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NUTRITIVE VALUE AND MINERAL COMPOSITION OF HUSKED AND NAKED SPRING WHEAT SPECIES IN RELATION TO CULTIVATION TECHNOLOGY

Leszek Rachoń[1], Grzegorz Szumiło[1], Andrzej Woźniak[2],
Barbara Krochmal-Marczak[3], Anna Szafrańska[4]

[1]*Department of Plant Production Technology and Commodities Science,*
[2]*Department of Herbology and Plant Cultivation Techniques, University of Life Sciences in Lublin, Akademicka 13, 20-950 Lublin*
[3]*State Higher Vocational School Stanislaus Pigonia in Krosno, Dmochowskiego 22, 38-400 Krosno*
[4]*Prof. Wacław Dąbrowski Institute of Agricultural and Food Biotechnology, Rakowiecka 36, 02-532 Warsaw*

Abstract. The test material originated from a field experiment conducted in 2011–2013, at the Experimental Farm in Felin (51°22′ N, 22°64′ E), which belongs to the University if Life Sciences in Lublin. A two-factor experiment was conducted in randomised blocks with 4 replicates. The chemical composition of grain of 4 spring wheat species was analysed: common wheat (*Triticum aestivum* ssp. *aestivum* L.) cv. Parabola, durum wheat (*Triticum durum* Desf.) cv. SMH 87, spelt (*Triticum aestivum* ssp. *spelta* (L.) Thell.) cv. Blauer Samtiger, and emmer wheat (*Triticum dicoccum* (Schrank, Schubler) line PL 24062 (material acquired from the National Centre of the Plant Gene Pool), grown at different production technology intensity (medium and high level of cultivation technology). The analyses on wheat grain included the content of total protein, crude ash, crude fat, crude fibre, carbohydrates, phosphorus, potassium, magnesium, calcium, copper, iron, manganese and zinc. The results were subjected to an analysis of variance, while the differences were estimated by the Tukey's test at the significance level of $p = 0.05$. The were calculated coefficients of variation (CV, %). Irrespective of the level of cultivation technology, husked wheats had higher quality parameters compared to naked cultivars. Emmer wheat was characterised by the highest content of proteins, ash, and macro and microelements in the grain and the spelt wheat cultivar Blauer Samtiger was characterised by the highest fat content. Compared to the husked species, the common wheat cultivar Parabola had the lowest content of proteins and ash, and a low content of macro and microelements. Both the husked and the naked wheats had better quality parameters in treatments with more intensive cultivation technology.

Key words: common wheat, durum wheat, spelt wheat, emmer wheat, microelements, macroelements

INTRODUCTION

Striving to preserve environmental biodiversity in the conditions of sustainable agriculture, more and more often were revert to the cultivation of almost forgotten species of crop plants, e.g. such cereals as spelt wheat *(Triticum aestivum* ssp. *spelta)* or emmer wheat (*Triticum dicoccum*), the cultivation of which has been given up due to their low productivity and problems with grain cleaning (dehusking). The results of research conducted by many authors confirm

[1] *Corresponding address* – Adres do korespondencji: leszek.rachon@up.lublin.pl

that those species have numerous advantages, e.g. lower habitat and cultivation technology requirements (reduced fertilisation and plant protection) or very high grain quality (high content of proteins, gluten, minerals and vitamins) [Anglani 1998, Brandolini et al. 2008, Imtiaz et al. 2010, Rachoń et al. 2015, Suchowilska et al. 2012, Zhao et al. 2009]. Spelt wheat is an excellent source of fibre, silicon, group B vitamins, zinc, magnesium. Compared to grain of common wheat, it also has a higher content of basic amino acids and unsaturated fatty acids. Spelt diet contributes to a lowering o the level of cholesterol in the blood. Grain of spelt wheat contains also substances with antioxidant properties, such as phytic acids, plant phenols and linals, that inhibit the formation of cancer cells [Cyrkler-Degulis and Bulińska-Radomska 2007, Erkkila et al. 2005, Liu 2004, Serpen et al. 2008]. In ancient times, emmer wheat was valued for its excellent taste and high protein content, though its yields were lower than those of spelt wheat. Due to the above properties, products of husked wheat species come back onto our tables. Those wheat species are especially recommended in organic farming, where cultivation is based on natural means of production [Cyrkler-Degulis and Bulińska-Radomska 2007]. In the study presented here, an attempt was made at estimating the nutritional value of husked wheat species (spelt and emmer wheat) in comparison with common and durum wheat in the conditions of diverse cultivation technologies. The research hypothesis assumed that due to their high nutritional values (more healthy and at the same time cheaper as a result of reduced use of chemical agents in the production), they can be an alternative source of plant material.

