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COMPARISON OF THE CHEMICAL COMPOSITION OF SPRING DURUM WHEAT GRAIN (*TRITICUM DURUM*) AND COMMON WHEAT GRAIN (*TRITICUM AESTIVUM* SSP. *VULGARE*)

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Abstract

The research was conducted at the Experimental Farm in Felin, property of the University of Life Sciences in Lublin, in 2007–2009. The experiment was located on soil of good wheat complex. The research included the spring form of durum wheat (*Triticum durum* Desf.) – breeding line LGR 896/23 (selected at ULS, Lublin) and cultivars Lloyd (American), Chado and Kharkivska 27 (Ukrainian), which were compared with spring common wheat (*Triticum aestivum ssp. vulgare*) cv. Torka.

In the study, the chemical composition of durum wheat grain and common wheat grain was analysed. The content of total protein, fibre, fat, ash, nitrogen–free extracts, macronutrients (phosphorus, potassium, calcium, magnesium) and micronutrients (copper, iron, manganese, zinc) was determined. Variation coefficients and coefficients of correlation were also calculated.

All the lines and cultivars of spring durum wheat were characterised by a higher content of total protein and zinc compared to common wheat. Common wheat showed a higher content of copper and manganese in grain compared to durum wheat. Among the quality traits of wheat grain, regardless of the species, the content of nitrogen–free extracts was the least variable (cv=1.5%), whereas the highest variability (cv=37.2%) characterised the content of manganese. Significant correlations were shown in wheat grain for the following pairs of quality traits: protein–nitrogen–free extracts, protein–ash, and ash–protein–free extracts. The results of the qualitative evaluation of the wheat species show that the line and cultivars of durum wheat as well as the cultivars of common wheat fulfil the protein content norms set for raw material for pasta production. Higher ash levels in flour may cause a risk of obtaining darker colour pasta.

Key words: durum wheat, common wheat, pasta, grain quality, chemical composition, macroelements, microelements, coefficient of variation, correlation coefficient.

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PORÓWNANIE SKŁADU CHEMICZNEGO ZIARNA PSZENICY JAREJ TWARDEJ (*TRITICUM DURUM*) Z PSZENICĄ ZWYCZAJNĄ (*TRITICUM AESTIVUM* SSP. *VULGARE)*

Abstrakt

Badania przeprowadzono w latach 2007–2009 na terenie Gospodarstwa Doœwiadczalnego w Felinie, należącego do Uniwersytetu Przyrodniczego w Lublinie. Doœwiadczenie zlokalizowano na glebie zaliczanej do kompleksu pszennego dobrego. Badaniami objêto formê jarą pszenicy twardej (*Triticum durum* Desf.): linia hodowlana LGR 896/23 (wyselekcjonowana w UP w Lublinie) i odmiany Lloyd (amerykańska), Chado i Kharkivska 27 (ukraińskie), której porównano z pszenicą jarą zwyczajną (*Triticum aestivum* ssp. *vulgare*) odmiany Torka.

W pracy analizowano skład chemiczny ziarna pszenicy twardej i pszenicy zwyczajnej. Okreœlono zawartoœæ białka ogólnego, włókna, tłuszczu, popiołu, bezazotowych substancji wyciągowych, makroelementów (fosforu, potasu, wapnia, magnezu) i mikroelementów (miedzi, żelaza, manganu, cynku). Obliczono także współczynniki zmiennoœci oraz współczynniki korelacji.

Wszystkie badane linie i odmiany pszenicy jarej twardej zawierały więcej białka ogólnego oraz cynku w porównaniu z pszenicą zwyczajną. Pszenica zwyczajna miała wyższą zawartoœæ miedzi i manganu w ziarnie w porównaniu z pszenicą twardą. Spoœród cech jakoœciowych ziarna badanych pszenic, niezależnie od gatunku, zawartoœæ substancji bezazotowych wyciągowych okazała siê cechą najmniej zmienną (cv=1,5%), najwiêksz± zaœ zmiennoœæ (cv=37,2%) stwierdzono w przypadku zawartoœci manganu. W ziarnie pszenicy wykazano istotne korelacje dla nastêpujących par cech jakoœciowych: białko–substancje bezazotowe wyciągowe, białko–popió³, oraz popió³–substancje bezazotowe wyciagowe. Wykazano, że zarówno linia i odmiany pszenicy twardej, jak też odmiana pszenicy zwyczajnej spełniają normy surowca do produkcji makaronu pod wzglêdem zawartoœci białka. Podwyższona popiołowoœæ mąki może stwarzać niebezpieczeństwo uzyskania makaronu o ciemniejszej barwie.

