGICZNĄ ZIARNA PÓŁKARŁOWEGO PSZENŻYTA OZIMEGO ODMIAN ALEKTO I GNIEWKO

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S ł o w a k l u c z o w e: półkarłowe pszenżyto ozime, odmiany, nawożenie azotem, cechy jakościowe, próbny wypiek.

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Abstrakt

W pracy oceniono wartość przemiałową i wypiekową ziarna i mąki dwóch odmian półkarłowych pszenżyta ozimego (Alekto i Gniewko) uprawianego w warunkach zróżnicowanych dawek azotu (60, 90 (60+30), 120 (90+30), 150 (90+60) kg N·ha^{-1}). Ocenie poddano surowiec zebrany w sezonie wegetacyjnym 2008/2009 i 2010/2011. Nawożenie azotem istotnie wpłynęło na gęstość ziarna, wyciąg mąki, zawartość białka, test sedymentacji, rozwój i stałość ciasta. Porównywane odmiany wykazały istotne zróżnicowanie w wyciągu mąki, teście sedymentacji i kolorze mąki. Wykazano, że otrzymany w doświadczeniu surowiec pochodzący z odmian półkarłowych pszenżyta ozimego uprawianego w warunkach różnych dawek azotu nie spełniał wymagań co do wartości wypiekowej jakie stawia się dla ziarna przeznaczonego do wyrobu pieczywa o dobrej jakości. Decydowały o tym głównie niska liczba opadania (wysoka aktywność α-amylazy) oraz mała zawartość i niska jakość glutenu mokrego w ziarnie, które nie pozwalały na wytworzenie ciasta o dobrych cechach farinograficznych, a także odpowiednio wysokiej wydajności i objętości chleba. Przeprowadzona analiza korelacji wykazała istotny, dodatni związek pomiędzy nawożeniem azotem a zawartością białka i glutenu mokrego w ziarnie pszenżyta ozimego oraz rozwojem i stałością ciasta.

Introduction

Owing to its high yielding potential and good nutritional values (JONNALA et al. 2010, HANSEN 2012), triticale has received much interest as foodstuff for the food industry (DOXASTAKIS et al. 2002, NAEEM et al. 2002, RAKHA et al. 2011, NAKURTE et al. 2012, PATTISON and TRETHOWAN 2013). The most promising future use of triticale as food depends on its identified suitability for baking (MCKEVITH 2004, TOHVER et al. 2005, RAKHA et al. 2011, NAUKURTE et al. 2012). Unfortunately, the technological quality of triticale grain is limited by the high activity of α-amylase, high ash content and low content and quality of. Although triticale can be a useful component in human diet, it now occupies a minor position on the food market (AGUIRRE et al. 2011).

Possible improvement of triticale grain quality traits can be achieved through progress in the breeding of new cultivars, which encodes the chemical composition, mainly proteins and carbohydrates (CEGLIŃSKA et al. 2006) and in the elaboration of adequate cultivation technologies. Nitrogen fertilisation is the agronomic factor that most distinctly modifies the quality traits of grain (MUT et al. 2005). An appropriate dose and application schedule can facilitate the production of a good quality plant product and are very important for effective use of nitrogen. The current triticale breeding programme aims at producing cultivars useful in the baking industry, able to retain the yielding potential of wheat and adaptability of rye from almost all geographical locations (MCGOVERIN et al. 2011).

The breeding of winter triticale has developed two forms: traditional and semi-dwarf. Semi-dwarf forms have their own, characteristic agronomic requirements. They are more resistant to lodging (shorter stem), which makes them particularly suitable for intensive cultivation, including better utilization of higher nitrogen doses. Recognition of their response to nitrogen fertilisation levels in the context of modelling the quality of grain and baking flour would open up a new vista for further expansion of this crop. Such experiments on semi-dwarf triticale have not been conducted until now, which has encouraged us to undertake this research with the aim of analysing the milling and baking value of grain harvested from semi-dwarf winter triticale varieties grown at different nitrogen fertilisation doses.