MATERIALS AND METHODS

The test material originated from a field experiment conducted in the period of 2011–2013 at the Experimental Farm Felin (51°22′ N, 22°64′ E) of the University if Life Sciences in Lublin. The two-factor experiment was conducted with the method of randomised blocks in 4 replicates. The experimental field was situated on a soil developed from silts of loess origin, classified in the good wheat complex. The soil was rich in phosphorus and potassium (P – 79 and K – 180 $mg \cdot kg^{-1}$ soil), while its content of magnesium was at a low level (40 $mg \cdot kg^{-1}$), [Rachoń et al. 2012].

The first experimental factor included 4 species of spring wheat: common wheat (*Triticum aestivum* ssp. *aestivum* L.) – cv. Parabola, durum wheat (*Triticum durum* Desf.) – cv. SMH87, spelt wheat (*Triticum aestivum* ssp. *spelta* (L.) Thell.) – cv. Blauer Samtiger, and emmer wheat (*Triticum dicoccum* (Schrank) Schübler) – PL24062 (material acquired from the National Centre of Plant Gene Pool). The second factor comprised 2 levels of cultivation technology: 1) medium level: mineral fertilisation (N – 70, P – 30.5 and K – 99.6 $kg \cdot ha^{-1}$), grain priming and weed control; 2) high level: increased nitrogen fertilisation (N – 140, P – 30.5 and K – 99.6 $kg \cdot ha^{-1}$), grain priming, weed control, 2 treatments against diseases, insecticide and growth regulator.

Prior to sowing the wheat grain was primed with the preparation Baytan Universal 094 FS in the dose of 400 ml of the agent with 200 ml of water per 100 kg of grain. Soil tillage was typical of the plough system. After the harvest of the previous crop, a set of post-harvest tillage treatments was performed, as well as phosphorus and potassium fertilisation. The pre-winter ploughing was made in the last days of October. The first spring treatment was harrowing, after which, in the conditions of optimum field moisture, the soil was prepared for sowing using a combined tillage set.

The sown area of the experimental plots was 22 m^2, and the harvest area – 10 m^2. Sowing at the rate of 500 kernels per 1 m^2 was performed at the optimum time, on a stand after winter rapeseed. After harvest the grain was dried and cleaned with the use of a laboratory thresher, and then every year grain samples were taken for the chemical analyses.

Table 1. Rainfalls and air temperatures according to the Meteorological Observatory at Felin

Year	Months					
	III	IV	V	VI	VII	VIII
	Rainfalls in mm					
2011	8.1	29.9	42.2	67.8	189.0	65.3
2012	28.6	34.0	56.3	62.8	52.3	37.6
2013	60.8	51.1	101.6	105.9	126.1	17.8
1951–2010	28.0	39.0	60.7	65.9	82.0	70.7
Year	Air temperature in °C					
2011	2.3	10.3	14.2	18.6	18.4	18.8
2012	4.3	9.5	15.0	17.3	21.5	19.2
2013	-2.4	8.1	15.3	18.5	19.2	19.2
1951–2010	1.0	7.4	13.0	16.3	18.0	17.2

The assays performed for the grain included the content of total protein (total nitrogen content with Kjeldahl method × 5.75), crude ash (gravimetric method), crude fat (gravimetric method acc. to Soxhlet), crude fibre (gravimetric method), carbohydrates (by detracting other dry matter components), phosphorus (CFA method), potassium (atomic emission spectrometry), magnesium, calcium, copper, iron, manganese and zinc (AAS method -atomic absorption spectrometry)

The results were analysed with the analysis of variance and the differences were assessed with the Tukey test (HSD) at significance level of $p = 0.05$. Coefficients of variation were calculated (CV in %), and standard deviation (SD).

Analysing the weather conditions in the years of the study, note should be taken of considerable variation in air temperatures and precipitation sums in the 3-year period, as well as in comparison with mean values for the long-term period of 1951–2010 (Table 1). More significant differences were noted in the amounts of precipitation. The vegetation season of 2013 was the wettest, with a good precipitation distribution, but that had a negative effect on grain quality (lowest protein content). Whereas, lower precipitations, high air temperatures and good insolation in the season of 2012 resulted in the highest content of protein.