S³owa kluczowe: pszenica twarda, pszenica zwyczajna, makaron, jakoœæ ziarna, sk³ad chemiczny, makroelementy, mikroelementy, wspó³czynnik zmiennoœci, wspó³czynnik korelacji.

INTRODUCTION

Because of its high content of carotenoid pigments and high kernel glassiness and hardness, durum wheat is mainly used in the production of special coarse flour, known as semolina, from which pasta is made (Szwed-Urbaœ et al. 1997). However, high quality semolina can be obtained only from high quality grain, and then pasta has appropriate viscoelasticity, colour, and does not form clusters while drying or overcooking, as may happen when flour from common wheat is used (Obuchowski 1998). The chemical and mineral composition of wheat grain has essential influence on its quality. Minerals are a group of compounds necessary in human nutrition. The human organism is incapable of producing them, hence they must be supplied in appropriate amounts with food. *Triticum durum* grain should not contain large amounts of ash because ash gives a dark colour to pasta, which should be yellow owing to the natural concentration of carotenoid

pigments (ZALEWSKI, BOJARCZUK 2004). The colour of semolina and flour obtained from *T. durum* grain is very important, because synthetic dyes are not used in the production of pasta (SZWED-URBAŒ et al. 1997). At the same time, grain of this species should be rich in proteins for the semolina will contain a minimum 12-13% of protein and no less than 30% of gluten. With lower levels of these components, the pasta will be brittle and fragile (OBUCHOWSKI 2000, RACHOŃ 2004), prone to cracking during drying and transport (RACHOŃ et al. 2002), and thus of lower quality.

At present, the demand of the Polish the food industry for durum wheat grain is covered entirely by import (SZWED-URBAŒ 1997, RACHOŃ 2004). However, high prices of grain of this species on the international market and the industry's increasing demand, dictated by the increased consumption of products made from durum wheat (e.g. pastas, grits), have renewed the interest in cultivation of specific varieties of this wheat in our country (SZWED-URBAŒ et al. 2000, RACHOŃ, SZUMIŁO 2006). Since 1976, research has been conducted in the Lublin region with the goal of studying the world resources of *Triticum durum* and choosing appropriate initial material for the national program of cultivating this wheat (SZWED-URBAŒ 1992).

The aim of this study has been to determine the chemical composition of grain of spring varieties and lines of durum wheat in comparison to common wheat and to assess their technological suitability for the production of pasta.

MATERIAL AND METHODS

A field experiment was conducted in 2007-2009 at the Experimental Farm in Felin, property of the University of Life Sciences in Lublin. The experimental field was located on soil of good wheat complex, rich in nutrients: P –76, K –119 and Mg –55 (in mg kg^{-1} of soil), with slightly acid reaction (pH in KCl solution – 6.3) (RACHOŃ 2001).

The experiment was set up on soil after winter rape in random blocks with 4 replications. The research covered the spring form of durum wheat: breeding line LGR 896/23 (selected in the Institute of Plant Genetics, Breeding and Biotechnology, ULS in Lublin) and cultivars Lloyd (American), Chado and Kharkivska 27 (Ukrainian), and spring common wheat of cv. Torka, which belongs to the grain technology value group E. The harvest area of the plots was 10 m^2. Soil tillage was a typical plough system. The following were applied pre-sowing: phosphorus fertilisation at a dose of 26.2 kg P ha^{-1}, potassium at a dose of 66.6 kg K ha^{-1} and nitrogen at a dose of 40.0 kg N ha^{-1}. Another dose of nitrogen (40.0 kg N ha^{-1}) was applied as top dressing. Sowing density of both species was 5 million germinating kernels per 1 ha. Treatments (herbicides, fungicides, insecticides, retardant) were performed according to current recommendations.