The working hypothesis assumes that, when fertilised with a certain nitrogen dose, the selected winter triticale cultivars (Gniewko and Alekto) would meet the qualitative requirements for grain intended for bread baking and would thus determine a new direction of triticale flour utilisation for baking. The aim of the study was determining the suitability of the new winter triticale grain in the baking industry, including evaluation of grain quality traits selected depending on the applied nitrogen fertilisation on the value of the milling and baking.

Materials and Methods

The analyses were based on results obtained from a two-year controlled field experiment conducted at the Experimental Station in Bałcyny, Poland (N=53°35'49''; E=19°51'20.3''). The experiment was set up on grey-brown podozolic soil developed on light clay, according to the split-plot method with four replications. Two semi-dwarf winter triticale cultivars (Alekto and Gniewko) were grown on plots supplied with different doses of nitrogen, in the following scheme: A – 60 $kg \cdot ha^{-1}$ with a single application of the whole dose, B - 90 $kg \cdot ha^{-1}$ split into 60+30, C – 120 $kg \cdot ha^{-1}$ split into 90+30 and D – 150 $kg \cdot ha^{-1}$ split into 90+60. The whole dose of 60 $kg \cdot ha^{-1}$ (variant A) or the first part of a higher dose (variants B, C and D) were applied in spring, at the resumed plant growth (29 stage on the BBCH scale), while the second part was supplied at the 38 BBCH plant growth stage. Phosphorus and potassium fertilisation was carried out in a single application before sowing, in doses of 30 kg $P \cdot ha^{-1}$ and 75 kg $K \cdot ha^{-1}$. Winter triticale was sown in the last ten days of September, using 400 seeds per 1 m^{-2}. The seeds were treated with the seed dressing preparation Baytan Universal 094 FS (active ingredient *triadimenol* + *imazalil* + *fuberidazole*). The antifungal protection consisted of a spraying treatment with the preparation Input 460 EC in the amount of 1 $l \cdot ha^{-1}$ (*spiroxamine* + *prothiocanazole*) during the first node phase (31 BBCH) and the application of the fungicide Prosaro 250 EC in the dose of 0.6 1 $l \cdot ha^{-1}$) (*tebuconazole* + *prothiocanazole*) during the full heading phase (58 BBCH). Weed control was composed of a single spraying treatment with a mixture of herbicides (Boxer 800 EC 2 l·ha^{-1} – a.i. *prosulfocarb* , Glean 75 WG 5 g·ha^{-1} – a.i. *chlorosulfuron*, Legato 500 SC 0.5 l·ha^{-1} – a.i. d*iflufenican*) carried out in autumn, during the BBCH 29 growth stage.

Alekto is semi dwarf variety (one of the shortest among triticale varieties registered in Poland), distinguished by a high yield potential in different soil and climatic. Alecto has very good resistance against most fungal diseases, variety with good winter hardiness. The advantage of this variety is high in protein. Gniewko is semi dwarf variety also but with a relatively small frost resistance. High resistance to *Blumeria graminis* and *Puccinia recondita* and average resistance to *Septoria tritici* and *nodorum*, low resistance to *Fusarium* spp. and stem base diseases. The plants are characterized by rather low resistance to sprouting of grain in the ear and small falling number. The scientific literature to date has not presented research results with the above-mentioned winter triticale varieties. There is a new opportunity to improve the value of this cereal grain baking. In 2006, entered into the National Register semi-dwarf, Gniewko variety of high protein content, which stated by PCR method increased participation of macromolecular gluten proteins.

Samples of grains were analysed, including the following determinations: bulk density of grain using a densitometer, protein content with Kjeldahl's method (N x 6.25) according to the ICC-105/2 standard modified by Tecator, sedimentation rate in a solution of SDS (sodium dodecyl sulphate) (AXFORD et al. 1979), falling number according to ICC standard 107/1 Falling Number 1400 (ICCH), wet gluten content according to ICC standard 155 (a Glutomatic 2200 system, ICCH), flour yield on a Quadrumat Senior Brabender. Farinographic analyses determined: hygroscopicity of flour, dough development, stability and weakening. These determinations were made according to ICC standard 115/1 on a Brabender farinograph (ICCH). Samples of grain were ground in an MLU 202 laboratory mill (manufactured by Buhler) according to Sitkowski's method. Whiteness of the flour was determined in a Karl Zeiss Jena leucometer. The bread baking test made in a laboratory electric oven provided data for determinations of the bread yield and volume.