RESULTS AND DISCUSSION

The study revealed significant variation in the content of proteins in grain of spring wheat in relation to the analysed factors (Table 2). Irrespective of the level of cultivation technology, the highest protein content was shown for emmer wheat – 3-year mean of 20.8%, lower values being found for the remaining species: spelt wheat – 16.9%, durum wheat – 16.2% and common wheat – 14.9%, respectively. Also in studies conducted by other authors, e.g. Brandolini et al. [2008], Krawczyk et. al. [2008], Rachoń et al. [2015], Stolickova and Konvalina [2014), protein content in common wheat grain was at the lowest level as compared to the other species under study. Irrespective of the compared species, with increase in the intensity of cultivation

Table 2. Content of total protein. crude fat and crude ash in grain of wheat (% dry matter)

Genotypes		Total protein			Crude fat			Crude ash		
		ML	HL	Mean	ML	HL	Mean	ML	HL	Mean
Parabola *T. aestivum* ssp. *aestivum*	M	14.2	15.6	14.9	2.04	2.51	2.27	1.95	1.94	1.94
	SD	0.70	0.90	1.05	0.76	0.21	0.60	0.24	0.23	0.23
PL24062 *T. dicoccum*	M	20.1	21.5	20.8	2.56	2.58	2.57	2.48	2.42	2.45
	SD	2.09	1.61	1.96	0.77	0.78	0.75	0.11	0.16	0.14
SMH87 *T. durum*	M	15.7	16.7	16.2	2.17	1.98	2.08	2.06	2.01	2.03
	SD	0.70	0.37	0.75	0.53	0.59	0.56	0.19	0.23	0.21
Blauer Samtiger *T. aestivum* ssp. *spelta*	M	16.1	17.6	16.9	2.73	2.79	2.76	2.18	2.09	2.13
	SD	1.18	1.16	1.36	0.65	0.88	0.76	0.18	0.18	0.18
Mean		16.5	17.8	–	2.37	2.46	–	2.17	2.11	–
HSD		a – 0.32; b – 0.17; a×b – ns			a – 0.09; b – 0.05; a×b – 0.13			a – 0.08; b – 0.04; a×b – ns		
CV (%)		15.4	14.2	–	30.2	28.6	–	12.4	12.8	–

ML − medium level of cultivation technology; HL − high level of cultivation technology; M – mean for the years 2011–2013; SD – standard deviation; CV – coefficient of variation; HSD (p=0.05); a – for genotypes; b – for cultivation technology; a×b – for interaction genotypes × cultivation technology;
ns − no significante differences

there was an increase in the value of that indicator, from 16.5% to 17.8%. The responses of the compared species were similar, which finds support in the study by Stępień et al. [2016], where both common wheat and spelt wheat noted a significant increase of protein content at higher fertilisation level, and in studies by Brzozowska [2008], Rachoń et al. [2015] and Woźniak et al. [2014]].

The content of fat was differentiated by all of the analysed factors (Table 2). The highest concentration of that component was noted in grain of spelt wheat Blauer Samtiger – 2.76%, and the lowest in grain of durum wheat SMH 87 – 2.08%. Similar relations were noted by Piergiovanni et al. [1996]. In the study by Rachoń et al. [2015], the lowest content of fat was noted in grain of common wheat – 1.60%. A higher fat content was noted at the higher level of cultivation technology. The responses of the species were varied. An increase of fat content was noted in the case of common wheat (Parabola) – from 2.04 to 2.51%, and a decrease from 2.17 to 1.98% in the case of durum wheat SMH 87. Emmer wheat 24062 and spelt wheat Blauer Samtiger did not display any significant differences.

A different tendency was noted in the case of the content of fibre (Table 3). The highest content – 2.59% – was noted in grain of durum wheat, followed by common wheat – 2.28%, spelt – 2.26%, and the lowest in grain of emmer wheat – 1.87%. Abdel-Aal et al. [1995] noted the highest level of that component in einkorn wheat, while Rachoń et al. [2015] in common wheat. With increase of the intensity of cultivation, the content of fibre decreased. On average, irrespective of the species, that decrease amounted to 0.07%. The responses of the individual species were varied. A significant decrease in fibre content was noted in grain and emmer wheat, and a significant increase in grain of common and durum wheat.