Chemical analyses were performed annually in grain samples taken from the plots. After wet mineralisation (concentrated sulphuric acid + hydrogen peroxide), the amounts of the following were determined: fibre (gravimetric method), fat (Soxhlet gravimetric method) and ash (gravimetric method at 580°C) – PN-ISO 2171. Protein content was determined using Kjeldahl method (N%·5.75) – PN-75/A-04018. Nitrogen-free extract content was obtained by subtracting the sum of the other ingredients of dry matter from 100. The concentration of the following macro- and micronutrients was also determined: P (flow spectrophotometry), K (flame spectrometry emission), Ca, Mg, Cu, Fe, Mn and Zn (atomic absorption spectrometry).

The experimental results were statistically processed with the analysis of variance, determining the significance of differences by means of Tukey's test at the significance level 0.05. The results were given as average values from three years of the research with standard deviation (SD). The variability of the examined grain quality parameters was determined based on the variation coefficient. Next, the relationships between grain quality traits were determined by calculating the coefficients of correlation for the significance level 0.05.

The weather conditions during the experiment were highly variable (Table 1). In 2007, April was dry, which had an unfavourable effect on the germination of wheat. Later, from May to July of that year, high temperatures were noted and the rainfall was above the long-term average (1951--2000), which was favourable for intensive growth and development of the plants. In 2008, April was warm, with the rainfall above the long-term norm,

Table 1

Rainfalls and air temperatures according to the Meteorological Observatory at Felin

Year	Month						Period March-August
	March	April	May	June	July	August	
Rainfalls (mm)							sum
2007	30.2	17.4	81.5	87.8	87.0	37.6	341.5
2008	64.8	55.8	101.6	25.9	77.1	45.0	370.2
2009	69.6	2.9	71.1	125.5	57.1	54.7	380.9
Mean for years 1951-2000	25.8	40.6	58.3	65.8	78.0	69.7	338.2
Temperature (°C)							mean
2007	6.2	8.7	15.0	18.1	19.2	18.4	14.3
2008	3.4	9.3	12.8	17.7	18.3	19.3	13.5
2009	1.4	11.4	13.6	16.4	19.9	19.0	13.6
Mean for years 1951-2000	1.0	7.5	13.0	16.5	17.9	17.3	12.2

which favoured the sprouting of cereals. May was characterised by moderate temperatures and a significant surplus of rainfall, a deficiency of which occurred in June, whereas in July the temperature and precipitation were close to the long-term average. In the last year of the research (2009), severe precipitation deficit in April and at the beginning of May inhibited the germination, growth and development of spring wheat, and frequent rainfall in June encouraged re-infestation of the plantation with weeds. In 2009, the lowest quality of durum and common wheat grain was obtained.

RESULTS AND DISCUSSION

Chemical composition analysis of the grain of the examined species of wheat and their lines and varieties showed significant variations of most of the examined characteristics (Table 2). One of the more important distin-

Table 2

The chemical composition of spring wheat (g kg^{-1} d.m.)

Cultivars and line		Total protein	Crude fibre	Crude fat	Crude ash	N-free extract
Common wheat						
Torka	M	136	22.0	20.0	22.0	801
	SD	12.0	1.2	0.9	2.1	32.7
Durum wheat						
LGR 896/23	M	154	23.0	19.0	23.0	781
	SD	13.5	1.2	1.6	1.9	32.5
Lloyd	M	148	20.0	19.0	22.0	791
	SD	10.5	1.7	1.2	1.5	31.6
Chado	M	148	24.0	19.0	21.0	788
	SD	5.6	2.1	1.1	0.12	29.8
Kharkivska 27	M	147	22.0	18.0	21.0	792
	SD	9.9	1.1	2.1	1.5	31.1
Mean		149	22.3	18.7	21.8	788
LSD		11.3	2.10	1.50	1.40	13.6
CV (%)		7.4	7.4	6.9	7.3	1.5

