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ESTIMATION OF TECHNOLOGICAL VALUE AND CHEMICAL COMPOSITION OF SELECTED COMMON WHEAT CULTIVARS (*TRITICUM AESTIVUM* L.)

ABSTRACT

The aim of the study was to estimate the technological value and chemical composition of new common wheat cultivars. The experimental material consisted of grain and flour obtained from 5 cultivars of common wheat, registered in 2017-2019, donated by Plant Breeding Strzelce - IHAR Group Ltd., Co., and harvested in years 2017-2018. The physical characteristics of the grain were determined: milling yield, falling number, gluten content, Zeleny sedimentation index as well as farinograph analysis and laboratory baking were performed. Furthermore, the content of grain nutrients and dietary fiber was determined. Significant differences between cultivars in terms of technological parameters and chemical composition have been demonstrated. The protein content in the grain was in the range of 13.3-15.2%, and the amount of gluten in the range of 28.6-36.8%. The cultivars were characterized by low alpha-amylase activity with an average falling number value 331s. The average water absorption of flour was 62.1%, and the volume of obtained bread was in the range 318-381cm^3. The bread of best quality was obtained from the Wilejka cultivar, that was also the richest source of protein. The average dietary fiber content from two years of research was 10.8%, including 7.7% of non-starch polysaccharides (NSP), of which 5.8% of the insoluble fraction (I-NSP) and 1.9% of the soluble fraction (S-NSP). The spring wheat Alibi has been recognized as the richest source of dietary fiber. The tested cultivars were characterized by high technological value and very good chemical composition and can be recommended for use in the food industry.

Key words: bread, falling number, flour, gluten, protein, wheat

INTRODUCTION

Wheat is the world's first consumer grain (OECD/FAO, 2020). The two most popular species of this cereal are common or bread wheat (*Triticum aestivum* ssp. *vulgare*), which covers about 93% of the total crop area, and durum wheat (*Triticum turgidum* ssp. *durum*) used for pasta, covering about 7% of the area (Guzman *et al.*, 2019; Stevenson *et al.*, 2012). Wheat is used for consumption mainly as a white flour, although most of the valuable grain components are found in the bran fraction removed during

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milling (Lærke and Bach Knudsen, 2011). However, the share of bread and cereal products in the diet is large enough, that wheat, like other cereals, is an important source of energy and nutrients. Wheat covers about 50% of the daily requirement for carbohydrates and 30% for protein. It is also a valuable source of B vitamins, minerals and bioactive substances such as dietary fiber, exerting a number of health-promoting effects. Consuming fiber-rich products reduces the risk of diseases such as obesity, atherosclerosis, coronary artery disease, type 2 diabetes, and prevents the onset of some cancers (Shewry and Hey, 2015; Kendall *et al.*, 2010).

Depending on the direction of use, the wheat grain must meet certain quality criteria. When used for milling and baking purposes, appropriate grain and flour parameters are required. The quality of wheat flour depends on many factors, such as growing and environmental conditions and chemical composition of grain, in particular with regard to protein and starch content (Tomić *et al.*, 2015). In breeding works and in laboratories of the cereal-milling industry the estimation of wheat grain quality is most often based on the following factors: protein content, gluten content, sedimentation index, falling number and rheological properties (Szafrańska, 2012). Recently the growing number of diet-related diseases in the society indicates the need to search for raw materials, rich in nutrients and pro-healthy components that are useful for the production of high-quality food. Breeding works on wheat besides the amount of the harvest yield also strives to improve the quality of grain (Skrzypek A., 2019). For that reason, it is necessary to monitor newly introduced wheat cultivars in terms of a wide range of quality features. The most desirable raw materials for use in food are cultivars, which except to high technological value are also distinguished by good chemical composition. Therefore, the purpose of the research was to assess the technological suitability and chemical composition of new cultivars of common wheat.

MATERIALS AND METHODS

The research material consisted of grain and flour obtained from 5 cultivars of common wheat including four winter and one spring, kindly donated by the Plant Breeding Strzelce Ltd, Co., and registered in 2017-2019. The Euforia, Poezja and Wilejka cultivars belong to the quality group (A), while the Alibi and Plejada cultivars are bread wheats (B). The material was cultivated in the same environmental conditions in 2017-2018.