Decidedly the highest ash content was determined in grain of emmer wheat – 2.45% (Table 2). Significantly lower values were noted in grain of spelt wheat – 2.13%, durum wheat –

Table 3. Content of crude fibre and N-free extract in grain of wheat (% dry matter)

Genotypes		Crude fibre			Carbohydrates		
		ML	HL	Mean	ML	HL	Mean
Parabola *T. aestivum* ssp. *aestivum*	M	2.18	2.37	2.28	79.7	77.7	78.7
	SD	0.13	0.19	0.18	1.78	1.42	1.88
PL24062 *T. dicoccum*	M	1.96	1.79	1.87	72.9	71.7	72.3
	SD	0.38	0.29	0.34	2.21	1.73	2.02
SMH87 *T. durum*	M	2.56	2.61	2.59	77.5	76.8	77.2
	SD	0.14	0.18	0.16	1.32	0.87	1.16
Blauer Samtiger *T. aestivum* ssp. *spelta*	M	2.42	2.09	2.26	76.6	75.4	76,0
	SD	0.29	0.24	0.31	1.79	1.77	1.82
Mean		2.28	2.21	–	76.7	75.4	–
HSD		a – 0.08; b – 0.04; a×b – 0.11			a – 0.55; b – 0.30; a×b – 0.78		
CV (%)		14.9	17.2	–	3.9	3.6	–

Key under Table 2

2.03%, and common wheat – 1.94%. In the study by Piergiovanni et al. [1996], the highest ash content was characteristic of spelt wheat, and the lowest – durum wheat. Krawczyk et al. [2008] demonstrated a higher ash content in spelt wheat, relative to common wheat. Irrespective of the compared species, intensification of cultivation technology caused an average decrease of ash content by 0.06%, which was not supported in the study by Rachoń et al. [2015]. The responses of the individual species were similar to each other.

The content of hydrocarbons was the highest in grain of common wheat – 78.7%, and the lowest in that of emmer wheat – 72.3% (Table 3). Intensification of cultivation technology caused a reduction in the content of hydrocarbons, by 1.3% on average, irrespective of the analysed species, which is in support of the study by Rachoń et al. [2015]. No interaction was observed between the species and the intensity of cultivation technology.

Significant differences were noted in the content of macroelements in relation to the analysed factors (Table 4, 5). The highest levels of macroelements were noted in the case of grain of emmer wheat. The highest content of phosphorus was determined at 0.563%, potassium – 0.497%, calcium – 0.068, and magnesium – 0.165%. The lowest content of macroelements was found in grain of common wheat and spelt wheat. Partial support for these results can be found in a study by Suchowilska et al. [2012] (highest levels of phosphorus and magnesium), though the levels of potassium and calcium turned out to be the highest in grain of common wheat. In turn, Piergiovanni et al. [2009] demonstrated a higher content of potassium, calcium and magnesium, compared to emmer wheat and durum wheat.

With increase of the level of cultivation technology, there was a decrease in the content of potassium and magnesium, an increase in that of calcium, while the level of phosphorus remained unchanged. In the study by Rachoń et al. [2015], with increase in the level of cultivation technology there was a decrease in the content of phosphorus, and an increase in that of potassium, calcium and magnesium. An interaction was noted between wheat species and the level of

Table 4. Content of phosphorus and potassium in grain of wheat (% dry matter)

Genotypes		Phosphorus			Potassium		
		ML	HL	Mean	ML	HL	Mean
Parabola *T. aestivum* ssp. *aestivum*	M	0.441	0.393	0.417	0.490	0.450	0.470
	SD	0.025	0.032	0.037	0.129	0.122	0.124
PL24062 *T. dicoccum*	M	0.551	0.575	0.563	0.531	0.463	0.497
	SD	0.067	0.036	0.054	0.101	0.096	0.102
SMH87 *T. durum*	M	0.436	0.419	0.428	0.490	0.481	0.486
	SD	0.050	0.055	0.052	0.162	0.165	0.159
Blauer Samtiger *T. aestivum* ssp. *spelta*	M	0.427	0.436	0.432	0.487	0.449	0.468
	SD	0.086	0.051	0.069	0.144	0.147	0.143
Mean		0.464	0.456	–	0.500	0.461	–
HSD		a – 0.019; b – ns; a×b – 0.026			a – 0.020; b – 0.011; a×b – 0.028		
CV (%)		16,8	18,2	–	26.3	28.2	–

Key under Table 2

Table 5. Content of calcium and magnesium in grain of wheat (% dry matter)