M – mean for the years 2007-2009
SD – standard deviation
LSD(p=0.05) for cultivars and line
CV – coefficient of variation

guishing qualities of wheat is the grain protein content. The average protein content in durum wheat grain equalled 149 g kg^{-1} and was significantly higher compared to common wheat of Torka variety (136 g kg^{-1}). The examined lines and varieties of durum wheat were characterised by high total protein content in the grain. The highest protein content (154 g kg^{-1}) was noted in the grain of durum wheat of line LGR 896/23, and the lowest (147 g kg^{-1}) was determined in the grain of cv. Kharkivska 27. Many authors point out a higher protein content in durum wheat grain compared to common wheat. In the studies by RACHOÑ and KULPA (2004) and RACHOÑ and SZUMIŁO (2006, 2009), durum wheat contained on average 2.3-3.1% more protein, whereas in the investigations by SZWED-URBAŒ (1993) and SEGIT and SZWED--URBAŒ (2006), the differences were even bigger and reached up to 4.6%. In the study by RACHOÑ and SZUMIŁO (2002), the protein content in grain of cv. Torka equalled 135 g kg^{-1} and was close to the content of this component in another variety of common wheat – Sigma (135 g kg^{-1}), but significantly lower (by 2.9%) compared to lines and varieties of durum wheat.

The average fibre content in durum wheat grain equalled 22.3 g kg^{-1}, and fat – 18.7 g $kg^{-1,}$ in which they did not differ significantly from the common wheat variety (22.0 g kg^{-1} and 20.0 g kg^{-1}, respectively). Among the compared lines and varieties of durum wheat, significant differences in fibre content were noted between the cultivars Chado (24.0 g kg^{-1}) and Lloyd (20.0 g kg^{-1}). The nitrogen-free extract content was similar in both compared wheat species. A significant difference was noted only between line LGR 896/23 of durum wheat (781.0 g kg^{-1}) and common wheat (801.0 g kg^{-1}).

Determination of the ash content and level of minerals is significant for a comprehensive analysis of wheat grain quality traits, as these components determine whether it is technologically possible to process given wheat into final products i.e. bread or pasta. Cereal products, which form 40-50% of the human diet, are one of the main sources of minerals. High content of minerals is nutritionally beneficial, but an excessive ash content may impede technological processes and production high quality food (e.g. darkening of pasta). In our study, the average ash content in durum wheat grain equalled 21.8 g kg^{-1} and did not significantly differ compared to common wheat (22.0 g kg^{-1}). A significant difference was noted only between line LGR 896/23 (23.0 g kg^{-1}) and cv. Chado v (21.0 g kg^{-1}). Other authors, e.g. G¥SIOROWSKI and OBUCHOWSKI (1978), MAKARSKA et al. (2001), RACHOÑ (2001), RACHOÑ and SZUMIŁO (2009), demonstrated a higher content of this component in durum wheat grain compared to common wheat.

For an organism to function properly, the daily supply of basic nutrients is just as important as the availability, often even in trace amounts, of elements participating in the metabolism: macro- and micronutrients. One of their sources is wheat grain.

Among the analysed macroelements, phosphorus, calcium and magnesium were demonstrated to vary in their content (Table 3). The average phosphorus content of durum wheat grain was 4.73 g kg^{-1} and did not differ

Table 3

The content of macronutrients in spring wheat (g kg $^{-1}$ d.m.)

Cultivars and line		Phosphorus	Potassium	Calcium	Magnesium
Common wheat					
Torka	M	4.60	5.00	0.77	1.40
	SD	0.35	0.65	0.11	0.18
Durum wheat					
LGR 896/23	M	5.00	5.50	0.64	1.40
	SD	0.45	0.94	0.12	0.10
Lloyd	M	4.70	5.20	0.86	1.20
	SD	0.43	0.88	0.06	0.10
Chado	M	4.60	5.30	0.76	1.30
	SD	0.35	0.64	0.11	0.11
Kharkivska 27	M	4.60	4.90	0.74	1.20
	SD	0.45	0.65	0.06	0.10
Mean		4.73	5.23	0.75	1.28
LSD		0.250	n.s.	0.120	1.800
CV (%)		8.4	14.5	15.0	11.1