To produce flour the wheat grain was conditioned to 14% moisture content and ground on the Quadrumat Senior Laboratory Mill (Brabender), according to AACC 26 -50 (2003) procedure. The obtained flour was subjected to farinographic analysis, in accordance with ICC 115/1 (2005) procedure. The laboratory baking was carried out in duplicate according to the standard ICC 131 (2005) method with modifications using 100g of flour, 1.5g of salt and 3% of yeast. The bread volume was measured using 3D laser scanner Next Engine (Santa Monica, USA) with Scan Studio HD software. The falling number (FN) was analysed using the Falling Number 1800 Perten apparatus (Hagerstern, Sweden) according to the ICC 107/1 (2005) procedure. The wet gluten content was measured according PN-EN ISO 2145-2:2015-2 method, whereas the Zeleny sedimentation index according to PN-EN ISO 5529:2010 procedure.

The material for chemical analysis has been ground in the Perten Laboratory Mill 3100 (Hagerstern, Sweden) with a sieve diameter of 0.5 mm. The protein content was analysed using the Dumas method in the Rapid N Cube apparatus (Elementar, Germany), according to the AACC 46-30 method (2003). The ash content was performed gravimetrically, according to AOAC 923.03 method (1995), and the starch content was measured using the colorimetric method, according to the AACC 76-13 procedure (2003). The lipids content was assessed gravimetrically by extraction with solvent consisting of 60:40:1 (v/v/v) chloroform, methanol and concentrated hydrochloric acid, as described by Marchello *et al.* (1971). Dietary fibre content (DF) was determined using the enzymatic-chemical method as a sum of nonstarch polysaccharides (NSP), lignin and associated polyphenols in accordance with AACC 32-25 procedure (2003). NSP content with its fractionation to insoluble (I-NSP) and soluble (S-NSP) fraction was determined using gas chromatography as previously described by Englyst and Cummings (1984), as a sum of individual monomers: arabinose, xylose, mannose, galactose and glucose. Lignin and other insoluble residues were determined gravimetrically as described by Theander and Westerlund (1986). All analyses were performed in duplicate and the results reported on dry weight basis [% of d.w.].

The weather conditions in the subsequent years of plant cultivation were characterized based on the Sielianinowa (K) hydrothermal coefficients (Table 1) and calculated on the basis of the sum of average daily temperatures and the sum of precipitation for each month. The months were classified as follows: $K \leq 0.4$-month extremely dry; $0.4 < K \leq 0.7$ - very dry; $0.7 < K \leq 1$ - dry; $1.0 < K \leq 1.3$ - quite dry; $1.3 < K \leq 1.6$ - optimal; $1.6 < K \leq 2.0$ - moderately moist; $2.0 < K \leq 2.5$ - moist; $2.5 < K \leq 3.0$ - very humid; $K > 3.0$ - extremely humid (Skowera, 2014). Meteorological data were obtained from the meteorological station of Plant Breeding Strzelce, located near the place where wheat was grown.

Table 1

Sielianinowa coefficients (K) for the months of spring vegetation in the two years of research.

Months	Growing season	
	2017	2018
March	1.9	4.6
April	2.4	0.5
May	0.7	1.3
June	2.4	0.7
July	1.3	2.7
Entire growing season	1.6	1.4

The obtained results were subjected to statistical analysis. To determine the variability of individual technological parameters and chemical components between cultivars and years of cultivation, a two-way fixed model of analysis of variance (ANOVA) and Tukey's contrast analysis were performed. The significance level was set to $p < 0.01$ and $p < 0.05$. Statistical analyses were performed using Statistica 13.3 software (TIBCO Software, USA).