Genotypes		Calcium			Magnesium		
		ML	HL	Mean	ML	HL	Mean
Parabola *T. aestivum* ssp. *aestivum*	M	0.059	0.056	0.057	0.140	0.130	0.135
	SD	0.013	0.010	0.011	0.023	0.016	0.020
PL24062 *T. dicoccum*	M	0.068	0.067	0.068	0.170	0.161	0.165
	SD	0.008	0.007	0.007	0.011	0.017	0.015
SMH87 *T. durum*	M	0.063	0.072	0.067	0.143	0.144	0.143
	SD	0.015	0.018	0.017	0.022	0.021	0.021
Blauer Samtiger *T. aestivum* ssp. *spelta*	M	0.045	0.054	0.050	0.143	0.145	0.144
	SD	0.012	0.003	0.009	0.022	0.031	0.026
Mean		0.059	0.062	–	0.149	0.145	–
HSD		a – 0.003; b – 0.001; a×b – 0.004			a – 0.007; b – 0.004; a×b – ns		
CV (%)		24.7	21.0	–	15.2	16.5	–

Key under Table 2

cultivation technology for phosphorus, potassium and calcium. Common wheat responded with a decrease of the content of all 3 macroelements at the higher level of cultivation technology, in the case of emmer wheat there was decrease in the content of potassium and calcium, in durum wheat – a decrease in the content of phosphorus and potassium, and in spelt wheat – a decrease in the content of potassium.

Similar relationships were found after the analysis of microelements (Table 6, 7). The highest content of iron (63.1 mg·kg^{-1}), copper (3.86 mg·kg^{-1}), zinc (81.1 mg·kg^{-1}) and manganese

Table 6. Content of copper and iron in grain of wheat (mg·kg^{-1} dry matter)

Genotypes		Copper			Iron		
		ML	HL	Mean	ML	HL	Mean
Parabola *T. aestivum* ssp. *aestivum*	M	3.17	3.25	3.21	42.2	42.9	42.6
	SD	0.61	0.77	0.67	4.53	3.07	3.77
PL24062 *T. dicoccum*	M	3.98	3.74	3.86	62.3	64,0	63.2
	SD	0.58	0.53	0.55	15.20	6.53	11.38
SMH87 *T. durum*	M	2.75	2.62	2.68	40.5	42.7	41.6
	SD	0.69	0.45	0.57	6.80	8.16	7.36
Blauer Samtiger *T. aestivum* ssp. *spelta*	M	3.34	3.24	3.29	41.7	45,0	43.4
	SD	0.54	0.27	0.42	3.77	4.15	4.20
Mean		3.31	3.21	–	46.7	48.6	–
HSD		a – 0.12; b – 0.06; a×b – 0.17			a – 1.75; b – 0.94; a×b – ns		
CV (%)		22.2	20.3	–	26.7	21.8	–

Key under Table 2

Table 7. Content of manganese and zinc in grain of wheat (mg·kg^{-1} dry matter)

Genotypes		Manganese			Zinc		
		ML	HL	Mean	ML	HL	Mean
Parabola *T. aestivum* ssp. *aestivum*	M	48.5	51.2	49.9	43.4	46.9	45.2
	SD	5.65	10.58	8.34	6.63	3.70	5.51
PL24062 *T. dicoccum*	M	64.9	67.8	66.4	83.3	78.9	81.1
	SD	17.3	12.6	14.9	25,0	9.96	18.5
SMH87 *T. durum*	M	44.2	49.7	47,0	53.7	54.7	54.2
	SD	4.99	9.88	8.11	6.90	7.24	6.89
Blauer Samtiger *T. aestivum* ssp. *spelta*	M	45.3	50.8	48.1	45.7	49.6	47.6
	SD	6.51	6.73	7.03	2.46	3.36	3.47
Mean		50.7	54.9	–	56.5	57.5	–
HSD		a – 2.10; b – 1.12; a×b – ns			a – 2.16; b – ns; a×b – 3.05		
CV (%)		25.2	22.5	–	36.5	24.9	–

