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EFFECT OF NITROGEN FERTILIZATION OF DURUM WHEAT VARIETIES ON SOME CHARACTERISTICS IMPORTANT FOR PASTA PRODUCTION

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Abstract. In the study the effect of nitrogen fertilization of durum wheat on grain and flour properties was examined. Grain of four durum wheat varieties: 'Durabon', 'Durabonus', 'Duraprimus' and 'Rusticano' cultivated in the Swadzim at Experimental Station of Agricultural University of Poznań were investigated. Three different doses of nitrogen fertilization (50, 100 and 150 kg per hectare) were applied during plant growth. In addition, grain cultivated in the same conditions without any nitrogen fertilization was examined. The results indicate that nitrogen fertilization had a distinct effect on grain physical characteristics such as hardness and vitreousness. It also influenced protein and wet gluten content in flour. No significant effect on carotenoids content and colour of pasta dough was observed.

Key words: durum wheat, nitrogen fertilization, quality parameters, grain, flour, pasta raw material

INTRODUCTION

Durum wheat owing to its unique properties such as high carotenoid pigments content, high vitreousness and hardness as well as gluten proteins composition is used by pasta industry [Obuchowski 1997, Rachoń and Szumiło 2002]. Because of its specific climatic requirements it is not grown in Poland so far. Nevertheless, for the reasons of growing demand for good quality pasta raw material and its price, attempts to grow durum wheat in climatic condition of our country have been made for a long time [Mazurek and Ruszkowski 1965]. Apart from climatic and soil conditions grain quality may be also determined by fertilization. A special role plays here nitrogen fertilization. Properly applied nitrogen fertilizer has a positive effect on crop yield. At a high level of such fertilization it is advantageous to apply it twice or three times to plants at different

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stages of development. According to foreign and Polish research the most effective in obtaining high crop yields is a dose of 80-120 kg N/ha [Rachoń 1999].

In the study the effect of nitrogen fertilization on durum wheat quality characteristics important for pasta production was examined.

MATERIAL AND METHODS

Grain of four spring durum wheat varieties: 'Durabon' (Germany), 'Durabonus' (Austria), 'Duraprimus' (Austria) and 'Rusticano' (Italy) cultivated at the Agricultural University Experimental Station in Swadzim, harvested in 2006 was used. During growing season fields were fertilized with nitrogen in following doses: 0 kg N/ha, 50 kg N/ha (before sowing), 100 kg N/ha (divided into two equal doses – before sowing and at the stage of shooting in stalk), 150 kg N/ha (divided into three doses – before sowing, at the stage of shooting and at the stage of earing).

Moreover in all experiments even doses of phosphorus (P_2O_5, 80 kg/ha) and potassium (K_2O, 100 kg/ha) fertilizers were applied. Experimental fields were protected against weeds with Chwastox D 197 SL (5 l/ha). Forecrop for the experiment was common wheat. The other agricultural measures were taken according to good agricultural practice for spring wheat. The soil of experimental fields according to PTG classification was typical grey-brown podsolic soil [Mocek et al. 1997]. It was classified as IV A and according to agricultural suitability it belongs to complex 5 (rye good).

To determine the effect of variety and fertilization of durum wheat on raw material characteristics important for pasta production following analyses of grain were carried out:

- 1000 kernel weight (PN-68/R-74017),
- weight per unit volume (test weight; PN-ISO 7971-2:1998),
- vitreousness [PN-70/R-74008],
- kernel hardness (Jakubczyk and Haber 1981),
- protein content [Kjeldahl method AACC 46-11A].

Grain was milled using Quadrumat-Senior mill and for further qualitative analyses semolina of constant for all varieties milling yield 65% was used. At the next stage falling number [PN-ISO 3093], quantity and weakening of wet gluten [PN-77/A--74041], yellow pigments content [ISO 11052] and colour of pasta dough made from the obtained flour [AACC 14-22] were determined.

Analysis of variance (one-way ANOVA for repeated measures) was applied to all the results obtained, as well as correlation and regression equation ($n = 16$). Significant differences were verified at $\alpha = 0.05$.