RESULTS AND DISCUSSION

The grain milling process significantly affects flour yield and its chemical composition. The milling yield did not differ significantly between wheat cultivars, and the values ranged from 68.7% to 73.8%, for the Poezja and Plejada cultivars respectively. However, significant differences were observed between subsequent harvest years, which confirms the impact of environmental conditions on this parameter. Higher values were found for cultivars harvested in 2018 (Table 2). Other researchers obtained wheat flour yields at a similar level, and the values ranged from 68.0% to 72.2% (Kweon *et al.*, 2009). The falling number, which is a measure of the activity of amylolytic enzymes, increases due to grain sprouting and is largely dependent on weather conditions, which is confirmed by significant differences in the value of this feature between harvest years (374s vs. 288s). Considering the hydrothermal conditions in July, being the pre-harvest period, 2018 was distinguished by two-fold higher value of the K factor (Table 1), which may result in greater amylolytic activity of grain from this year. The analysed wheat cultivars were characterized by low alpha-amylase activity in the range from 246s for the Alibi cultivar to 443s for the Euforia cultivar. Similar values in the range from 253s to 476s were previously described by Szafrańska (2014) and Ktenioudaki *et al.* (2011). The protein content and the amount of gluten significantly determine the usefulness of grain in breadmaking. Klockiewicz-Kamińska and Brzeziński (1997) reported that the protein content in grain intended for technological purposes should be in the range of 11.0-15.0% for winter cultivars and 12.0-16.0% for spring cultivars, while the minimum gluten content should be at a level of 20%. Considering the protein substances, significant differences were found between the harvest years in protein content (Table 4) and the amount of gluten (Table 1) with better values for the year 2017. The cultivars differed significantly in terms of these characteristics. The highest average protein and gluten content was observed in the Wilejka cultivar (15.2% and 36.8%, respectively), while the lowest content was found in the Plejada cultivar (13.3% and 28.6%, respectively). The grain of common wheat tested by other authors showed similar content of these parameters (Kiczorowska *et al.*, 2015; Warechowska *et al.*, 2013; Szafrańska 2012). One of the preliminary methods for assessing the baking value of wheat flour is determination of the Zeleny sedimentation index, which allows quantitative and qualitative assessment of gluten in grain and flour. The higher value of this parameter, the greater the share of gluten proteins in flour, especially glutenin, which is characterized by high swelling capacity and affect good baking value (Szafrańska, 2012; Gąsiorowski, 2004). The analysed wheat cultivars were significantly diversified and were characterized by a high value of this parameter in the range from 42cm^3 for the Alibi cultivar to 59 cm^3 for the Wilejka cultivar, which proves their high breadmaking usefulness. There were also significant correlations between the protein content and the amount of gluten (0.965) and the sedimentation index (0.934), as well as between the amount of gluten and the sedimentation index (0.875). Szafrańska (2012) obtained comparable values of this parameter for common wheat cultivars, in the range from 48 cm^3 to 55 cm^3, while values described by Jaskulska *et al.* (2018) and Harasim and Wesołowski (2013) were not higher than 40 cm^3.

Table 2

Physical properties of grain of common wheat cultivars

Parameter	Milling yield [%]	Falling numer [s]	Gluten content [%]	Zeleny sedimentation index [cm^3]
Cultivars				
Alibi	71.9^a	246^d	29.0^c	42^c
Euforia	73.5^a	443^a	30.8^b	47^b
Plejada	73.8^a	292^c	28.6^c	45^b
Poezja	68.7^a	300^c	28.8^c	48^b
Wilejka	71.1^a	374^b	36.8^a	59^a
F-Statistic	2.57	215.35	214.82	107.55
p-value	0.1032	0.0000	0.0000	0.0000
Growing seasons				
2017	69.9^b	374^a	33.5^a	51^a
2018	73.7^a	288^b	28.2^b	46^b
F-Statistic	11.57	326.72	621.85	76.43
p-value	0.0067	0.0000	0.0000	0.0000