For the statistical analysis have been selected average samples from nitrogen fertilisation objects. The results were submitted as two factorial Anova for the model of the completely randomized design (CRD) with Statistica®10. Tukey's test at a significance of 0.05 was applied to verify the significance of differences. Pearson correlation coefficients were computed.

The two years when the field experiments were conducted were varied in the weather conditions, especially in the distribution of rainfalls during the growing season (fig. 1). This had a direct impact on the growth and development of winter triticale. In the analyzed seasons, the early autumn plant growth was accompanied by rainfall shortages and temperatures higher than multi-annual average. In the growing seasons of 2008 April was a very dry and warm month, while May and June were wet. In the growing season 2010 wet conditions were similar to multi-annual average. Air temperatures higher than the average occurred in July, which was favorable for the plants as it helped the grain and straw to dry properly. Triticale harvest was particularly troublesome in 2011, when the rainfall in July was as much as 211% higher than the multi-year mean.

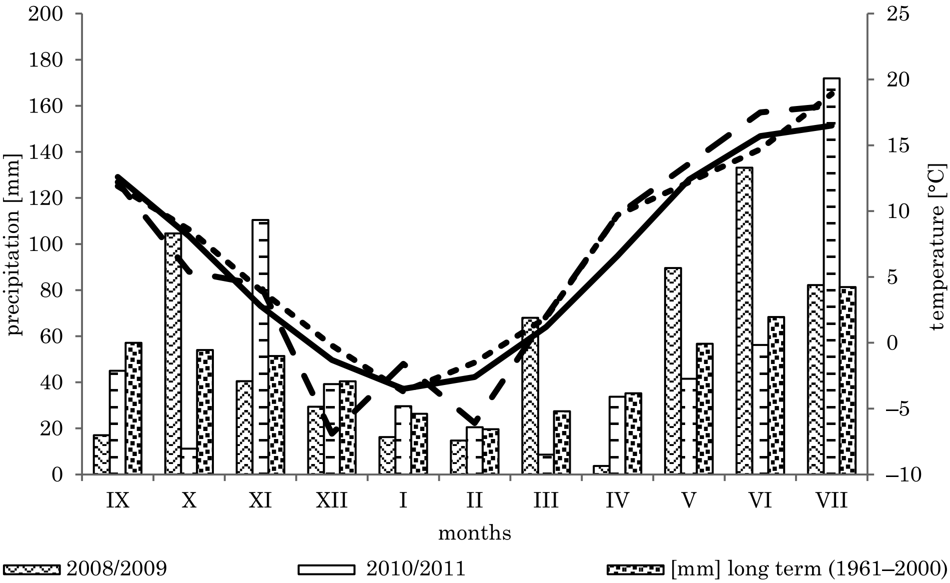

Fig. 1. Rainfall and temperature distribution during the growing seasons

Results and Discussion

Grain density is a volumetric measure of grain mass in kilos per hectolitre. High grain density confirms good grain filling, whereas low density suggests that kernels are wrinkled and the endosperm is poorly filled. In our analyses, triticale grain demonstrated a volumetric mass in the range of 68.5–71.4 kg·hl^{-1}, significantly differentiated by the nitrogen doses (Table 1). Similar grain density values for this cereal species (65.4–71.5 kg·hl^{-1}) were experimentally assessed by KALNIN et al. (2013). In our experiment, the highest triticale grain density was achieved from the plot supplied 90 kg N·ha^{-1}. The cultivar x nitrogen fertilisation interactions demonstrated that the highest grain volumetric mass was produced by cv. Alekto in response to the nitrogen doses of 60 and 90 kg N·ha^{-1}, and by cv. Gniewko fertilised supplied 90 and 120 kg N·ha^{-1}.