RESULTS AND DISCUSSION

Characterisation of grain was the first step of the study (Table 1 and 2). The results showed that the varieties were characterized by high 1000 kernel weight, ranging from 43.6 g to 56.3 g. Similar values were noted by Szwed-Urbaś at al. [1995] when they analysed quality of durum wheat grown in Lubelszczyzna region, whereas lower values

Table 1. Durum wheat grain characteristics depending on variety
Tabela 1. Wyróżniki oceny towaroznawczej ziarna pszenicy durum w zależności od odmiany

Variability factor Czynnik zmienności	Weight per 1000 kernels Masa 1000 ziaren g	Test weight Gęstość ziarna w stanie zsypnym kg/hl	Kernel hardness Twardość ziarna B.U.	Vitreousness Szklistość ziarna %	Total protein content, % d.m. Zawartość białka ogółem, % s.m.
Durabon	43.6-48.1 46.3	75.0-79.7 75.6	390-450 421	61-81 69	14.1-15.2 14.6
Durabonus	50.0-56.3 52.9	77.2-78.0 77.5	390-450 416	71-85 75	13.2-15.0 13.9
Duraprimus	50.7-55.7 53.8	77.2-79.3 78.2	470-510 485	75-88 82	14.0-15.8 14.6
Rusticano	46.1-48.7 47.7	72.4-73.2 76.4	425-495 456	33-61 50	13.6-15.4 14.4
$LSD_{(0.05)}$ $NIR_{(0,05)}$	0.50	0.58	25.7	3.2	0.40

Table 2. Durum wheat grain characteristics depending on nitrogen fertilization level
Tabela 2. Wyróżniki oceny towaroznawczej ziarna pszenicy durum w zależności od poziomu nawożenia azotowego

Variability factor Czynnik zmienności kg/ha N	Weight per 1000 kernels Masa 1000 ziaren g	Test weight Gęstość ziarna w stanie zsypnym kg/hl	Kernel hardness Twardość ziarna B.U.	Vitreousness Szklistość ziarna %	Total protein content, % d.m. Zawartość białka ogółem, % s.m.
0	43.6-53.2 48.2	73.2-77.6 75.8	390-470 430	33-75 60	13.9-14.1 14.0
50	46.0-53.5 49.4	72.4-77.6 75.7	390-490 435	45-77 62	13.7-14.3 13.8
100	47.9-56.3 52.1	72.8-78.9 76.1	390-510 461	60-88 77	13.8-14.8 14.3
150	48.0-55.7 51.1	72.8-79.3 76.3	440-470 453	61-87 76	15.0-15.8 15.2
$LSD_{(0.05)}$ $NIR_{(0,05)}$	0.70	0.30	14.8	7.2	0.15

of this characteristic were obtained in the research of Rachoń and Szumiło [2002]. While analysing the effect of nitrogen fertilization on grain characteristics it was found that 1000 kernel weight increases with the increase in nitrogen dose up to 100 kg/ha. The next dose (N – 150 kg/ha) did not have a significant influence on this characteristic. Only in case of three out of four tested varieties further increase in the nitrogen dose resulted in the increase of 1000 kernel weight. Research carried out by Rachoń [1999] and Rachoń et al. [2002] did not confirm such a trend. The quoted author observed that by increasing nitrogen dose the number of grains in ear increased however, the decrease in 1000 kernel weight ensued.

More significant difference was found between varieties. Higher values of 1000 kernel weight were determined for the grain of Durabonus and Duraprimus varieties in comparison with Durabon and Rusticano varieties. Analysis of variance indicated the effect of both fertilization level and durum wheat variety on this characteristic. On the basis of regression equation for the dependence of 1000 kernel weight on fertilization dose within a tested range it was revealed that the function approached maximum value at 140 kg N/ha and then it was sloping down (Table 3).