* key under Table 2

significantly compared to common wheat – 4.60 g kg^{-1} The highest phosphorus content among the examined durum wheat lines and varieties was determined in line LGR 896/23 – 5.00 g kg^{-1}. Rachoń and Szumiło (2009) found a higher phosphorus content in durum wheat grain compared to common wheat. The highest content of calcium was observed in durum wheat grain of cv. Lloyd – 0.86 g kg^{-1}, and of magnesium in durum wheat grain of line LGR 896/23 and in the common wheat variety – 1.40 g kg^{-1}. At the same time, no significant differences were shown between the average content of both elements in durum wheat grain compared to common wheat, which in the case of magnesium is confirmed by Makarska et al. (2001). The calculated variance coefficients (cv) for the respective macroelements, regardless of the examined species, were varied. The highest variance was noted for calcium (cv=15.0%) and potassium (cv=14.5%), and the lowest one for phosphorus (cv=8.4%).

The examined species varied significantly in terms of copper, manganese and zinc content (Table 4). Common wheat grain was characterised by the highest copper and manganese content: 3.23 mg kg^{-1} and 37.7 mg kg^{-1}, respectively. Significantly lower values were obtained in durum wheat grain (2.54 mg kg^{-1} and 30.5 mg kg^{-1} on average). Of the examined durum wheat

Table 4

The content micronutrients in spring wheat (mg kg^{-1} d.m.)

Cultivars and line		Copper	Iron	Manganese	Zinc
Common wheat					
Torka	M	3.23	37.7	37.7	32.5
	SD	0.34	6.72	8.02	5.94
Durum wheat					
LGR 896/23	M	2.83	37.6	30.3	39.4
	SD	0.25	3.55	10.66	5.90
Lloyd	M	2.64	37.5	26.7	38.7
	SD	0.25	8.25	11.47	7.47
Chado	M	2.33	36.3	35.1	46.4
	SD	0.63	4.76	13.90	8.16
Kharkivska 27	M	2.35	34.6	29.8	40.8
	SD	0.47	1.92	12.59	9.21
Mean		2.54	36.5	30.5	41.3
LSD		0.680	n.s.	7.74	5.42
CV (%)		19.6	14.5	37.2	21.4

* key under Table 2

varieties, the lowest content of copper was noted in the grain of the cultivars Chado – 2.33 mg kg^{-1} and Kharkivska 27-2.35 mg kg^{-1}; in respect of manganese, the following varieties contained the smallest concentrations of this element: Lloyd – 26.7 mg kg^{-1} and Kharkivska 27-29.8 mg kg^{-1}. Significantly higher zinc content was shown in durum wheat grain (on average, 41.3 mg kg^{-1}) compared to common wheat (32.5 mg kg^{-1}). VILLEGAS et al. (1970), MAKARSKA et al. (2001) and RACHOŃ (2001) also indicate higher zinc content in durum wheat compared to common wheat. The lowest variance among the analysed micronutrients was demonstrated for iron (cv = 14.5%) and copper (cv=19.6%), and the highest one for manganese (cv = 37.2%).

In the above research, regardless of the wheat species, significant relations were observed between the protein content and ash or nitrogen-free extract content in grain (Table 5). The protein content in grain was positively correlated with ash (r=0.658) and negatively with nitrogen-free extract content (r=–0.985). RACHOŃ and SZUMIŁO (2009) also demonstrated a negative correlation between the protein content and nitrogen-free extracts in wheat grain. A negative, significant correlation was evidenced also between the ash content and nitrogen-free extracts in wheat grain (r=–0.696).

Table 5

Values of correlation coefficients

Correlation coefficients	Total protein	Crude fibre	Crude fat	Crude ash
Crude fibre	0.288	*x*		
Crude fat	-0.332	-0.149	*x*	
Crude ash	0.658*	0.169	-0.433	*x*
N-free extract	-0.985*	-0.400	0.266	-0.696*

* values of significant correlation coefficients

CONCLUSIONS

1. Durum wheat grain was characterised by a higher content of total protein and zinc compared to common wheat.

2. Common wheat showed a higher copper and manganese content in grain compared to durum wheat.

3. High protein content in the grain of the examined varieties and lines of durum wheat indicates its usefulness in the production of pasta, and the relatively high ash content in the grain indicates worse colouring of pasta.

4. In wheat grain, regardless of its species, significant correlations were shown for the following pairs of quality traits: protein-nitrogen-free extracts, protein-ash, and ash-protein-free extracts.

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