Table 1

Milling and baking features of winter triticale grain (mean value)

Parameter	Variety	Fertilisation N (kg·ha^{-1})				Mean
		60	90	120	150	
Test weight (kg·hl^{-1})	Gniewko	70.7	71.4	69.7	68.5	70.0
	Alekto	68.9	70.1	70.3	69.8	69.7
	mean	69.8	70.7	70.0	69.1	–
$LSD_{(0.05)}$ nitrogen fertilisation – 0.89, interaction – nitrogen fertilisation x varieties – 1.26, other – n.s.t						
Flour extract (%)	Gniewko	66.3	65.6	64.8	65.0	65.4
	Alekto	67.6	67.8	67.4	66.7	67.4
	mean	67.0	66.7	66.1	65.9	–
$LSD_{(0.05)}$ nitrogen fertilisation – 0.63, varieties – 0.44, other – n.s.						
Protein content (% s.m.)	Gniewko	9.6	10.4	11.5	11.7	10.8
	Alekto	10.8	11.0	11.5	11.8	11.3
	mean	10.2	10.7	11.5	11.7	–
$LSD_{(0.05)}$ nitrogen fertilisation – 0.82, other – n.s.						
Gluten content (%)	Gniewko	10.4	13.0	17.5	17.8	14.7
	Alekto	13.8	17.3	18.7	17.7	16.9
	mean	12.1	15.1	18.1	17.8	–
$LSD_{(0.05)}$ not significant difference						
SDS sediment value (ml)	Gniewko	35.6	38.4	41.3	41.3	39.1
	Alekto	45.5	46.5	45.5	48.5	46.5
	mean	40.5	42.4	43.4	44.9	–
$LSD_{(0.05)}$ nitrogen fertilisation – 1.58, varieties – 1.12, interaction nitrogen fertilization x varieties – 2.25						
Falling number (s)	Gniewko	118	125	145	136	131
	Alekto	176	128	139	164	152
	mean	147	127	142	150	–
$LSD_{(0.05)}$ not significant difference						

The flour extract from grain yielded by the two analysed triticale cultivars ranged from 64.8 to 67.8%, which is a rather low percentage range, as verified by the results of other authors (SOBCZYK et al. 2009). In our research, a significantly higher flour yield was obtained from cv. Alekto grain (Table 1). The most favourable flour extract was achieved from the plots fertilised with 60 or 90 kg N·ha^{-1}, while any further increase in nitrogen nourishment significantly depreciated this parameter. Similarly, in a study by CEGLIŃSKA et al. (2005), elevated nitrogen fertilisation depressed the yield of flour from triticale grain. However, other researchers (SOBCZYK et al. 2009) observed a small decline in flour yield at a nitrogen dose of 40 kg N·ha^{-1}, whereas higher doses (80 kg and 120 kg N·ha^{-1}) resulted in a relatively high increase of this parameter.

The grain baking value depends on the protein content. PELTONEN-SAINIO et al. (2012) claim that triticale is an interesting and promising cereal species, able to ensure a satisfactory protein yield per field area unit. The grain for bread baking should contain around 11.5% of protein. In our study, it ranged from 9.6 to 11.8%, and was significantly dependent on the nitrogen fertilisation level (Table 1). The highest percentage of protein in grain was about 8.6% recorded by JANUŠAUSKAITĖ (2013), 10.5–13.3% determined by DENNETT and TRETHOWAN (2013) and 17% reported by EREKUL and KÖHN (2006). In our investigations, higher doses of nitrogen under triticale caused an increase in the protein content in grain, with significant increments noted up to the dose of 120 kg $N \cdot ha^{-1}$ (Table 1). The protein content expected from bread baking grain was obtained only when triticale had received nitrogen doses of 120 or 150 kg $N \cdot ha^{-1}$. The positive relationship between nitrogen fertilisation and protein content in triticale grain was confirmed by the correlation analysis ($r = 0.77$) (Table 3). Likewise, in studies by CEGLIŃSKA et al. (2005), KARA and UYSAL (2009), GULMEZOGLU and AYTAC (2010), a higher dose of nitrogen supplied under triticale caused an increase in the total protein content in all tested cultivars. Similar observations were made by CIMRIN et al. (2004). According to ZHENG et al. (2009), the protein content in grain depends on the availability of nitrogen in soil. Its deficit depressed yields and the grain content of protein. ALARU et al. (2003) claimed that the protein concentration in triticale grain is more strongly dependent on the cultivar (i.e. genetic predispositions) than the environmental conditions. However, BUREŠOVÁ et al. (2010) would disagree, having observed a significant difference in the protein content in triticale grain depending on years of the research, while failing to detect such differences between the tested varieties.