Table 3. Regression equations for the dependence of the examined grain characteristics on nitrogen fertilization dose (n = 16)
Tabela 3. Funkcje regresji badanych cech towaroznawczych ziarna względem dawek nawożenia azotowego (n = 16)

Characteristic Cecha	Equation Równanie	R^2
Weight per 1000 kernels, g Masa 1000 ziaren, g	$y = -0.0002x^2 + 0.0558x + 47.9$	0.8508
Test weight, kg/hl Gęstość ziarna w stanie zsypnym, kg/hl	$y = 5 \cdot 10^{-5} x^2 + 0.0011x + 188.4$	0.8454
Total protein content, % d.m. Zawartość białka ogółem, % s.m.	$y = 0.0091x + 13.7$	0.761
Kernel hardness, B.U. Twardość ziarna, B.U.	$y = -0.0014x^2 + 0.3946x + 427$	0.754
Vitreousness, % Szklistość, %	$y = -0.0003x^2 + 0.1655x + 58.7$	0.8292

The next examined characteristic was weight per unit volume (test weight). The obtained results ranged from 72.5 kg/hl to 79.3 kg/hl. Similar results got Szwed-Urbaś et al. [1995] and Rachoń [1997]. Like in the case of previous characteristic 'Durabon' and 'Duraprimus' varieties were characterised by a higher test weight as compared to 'Durabon' or 'Rusticano' variety. The latter was distinguished by particularly low test weight in comparison with the others. Analysis of variance showed the influence of both variety and fertilization of durum wheat on test weight. In the experiment – in the case of no fertilization and the lowest nitrogen dose – test weight was at the same level but when the nitrogen dose increased to 100 and 150 kg N/ha the values were not much but still significantly higher. Rachoń et al. [2002] in his research obtained different results. According to him the increase in nitrogen dose was accompanied by the decrease in test weight.

The next feature correlated with grain milling properties is kernel hardness. Wheats of higher kernel hardness are potentially better raw material to produce semolina. Very hard grain has usually higher protein content while quantity and quality of reserve protein in flour affect pasta quality [Obuchowski 1997]. That is why pasta raw material producers favour hard grain which enables to obtain semolina with high protein content and then not crumbling and firm after cooking pasta. This characteristic is considered to be dependent on genetic features, environmental conditions as well as agricultural practices [Rachoń et al. 2002].

Analysing this characteristic it was shown that grain of 'Duraprimus' variety was distinguished by the highest kernel hardness (485 B.U.) a little lower values were determined in case of 'Rusticano' variety while the lowest hardness showed 'Durabonus' variety (416 B.U.). Kernel hardness was also dependent on the level of nitrogen fertilization of plants.

The obtained results were subjected to analysis of variance which revealed that kernel hardness is affected by both durum wheat variety and the dose of applied nitrogen fertilization. Different results of this research on domestic and foreign durum wheat varieties reported Rachoń [2004]. The results were higher than the ones determined in this study and did not differ significantly between the varieties. On the basis of regression equation for the dependence of kernel hardness on nitrogen dose it was shown that kernel hardness increased as the nitrogen dose increased up to 140.9 kg N/ha. However, the application of higher dose brought about a slight decrease of the characteristic value.

Vitreousness is a grain characteristic which affects largely its milling quality. While milling vitreous grain we obtain big amount of coarse groats. A specific character of durum wheat is its high vitreousness. From the pasta industry point of view it is a favourable property because the best raw material for pasta production is not flour but groats of granulation ca 350 nm [Obuchowski 1999]. On the basis of the conducted research it was found that grains of 'Duranbonus' and 'Duraprimus' varieties were characterised by a relatively high vitreousness (average 75% and 82% respectively). The lower results were obtained for 'Durabon' variety (69%) whereas 'Rusticano' wheat was rather mealy grain (50%). The higher results, ranging from 85% to 88%, were obtained in the research conducted by Rachoń and Szumiło [2002]. Woźniak [2005] however, showed that vitreousness to a large extent depends on the forecrop used. In this research these values ranged from 71% to 92% depending on the factor mentioned above. In case of durum wheat grown in continental climate (USA) grain of vitreousness over 90% is obtained [Obuchowski 1997]. It was shown that with the increase of fertilization dose within the tested range the vitreousness of grain increased. Other authors in their research came to similar conclusions [Mazurek and Biskupski 1978].