Water absorption of flour ranged from 60.2% for the Plejada cultivar to 64.5% for the Euforia cultivar (Table 3). There were no significant differences between both cultivars and harvest years. Szafrańska (2012) showed in her research an increase in water absorption along with the amount of gluten, which was also reflected in the results described in our study for all samples except the Wilejka cultivar. Other literature reports have shown that this parameter may be dependent on the protein content and sedimentation index, but no such relationships were found for the tested cultivars (Caffe-Treml *et al.*, 2010; Hruskova *et al.*, 2006). Szafrańska (2012) also described that wheat cultivars belonging to the quality group (A) according to the COBORU classification were characterized by greater water absorption than cultivars (B). It was confirmed only for the Euforia cultivar, for which the result of this parameter was the highest. Other farinographic parameters were characterized by significant differences both between the examined cultivars and the harvest years. The dough development time ranged from 3.5 min to 5.0 min, for the Alibi and Poezja as well as Euforia and Plejada cultivars, respectively and was significantly correlated with the water absorption of flour (0.464). The highest value of dough stability, which expresses the dough tolerance to kneading, was observed for the Poezja cultivar (12.5 min) and the smallest for the Alibi cultivar (4.0 min). The dough softening ranged from 40 BU (Brabender units) for the Poezja cultivar to 105 BU for the Alibi cultivar. For this parameter, the lower its value, the higher the dough's resistance to kneading and the better quality of gluten (Klockiewicz-Kamińska and Brzeziński, 1997). In relation to the research years, significantly higher values for dough development time and stability were reported for materials cultivated in 2017, while the higher average value of the degree of dough softening was characteristic for cultivars from 2018. The values of rheological features obtained from the farinographic analysis were similar to results described by other authors for wheat flour (Szafrańska 2012; Ktenioudaki *et al.*, 2011; Ktenioudaki *et al.*, 2010). The baking value of flour is determined directly by laboratory baking. The technological parameters of grain and flour discussed above had a significant impact on the volume of obtained bread. The analysed cultivars differed significantly in this parameter. The highest average volume was found for bread obtained from flour of the Wilejka cultivar, and the lowest for the Poezja cultivar, 381 cm^3 and 318 cm^3, respectively. Similar values of bread volume obtained from common wheat flour were reported by Radomski *et al.* (2007), while in other studies lower volumes in the range 150-190 cm^3 as well as (Ktenioudaki *et al.*, 2010) higher in the range 415– 517 cm^3 (Jaskulska *et al.*, 2018; Gambuś *et al.*, 2011) were showed. The differences in the obtained results could have been influenced by factors such as the grain milling method and baking technology. For analysed material the significant correlations were obtained between the bread volume and the amount of gluten (0.680), as well as such rheological parameters as water absorption of flour (0.613), dough development time (0.458) and a negative relationship with dough stability (-0.624). The obtained wheat breads had good organoleptic characteristics. They were all well-baked, with a smooth crust, a light crumb, and a typical wheat bread taste. The grain of the Wilejka cultivar had the best technological value among all tested samples. Except the largest volume it was distinguished by a golden, smooth crust and a delicate, non-sticky and elastic crumb with uniform porosity. Despite the low amount of gluten and the sedimentation index, the second best-rated cultivar in terms of technology was spring wheat Alibi. The Poezja cultivar was characterized by the weakest technological parameters and the lowest quality of bread.

Table 3

Rheological properties of dough obtained from flour of common wheat cultivars.

Parameter	Water absorbing [%]	Dough development time [min]	Stability [min]	Degree of softening [BU]*	Bread volume [cm^3]
Cultivars					
Alibi	63.2^{a}	3.5^{c}	4.0e	105^{a}	374^{ab}
Euforia	64.5^{a}	5.0^{a}	10.0^{b}	50^{c}	371d
Plejada	60.8^{a}	5.0^{a}	8.0^{c}	60^{b}	354^{b}
Poezja	60.2^{a}	3.5^{c}	12.5^{a}	40d	318^{c}
Wilejka	61.6^{a}	4.5^{b}	6.0d	65^{b}	381^{a}
F-Statistic	2.60	92.00	446.41	418.64	19.52
p-value	0.1008	0.0000	0.0000	0.0000	0.0001
Growing seasons					
2017	63.0^{a}	5.0^{a}	8.5^{a}	56^{b}	374^{a}
2018	61.1^{a}	3.5^{b}	8.0^{b}	72^{a}	345^{b}
F-Statistic	3.67	392.00	8.44	216.95	30.76
p-value	0.0845	0.0000	0.0157	0.0000	0.0002