For the baking industry, the content and composition of gluten proteins in flour are of utmost importance (BRANLARD et al. 2001, KOEHLERA et al. 2010). Grain which will be ground to flour should contain at least 25% of wet gluten, as this component plays an important part in technological processes involved in dough making and bread baking (UTHAYAKUMARAN et al. 1999). In our investigation, the content of wet gluten in grain was low, ranging from 10.4 to 18.7%, which is less than the required minimum (Table 1). Its content in grain was not significantly differentiated by the cultivar or nitrogen fertilisation level. There was just a tendency for a higher wet gluten content in grain from cv. Alekto and in response to the nitrogen doses raised to 120 kg $N \cdot ha^{-1}$. The analysis of correlations showed a significant, albeit weaker than for the protein content, relationship between the nitrogen fertilisation and wet gluten content ($r = 0.59$) (Table 3). TOHVER et al. (2005) concluded that triticale gluten behaves analogously to gluten in rye grain, but in terms of quality it is worse than gluten in bread baked from wheat flour.

A fundamental measure in the quality assessment of gluten proteins is the sedimentation rate. In our study, this property ranged from 35.6 ml to 48.5 ml, indicating poor quality of gluten. Its value depended on the cultivar and nitrogen fertilisation level (Table 1). A significantly higher sedimentation rate was obtained for the grain produced by cv. Alekto. Higher doses of nitrogen had a positive effect on the protein composition measured by the SDS test, with the improved results achieved for cv. Gniewko up to the level of 120 kg N·ha^{-1}, and for cv. Alekto – up to 150 kg N·ha^{-1}. The beneficial influence of increasing nitrogen doses on the value of sedimentation rate has also been implicated by others (CEGLIŃSKA et al. 2005).

The baking quality assessment devotes much attention to the enzymatic properties of grain, in particular the activity of α-amylase, which is measured by the falling number. It determines the usefulness of grain for baking and is strictly associated with the resistance of grain to sprouting. Grain with a moderate amylolytic activity, whose falling number is within 200–300 seconds, is best for flour production. In our experiment, the amylolytic activity of triticale grain was high (low falling numbers within 118–164 seconds) and rather weakly differentiated by the cultivars or nitrogen doses. Also, EREKUL and KÖHN (2006) determined a lower falling number for triticale than for wheat or rye. The literature contains frequent mentions of the falling number around 62–70 seconds (MARTINEK et al. 2008, KALNINA et al. 2013), 120 seconds (depending on the weather) (ALARU et al. 2009), up to 180 seconds, but the mean value is below 100 seconds (YASEEN et al. 2007). A low falling number is generally connected with kernels sprouting on triticale plants even before harvest, but other causes can be involved (MARES and MARVA 2008).

The colour of the flour was differentiated only by the cultivar (Table 2). Significantly whiter flour was obtained from grain of cv. Alekto. The influence of a cultivar and nitrogen dose on the water absorption by flour was statistically insignificant (Table 2). There was only a trend for a slightly better hygroscopicity of flour from the cv. Gniewko grain. CEGLIŃSKA et al. (2005) also did not demonstrate any significant differences in the water absorption by flour caused by cultivars or nitrogen fertilisation.

The dough development time and its stability were significantly varied depending on the nitrogen fertilisation levels (Table 2). Higher doses of nitrogen supplied to triticale fields resulted in the dough taking longer to develop, with significant differences observed between the doses of 60 and 150 kg N·ha^{-1}. The best dough stability was achieved for flour from the grain of triticale fertilised with the nitrogen dose equal 120 kg N·ha^{-1}. The correlation analysis showed a positive relationship between nitrogen nourishment and the time of dough development as well as dough stability ($r = 0.63$ and $r = 0.68$, respectively) (Table 3). Dough produced from flour obtained from cv. Gniewko grain, compared to cv. Alekto, revealed just a slight tendency for possessing an improved stability.