Total protein content determined in experimental material was found to be at the similar level in grain of all tested varieties. It was shown however that these values changed along with increasing dose of nitrogen fertilization. While in the case of the lowest dose – 50 kg N/ha protein content in grain was similar to one in grain grown without nitrogen fertilization, in the case of fertilization at the level of 150 kg N/ha these values were definitely higher. Analysis of variance showed the effect of both variety and dose of nitrogen fertilization on protein content in grain.

The regression function for the dependence of protein content on nitrogen dose within the tested range, at the determination coefficient of 0.761 takes a form of a straight line. On the basis of regression equation it was revealed that the increase in nitrogen dose is accompanied by the increase in protein content in grain (Table 3). Positive correlation between nitrogen dose and protein content in grain was noted also in the research of Rachoń [2001]. This regularity was confirmed by other authors as well [Ciołek and Makarska 2004, Rachoń et al. 2002, Szwed-Urbaś et al. 1997]. Changes in protein content resulting from different nitrogen fertilization are considered to be dependent to a large extent on varietal properties and habitat conditions [Mazurek and Biskupski 1978]. However, the limitation to use of high doses of this component may be the increase in susceptibility to lodging and deterioration of protein quality in grain [Rachoń 1999].

From the pasta industry point of view the most important raw material features are: wet gluten content and weakening, amylolytic activity and yellow pigments content.

The results of wet gluten content, its weakening and enzymatic activity of flour samples of tested hard wheat varieties fertilized with different nitrogen doses are presented below (Table 4 and 5).

Table 4. Durum wheat flour characteristics depending on variety
Tabela 4. Wyróżniki towaroznawcze mąki z pszenicy durum w zależności od odmiany

Variability factor Czynnik zmienności	Wet gluten content Wydajność mokrego glutenu %	Gluten weakening Rozpływalność glutenu mm	Falling number Liczba opadania s
Durabon	34-38 36	16-19 17	206-230 222
Durabonus	32-38 34	10-14 12	227-315 287
Duraprimus	32-40 36	4-11 8	285-364 322
Rusticano	30-33 32	5-10 8	217-233 221
$LSD_{(0.05)} - NIR_{(0,05)}$	1.2	0.6	3.6

Table 5. Durum wheat flour characteristics depending on nitrogen fertilization level
Tabela 5. Wyróżniki jakościowe mąki z pszenicy durum w zależności od nawożenia azotowego

Variability factor Czynnik zmienności kg/ha N	Wet gluten content Wydajność mokrego glutenu %	Gluten weakening Rozpływalność glutenu mm	Falling number Liczba opadania s
0	32-35 34	4-19 10	227-364 284
50	30-36 33	7-17 11	206-308 240
100	33-38 35	9-18 12	216-334 266
150	33-40 37	7-16 12	217-315 261
$LSD_{(0.05)} - NIR_{(0,05)}$	0.4	0.3	3.7

The analysed flour samples were characterised by wet gluten content ranging from 32 to 37%. These values were dependent on both variety and the fertilization level. The lowest value was determined for flour of 'Rusticano' variety (32%) whereas values at the level of 36% were obtained for 'Durabon' and 'Duraprimus' varieties. Similar and even lower values of wet gluten content were reported by Szwed-Urbaś at al. [1995]. Taking into consideration the differences resulting from applied doses of nitrogen fertilization it was found that gluten content increases with the increase in nitrogen fertilization what was shown also in other research [Rachoń 1999]. A function of relationship

between the two values takes here a form of straight line (determination coefficient 0.811). Similar positive correlation between gluten content and nitrogen fertilization revealed Rachoń [1999].

While wet gluten content increases with fertilization dose, its quality deteriorates. This may be the result of changes in gluten protein characteristic which are connected with the increase in amount of low molecular weight gliadin affecting gluten rheological properties [Achremowicz et al. 1995]. There are also reports that in some varieties high nitrogen doses improve wheat protein system whereas in others quite the contrary [Stankowski et al. 2004].

A specific character of durum wheat is a higher level of wet gluten weakening resulting from different gliadin – glutenin ratio in comparison with common wheat. Durum wheat gluten is less elastic and more plastic. According to the standards durum wheat gluten weakening may reach even 13 mm. The weakening of gluten obtained from flour of different durum wheat varieties differed widely and ranged from 8 mm (Duraprimus) to 17 mm (Durabon).