*BU – Brabender units

The content of nutrients and dietary fiber in all wheat cultivars were also evaluated (Table 4). The average protein content was 13.9% and was described above. Determination of ash content in grain provides information on the amount of mineral compounds that are important from a nutritional point of view, as well as allows to determine the suitability of grain as a raw material for flour production. The content of ash below 1.85% in wheat grain indicates that the studied cultivars constitute a valuable raw material for the production of white and wholemeal flour (Szafrańska, 2012). This parameter content differed significantly between cultivars and the years of research. The highest amount of ash, 1.8%, was found in the spring wheat cultivar Alibi, while the lowest, 1.5% in the Wilejka cultivar. In relation to the harvest years, significantly higher values were obtained for the 2017. Kiczorowska *et al.* (2015) obtained the ash in common wheat grain in the range of 1.8-1.9%, while Rachoń *et al.* (2012) showed its amount at the level of 2.2%. Spring wheat cultivars were characterized by a higher ash content compared to winter wheat cultivars, as confirmed in research described by Szafrańska (2012), and Woźniak and Staniszewski (2007) who obtained results at the level of 1.8% for spring wheat grain and 1.6% for winter form. The lipid content ranged from 1.9% for the Plejada cultivar to 2.6% for the Alibi and Euforia cultivars. The average starch content was 67.9%, its extremes were obtained for the Alibi and Plejada cultivars, 66.4% and 70.4%, respectively. Both parameters were also significantly different in the subsequent harvest years. Their content was higher for cultivars from the 2018 harvest year, the average lipids content was 2.5% whereas the starch content and was 69.3%. The obtained values were characteristic for common wheat grain and were consistent with the results described by other authors. Andersson *et al.* (2013) determined lipid content in the range of 2.04-3.6%, while Boros *et al.* (2015) described their average amount in winter wheat grain at a level of 2.4% and in spring wheat grain 2.7%. The same authors also provided an average starch content of 63.9% and 63.5% for winter and spring forms, respectively. Research described by Coles *et al.* (1997) indicates starch content in the range of 57.4-64.6%, while Shewry and Hey (2015) report its content at the level of 60-70%. For some determined chemical components, links between their content and technological parameters were observed. The protein content was significantly correlated with the bread volume (0.567), while in the case of starch a correlation with grain yield (0.501) and a negative relationship with the bread volume (-0.470) were found. The basic bioactive component of cereal grains is dietary fiber. From a nutritional point of view, it is important that the wheat cultivars available on the market contain as much of fibre as possible. The content of dietary fiber varied significantly and ranged from 9.8% for the Wilejka cultivar to 11.8% for the Alibi cultivar (Table 4). There were no significant differences in the content of this component between harvest years, and its average amount was at the level of 10.8%. The largest part of wheat fiber constitutes the non-starch polysaccharide fraction (NSP), of which about 70-80% is the insoluble part (I-NSP). In wheat grain, arabinoxylans are a key part of the NSP fraction. The NSP content ranged from 6.7% to 8.5%, including the content of the I-NSP fraction in the range from 4.7% to 6.6%. The extreme values for both parameters, as in the case of dietary fiber content, were observed for the Wilejka and Alibi cultivars. The average content of lignin, which is a part of insoluble fiber fraction, was 3.1%, and extreme values were found for the Plejada and Alibi cultivars. The content of insoluble dietary fiber components varied significantly between harvest years. The grain of cultivars grown in 2018 was characterized by a higher content of NSP and I-NSP, 7.8% and 5.9%, respectively, and a lower amount of lignin (3.0%) compared to 2017. The soluble fraction of dietary fiber, expressed as the content of soluble non-starch polysaccharides (S-NSP), was significantly different between cultivars and ranged from 1.6% for the Plejada cultivar to 2.0% for the Euforia and Wilejka cultivars. However, no significant differences were found for the S-NSP content between harvest years and the average value of this parameter was 1.9%. In the earlier studies Boros *et al.* (2015) showed an average fiber content in winter wheat grain at a level of 11.6% and in spring wheat grain at a level of 12.3%. According to the authors, the average content of the I-NSP and S-NSP fraction was 7.2% and 1.4% in winter wheat and 7.6% and 1.7% in spring wheat, respectively while the average level of lignin was 2.8%. Similar studies in common wheat grain were carried out by Gebruers *et al.* (2010) who showed a fiber content in the range of 9.6-14.4%, including 7.8-11.4% NSP, 1.25-2.25% S-NSP and an average lignin content of 2.1%. Stevenson *et al.* (2012) determined the amount of dietary fiber in wheat grain at a level of 13.2% and 1.9% of lignin while Barron *et al.* (2007) analysing the content of individual monosaccharides included in NSP received their total amount at the level of 7.1%. According to literature data, particular fractions of dietary fiber, especially arabinoxylans, which are the main part of NSP, have a significant impact on the baking process of wheat bread (Courtin and Delcour, 2002). In the case of dietary fiber fractions, a significant relationship was found between the content of S-NSP fraction and flour water absorption (0.491) and between TDF, NSP and I-NSP and the degree of softening (0.490, 0.492, 0.470, respectively). In addition, negative relationships were observed between the content of NSP and the I -NSP fraction and the amount of gluten ((-0.549) and (-0.619), respectively), as well as between TDF, NSP and the I-NSP fraction and the Zeleny sedimentation index ((-0.597), (-0.729) and (-0.793), respectively).