Key under Table 2

(66.4 mg·kg^{-1}) was noted in grain of emmer wheat. The lowest levels of iron, copper and manganese were found in grain of durum wheat, at 41.6 mg·kg^{-1}, 2.68 mg·kg^{-1} and 47.0 mg·kg^{-1}, respectively, and of zinc – in grain of common wheat (45.1 mg·kg^{-1}). The results obtained by Suchowilska et al. [2012] confirm the high concentration of microelements in emmer wheat only in the case of zinc. The remaining microelements, i.e. copper, iron and manganese, had the highest concentration in grain of spelt wheat. Durum wheat had the lowest concentration of the analysed microelements, which finds support in Suchowilska et al. [2012]. The effect of the level of cultivation technology proved to be significant in the case of iron, copper and manganese. With increase in the intensity of technology, irrespective of the species, there as an increase in the content if iron and manganese, and a decrease in the content of copper. In the study by Rachoń et al. [2015], the higher level of cultivation technology resulted in a significant increase in the content of all analysed microelements. Interactions were demonstrated only in the case of copper and zinc. Grain of common wheat and spelt wheat had a significantly higher content of copper at the higher level of cultivation technology, while the content of zinc increased in grain of common wheat and decreased in grain of spelt wheat, which corresponds with the results obtained by Stępień et al. [2016].

The calculated coefficients of variation determine the measure of differentiation of distribution of a given feature. Lower values indicate that a given feature is more stable. Low values of the coefficient of variation were obtained for the content of proteins, ash, fibre, carbohydrates, phosphorus and magnesium, and high values for the content of fat, potassium, calcium and microelements.

CONCLUSIONS

1. Most of the quality parameters of husked wheat species had higher values compared to naked wheat species.
2. Irrespective of the level of cultivation technology, emmer wheat was characterised by the highest content of proteins, ash, macro and microelements in grain.
3. Spelt wheat cultivar Blauer Samtiger was characterised by the highest content of fat.
4. Compared to the husked species, common wheat cultivar Parabola was characterised by the lowest content of protein and ash, and low content of macro and microelements.
5. Both the husked and the naked wheat species had better quality parameters in treatments with more intensive cultivation technology.

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L. Rachoń, G. Szumiło, A. Woźniak, B. Krochmal-Marczak, A. Szafrańska

WARTOŚĆ ODŻYWCZA I SKŁAD MINERALNY OPLEWIONYCH ORAZ NIEOPLEWIONYCH GATUNKÓW PSZENICY JAREJ W ZALEŻNOŚCI OD TECHNOLOGII UPRAWY

Synopsis. Materiał do badań pochodził z doświadczenia polowego przeprowadzonego w latach 2011–2013 w Gospodarstwie Doświadczalnym Felin (51°22′ N, 22°64′ E), Uniwersytetu Przyrodniczego w Lublinie. Doświadczenie dwuczynnikowe przeprowadzono metodą bloków losowanych w 4 powtórzeniach. Badano skład chemiczny ziarna 4 gatunków: pszenicy zwyczajnej (*Triticum aestivum* ssp. *aestivum* L.) – odmiana Parabola, pszenicy twardej (*Triticum durum* Desf.) – odmiana SMH87, orkiszu (*Triticum aestivum* ssp. *spelta* (L.) Thell.) – odmiana Bauer Samtiger i płaskurki (*Triticum dicoccum* (Schrank, Schubler) linia PL 24062 (materiał pozyskany z Krajowego Centrum Roślinnych Zasobów Genowych) w warunkach zróżnicowanej intensywności technologii produkcji (przeciętny poziom agrotechniki i wysoki poziom agrotechniki). W ziarnie określono zawartość: białka ogółem, popiołu całkowitego, tłuszczu surowego, włókna surowego, węglowodanów, fosforu, potasu, magnezu, wapnia, miedzi, żelaza, manganu i cynku. Wyniki poddano analizie wariancji, natomiast różnice oszacowano testem Tukeya na poziomie istotności p=0,05. Obliczono współczynniki zmienności (CV w %). Niezależnie od poziomu agrotechniki pszenice oplewione uzyskały wyższe parametry jakościowe w porównaniu z nieoplewionymi. Pszenica płaskurka cechowała się najwyższą zawartością białka i popiołu, makro i mikroelementów w ziarnie a pszenica orkiszowa Blauer Samtiger wyróżniała się najwyższą zawartością tłuszczu. Odmiana pszenicy zwyczajnej Parabola w porównaniu z gatunkami oplewionymi uzyskała najniższą zawartość białka i popiołu, cechowała się także niską zawartością składników mineralnych.. Lepsze parametry jakościowe zarówno pszenice oplewione jak i nagoziarniste uzyskały na obiektach z intensywniejszą technologią.

Słowa kluczowe: pszenica zwyczajna, pszenica durum, pszenica orkisz, pszenica płaskurka, mikroelementy, makroelementy

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