However, while analysing the influence of fertilization on this characteristic lower variability was found – from 10 mm (no fertilization) to 12 mm (doses of 100 and 150 kg N/ha). Szwed-Urbaś et al. [1997] showed that wet gluten content and weakening depend to a large extend on climatic conditions during vegetation. In the present study no significant correlation between wet gluten content and its weakening was established.

Table 6. Characteristics that determine pasta colour depending on durum wheat variety
Tabela 6. Wyróżniki determinujące barwę makaronu w zależności od odmiany pszenicy durum

Variability factor Czynnik zmienności	Carotenoid pigments content Zawartość karotenoidów mg%	Colour of pasta dough Barwa ciasta makaronowego	
		brightness jasność L, %	yellowness żółtość b, %
Durabon	0.213-0.231 0.222	75.1-77.2 76.3	14.1-14.7 14.4
Durabonus	0.206-0.221 0.213	72.2-75.0 73.9	13.9-15.3 14.7
Duraprimus	0.155-0.170 0.164	76.4-77.7 77.1	11.3-13.1 12.3
Rusticano	0.139-0.154 0.149	71.9-74.6 73.4	8.4-11.0 9.9
$LSD_{(0.05)}$ – $NIR_{(0,05)}$	0.003	0.23	0.73

From pasta quality point of view the raw material for its production should be characterised by low enzymatic activity which affects colour and stickiness of pasta. While determining enzymatic activity it was found that falling number varies more significantly according to variety (220-322 s) than to fertilization level (240-284 s). The highest enzymatic activity had 'Durabon' and 'Rusticano' varieties and the lowest 'Duraprimus'. The results at the level of 320-330 s in the research on durum wheat varieties were obtained also by Woźniak [2005]. At the same time he revealed significant corre-

lation between falling number and grain vitreousness what was not confirmed by this study. Ciołek and Makarska [2004] in their research show higher values of hard wheat falling number and negative correlation between nitrogen dose and falling number value. The authors explain this fact by increased susceptibility to lodging at the increased nitrogen dose and because of that possibility of sprouting. According to Obuchowski [1999] only the wheat durum milled products for which falling number value is higher than 250 s are suitable for pasta production. Otherwise pasta is darkening especially if the flour extraction is high. On the basis of conducted research no significant correlation between the falling number values and any of the tested grain or flour features was found.

Table 7. Characteristics that determine pasta colour depending on nitrogen fertilization level
Tabela 7. Wyróżniki determinujące barwę makaronu w zależności od nawożenia azotowego

Variability factor Czynnik zmienności kg/ha N	Carotenoid pigments content Zawartość karotenoidów mg%	Colour of pasta dough Barwa ciasta makaronowego	
		brightness jasność L, %	yellowness żółtość b, %
0	0.151-0.221 0.187	74.2-77.6 75.6	10.0-15.3 12.7
50	0.139-0.231 0.183	72.2-77.7 75.2	8.4-15.0 12.3
100	0.154-0.224 0.189	73.0-77.2 75.3	11.0-14.9 13.4
150	0.150-0.213 0.186	71.9-76.4 74.6	10.1-14.7 13.0
$LSD_{(0.05)} - NIR_{(0,05)}$	0.002	0.41	0.45

A feature which to a large extend determines pasta quality is colour. Its intensity on one hand depends on the amount of yellow pigments in raw material and on the other hand on activity of enzymes affecting colour changes.

The results of yellow pigments content (expressed in β-carotene) in flour of tested samples and also yellowness and brightness of dough obtained from the flours are presented in Table 8.

It was shown that yellow pigments content depends mainly on wheat variety and to a lesser degree on fertilization level. Determined values varied depending on variety between 0.149 (Rusticano) and 0.222 mg% (Durabon) while average values obtained at different level of nitrogen fertilization ranged from 0.183 to 0.189 mg%. Higher results were produced by Rachoń [2004] when he was assessing the usefulness of domestic and foreign hard spring varieties for pasta production and by Ciołek and Makarska [2004]. Obuchowski [1997] reports that yellow pigments content in hard Canadian wheat may reach even 0.760 mg%. The influence of fertilization on pigments content was also assessed by Ciołek and Makarska [2004] mentioned above. They found out that higher nitrogen fertilization level lowered total carotenoids content in grain. In the present study no correlation between this characteristic and fertilizer dose was established.