Table 2

Flour, dough and bread properties depending on nitrogen fertilisation (mean value)

Parameter	Variety	Fertilisation N ($kg \cdot ha^{-1}$)				Mean
		60	90	120	150	
Flour colour (% pattern)	Gniewko	80.9	81.3	81.1	81.5	81.2
	Alekto	84.8	84.6	84.2	84.3	84.5
	mean	82.8	82.9	82.6	82.9	–
LSD $_{(0.05)}$ varieties – 1.89, other – n.s.						
Flour water absorption (%)	Gniewko	50.6	50.9	51.9	51.8	51.3
	Alekto	46.9	48.2	48.1	49.5	48.1
	mean	50.6	50.9	51.9	51.8	–
LSD $_{(0.05)}$ not significant difference						
Dough development (min.)	Gniewko	0.9	1.3	1.1	1.8	1.2
	Alekto	1.0	1.2	1.4	1.2	1.2
	mean	0.9	1.2	1.3	1.5	–
LSD $_{(0.05)}$ nitrogen fertilisation – 0.36, other – n.s.						
Dough stability (min.)	Gniewko	1.0	1.9	2.7	2.3	2.0
	Alekto	0.6	1.0	2.3	1.8	1.4
	mean	0.8	1.5	2.5	2.0	–
LSD $_{(0.05)}$ nitrogen fertilisation – 0.80, other – n.s.						
Dough softening (uB)	Gniewko	181	170	168	171	172
	Alekto	146	180	152	153	158
	mean	163	175	160	162	–
LSD $_{(0.05)}$ not significant difference						
Yield of bread (%)	Gniewko	140	140	139	141	140
	Alekto	134	134	133	133	133
	mean	137	137	136	137	–
LSD $_{(0.05)}$ not significant difference						
Volume of bread (cm^3)	Gniewko	548	528	546	528	537
	Alekto	507	540	540	547	533
	mean	527	534	543	537	–
LSD $_{(0.05)}$ not significant difference						

Table 3

Coefficient correlation between nitrogen fertilisation of winter triticale and grain quality, flour, dough and bread traits

Test characteristic	Significance levels (p)	Correlation coefficient (r)
Test weight ($kg \cdot hl^{-1}$)	p=0.23	-0.32
Flour extract (%)	p=0.15	-0.38
Protein content (% s.m.)	p=0.00	0.77*
Wet gluten content (%)	p=0.02	0.59*
SDS sediment value (ml)	p=0.15	0.37
Falling number (s)	p=0.65	0.12
Flour colour (% pattern)	p=0.98	-0.01
Flour water absorption (%)	p=0.49	0.18
Dough development (min.)	p=0.01	0.63*
Dough stability (min.)	p=0.00	0.68*
Dough softening (uB)	p=0.71	-0.10
Yield of bread (%)	p=0.97	-0.01
Volume of bread (cm^3)	p=0.70	0.10

* coefficients statistically significant

The effect of a cultivar or nitrogen fertilisation on dough weakening was not significant (Table 2). A slightly higher value of dough weakening (worse quality dough) was determined for cv. Gniewko grain and for plots fertilised with a dose of 90 kg N·ha^{-1}.

Baking bread on a laboratory scale is a direct method to assess the baking quality of flour. In our study, the bread baked in a laboratory was characterized by poor volume yield, ranging from 507 to 548 cm^3. No significant effect of the cultivars or nitrogen fertilisation levels was demonstrated on this property of bread (Table 2), which is confirmed by the results reported by CEGLIŃSKA et al. (2005). In our study, the cultivar or nitrogen fertilisation factors also did not significantly modify the bread yield (Table 2) as was also reported by CEGLIŃSKA et al. (2005).

Conclusions

1. The nitrogen fertilisation had significant influence on the test weight, flour extract, protein content, sedimentation value, dough development and dough stability. Analised triticale varieties were differ in flour extract, sedimentation value and flour colour.
2. The grain harvested from semi-dwarf, winter triticale cultivars Alekto and Gniewko, grown at different nitrogen fertilisation levels, did not meet the requirements in terms of baking quality set for grains used to bake good quality bread.
3. The main reasons were a low falling number (high activity h-amylase) and a low content and poor quality of wet gluten in grain, which precluded making dough with good farinographic properties, or production of bread with sufficiently good yield and volume.
4. The correlation analysis showed a significant, positive relationship between the nitrogen fertilisation and the content of protein and wet gluten in winter triticale grain as well as the dough development and stability.

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