Based on the assessment of the chemical composition, the Wilejka cultivar was the richest source of nutrients, in particular protein among the tested cultivars, while the Alibi spring wheat cultivar were characterised by the highest content of dietary fibre.

Table 4

Chemical composition of grain of common wheat cultivars

Parameter	Protein [%]	Ash [%]	Lipids [%]	Starch [%]	I-NSP [%]	S-NSP [%]	NSP [%]	Lignin [%]	Dietary fibre [%]
Cultivars									
Alibi	13.4[c]	1.8[a]	2.6[a]	66.4[c]	6.6[a]	1.9[a]	8.5[a]	3.3[ab]	11.8[a]
Euforia	13.9[b]	1.6[c]	2.6[a]	67.4[bc]	5.7[c]	2.0[a]	7.7[b]	3.3[a]	10.9[b]
Plejada	13.3[c]	1.7[b]	1.9[d]	70.4[a]	6.2[b]	1.6[b]	7.7[b]	2.9[c]	10.7[b]
Poezja	13.7[b]	1.6b[c]	2.3[c]	67.8[b]	5.7[c]	1.9[a]	7.6[b]	3.0[c]	10.6[b]
Wilejka	15.2[a]	1.5[d]	2.5[b]	67.7[b]	4.7[d]	2.0[a]	6.7[c]	3.1[b]	9.8[c]
F-Statistic	161.8	82.06	390.8	28.2	85.74	22.88	46.08	35.14	45.54
p-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000
Growing seasons									
2017	14.4[a]	1.8[a]	2.3[b]	66.6[b]	5.7[b]	1.9[a]	7.6[b]	3.3[b]	10.8[a]
2018	13.4[b]	1.5[b]	2.5[a]	69.3[a]	5.9[a]	1.9[a]	7.8[a]	3.0[b]	10.7[a]
F-Statistic	400.7	409.96	99.7	120.4	10.73	0.95	5.03	188.37	1.50
p-value	0.0000	0.0000	0.0000	0.0000	0.0084	0.3537	0.0488	0.0000	0.2485

CONCLUSIONS

1. All common wheat cultivars were characterized by high technological suitability. The grain of the Wilejka cultivar was distinguished by the best technological parameters and the quality of obtained bread.
2. Evaluation of the chemical composition of grain showed that the highest content of protein and starch was characteristic for the Wilejka cultivar, while the grain of spring wheat Alibi was the richest source of dietary fibre.
3. In terms of determined technological parameters as well as nutrients and bioactive components, the significant differences were observed between analysed wheat cultivars. Many significant relationships were also found between selected chemical components of wheat grain and the analysed technological parameters.
4. The harvest year had a significant impact on most technological parameters and chemical components except for water absorption of flour and the content of S-NSP fraction and dietary fiber.

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