Colour of pasta dough was assessed with the reflectance colorimeter according to Hunter scale. Two values: L-brightness and b-yellowness were determined. It was shown that L value depends on both variety and fertilization. The highest brightness (L value) demonstrated dough from 'Duraprimus' variety – 77.1% and the lowest value was determined for 'Rustikano' – 73.5%. Slighter, but still significant effect on this characteristic had fertilization. On the basis of obtained results a negative correlation between dough brightness and nitrogen dose was established. Regression equation for the above dependence is presented in Table 8.

Table 8. Regression equations for the dependence of the examined durum wheat flour characteristics on nitrogen fertilization dose (n = 16)
Tabela 8. Równania regresji wykazanych zależności cech mąki względem dawek azotu (n = 16)

Characteristic Cecha	Equation Równanie	R^2
Brightness of pasta dough, L, % Jasność ciasta makaronowego, L, %	$y = –0.0061x + 75.6$	0.8159
Wet gluten content, % Wydajność mokrego glutenu, %	$y = 0.0264x + 32.9$	0.8112
Gluten weakening, mm Rozpływalność glutenu, mm	$y = –0.0002x^2 + 0.041x + 9.5$	0.9849

Definite influence of variety but no such a dependence on nitrogen fertilization was shown in case of yellowness of pasta dough "b". Depending on the variety this characteristic varied from 9.8% (Rustikano) to 14.7% (Durabonus). While the results dependent on nitrogen fertilization dose were within the narrow range: 12.3-13.4%. Rachoń [2004] in his research on different varieties of hard wheats cultivated in Poland obtained doughs of a little lower brightness index but with a similar yellowness index.

CONCLUSIONS

1. Nitrogen fertilization of durum wheat to the level of 140 kg N per 1 ha significantly affects grain structure represented as vitreousness and hardness of its endosperm. On the basis of determined regression equations it was found that the higher nitrogen doses (within the tested range) the more vitreous grain, whereas the increase in kernel hardness occurs only up to a certain nitrogen fertilization level.

2. Positive correlation was revealed between nitrogen dose and protein content in grain as well as wet gluten content. Fertilization level influenced also properties of gluten proteins.

3. No correlation was found between fertilization dose and carotenoid pigment content in durum wheat flour or the level of dough yellowness. However, the fertilization level had a negative effect on brightness of pasta dough. The values of these characteristics change more with variety than with dose of fertilization which indicates that these characteristics are genetically conditioned and to a lesser extend depend on agricultural practices.

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WPŁYW ODMIANY I NAWOŻENIA AZOTOWEGO PSZENICY DURUM NA WYBRANE CECHY JAKOŚCIOWE WAŻNE Z PUNKTU WIDZENIA PRODUKCJI MAKARONU

Streszczenie. W pracy badano wpływ nawożenia azotowego na właściwości ziarna i mąki z pszenicy durum. Analizie poddano cztery odmiany pszenicy durum: Durabon, Durabonus, Duraprimus i Rusticano, pochodzące z Zakładu Doświadczalnego w Swadzimiu, należącego do Akademii Rolniczej w Poznaniu. W czasie wegetacji poletka nawożono azotem, stosując następujące jego dawki: 50 kg/ha, 100 kg/ha i 150 kg/ha. Dodatkowo analizowano ziarno nienawożone, uprawiane w tych samych warunkach. Na podstawie przeprowadzonych analiz stwierdzono istotny wpływ nazwożenia azotowego na takie cechy ziarna, jak twardość i szklistość. Wykazano także, że wraz ze wzrostem dawki azotu zwiększa się zawartość białka w mące oraz wydajność mokrego glutenu. Nie stwierdzono natomiast istotnego wpływu nawożenia azotowego na zawartość barwników żółtych w mące oraz na barwę ciasta makaronowego.

Słowa kluczowe: pszenica durum, nawożenie azotowe, parametry jakościowe, ziarno, mąka, surowce do produkcji makaronu

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