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EFFECT OF SELECTED AGRONOMIC FACTORS ON THE BAKING QUALITY OF WINTER SPELT STRAINS AND CULTIVARS (*TRITICUM AESTIVUM* SSP. *SPELTA* L.) IN COMPARISON WITH COMMON WHEAT (*TRITICUM AESTIVUM* SSP. *VULGARE*)

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ABSTRACT

The treatments were: grains of winter spelt cultivars: Oberkulmer Rotkorn, five strains and common winter wheat cv. Tonacja, two methods of weed control and three sowing rates. Physical, quality and farinographic properties of grain were examined. Quality parameters significantly depended on the method of weed control, sowing rate and strain. Farinograpic characteristics significantly depended on strain. Most examined properties in the studied cultivars and strains were not influenced by the applied agronomic method, which is important from the point of view of ecological farming and indicates the possibility of lower spending on weed control on farms.

Key words: grain quality; sowing rate; weed control; spelt; wheat; organic farming.

INTRODUCTION

Spelt (*Triticum aestivum* ssp *spelta* L.) is one of the oldest cereals used by man. It has recently gained in popularity in Europe as part of the growing interest in foods with high nutritional and gustatory value (Campbell, 1997; Gabrovská et al., 2002). The lesser agronomic requirements of spelt and its high competitive ability against weeds (compared to wheat) make it an attractive crop for both organic farms and small conventional farms that use integrated methods of crop production (Campbell, 1997). In terms of nutritional value, spelt is more valuable than wheat. Spelt flour is a valuable raw material for the baking industry and, in comparison to wheat flour, contains more total fat, vitamins, microelements, macroelements and above all high-value protein with increased content of essential amino acids (Ranhotra et al., 1995; Abdel-Aal et al., 2002; Marconi et al., 2002; Schober et al., 2006, Spychaj-Fabisiak et al., 2014). However, the prevalence of spelt is low due to difficulties associated with production and processing of the grain (Ruibal-Mendieta et al., 2005).

Similar to common wheat flour, the technological value of spelt flour depends on the content of total protein and the gluten yield. Spelt has more total protein which translates into a higher gluten yield. However, its rheological properties make spelt flour less useful in standard baking methods. Highly extensible spelt flour dough cannot retain the carbon dioxide produced during fermentation, leading to undersized bread loaves (Bojňanská and Frančaková, 2002; Marconi et al., 2002). The rheological properties of dough to a large extent depend on the structure of gluten, a combination of gliadin and glutenin at an appropriate ratio. Spelt flour dough has a lower stability and elasticity with greater extensibility and viscosity compared to wheat flour dough (Abdel-Aal et al., 1997; Schober et al., 2002). Spelt bread usually has a smaller volume than wheat bread (Bonafaccia et al., 2000) and differs in taste and smell

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(Campbell, 1997). Although spelt bread is sought after by consumers who appreciate its flavour and nutritional qualities, spelt flour is often mixed with wheat flour in order to improve the baking properties; projects are also being carried out to create new cultivars that would retain the most advantageous features of wheat and spelt (Campbell, 1997).

The aim of this study was to evaluate the effect of two agronomic factors (weed control and sowing rate) on the baking value of grain spelt compared to common wheat.

MATERIAL AND METHODS

The materials consisted of grains obtained from an experiment conducted in 2011 at the Lipnik Agricultural Experimental Station (53º12'N, 14º27'E, Poland) on good rye complex soil. The study compared two methods of weed control (organic harrowing and the use of Legato Plus herbicide 1.25 l per ha) and 3 sowing rates (300, 400 and 500 grains per m2). The research materials were grains of winter spelt: German cultivar Oberkulmer Rotkorn, five Polish strains from crosses of common wheat and spelt from the Strzelce Plant Breeding centre (STH 8, STH 11, STH 28-4609, STH 28-4614, STH 28-4619) and for comparison, common winter wheat (cultivar Tonacja).

The N percentage of grain was determined based on the Kjeldahl micro-method, followed by colorimetric reading using a Buchi B-324 (Switzerland). Cereal protein concentration was calculated by multiplying N by 6.25. The following grain parameters were determined: thousand grain weight (g), test weight (kg/hl) and grain fractions (mm). Then the flour was determined by ICC standard methods: Hagberg-Perten falling number using an SWD-83 camera (Poland) (ICC, 1995), sedimentation rate (ICC, 1994), gluten content (%), gluten weakening in mm, gluten index (%), (ICC, 1994). Also the rheological properties of the dough were determined; flour water absorption (corrected to 14 %), stability (min), development time (min) and degree of softening (FU), using a Brabender farinograph (Duisburg, Germany) according to the standard method (AACC, 2000).

The results were analysed statistically using a three-way analysis of variance for a completely randomised design. The number of replications n = 2. Experimental error was estimated as the average square of the high order interactions. Confidence half-intervals for multiple comparisons were calculated using the Tukey's test at a confidence level p=0.95. For the comparison of group means, the following orthogonal contrasts were isolated:

C1=(xA+xB+xC+xD+xE)/5–xG;
C2=(xA+xB+xC+xD+xE)/5–xF;
C3=xF-xG,

where: A – STH 8; B – STH 11; C – STH 28-4609; D – STH 28-4614; E – STH 28-4619; F – Oberkulmer Rotkorn, G – Tonacja wheat. Group means were compared using the Scheffe method.

RESULTS AND DISCUSSION

Analysis of the physical properties of the grains showed their suitability for milling. The higher the thousand grain weight, the higher the flour extraction rate (Muhamad and Campbell, 2004). In our study, both the thousand grain weight and the test weight were influenced by the method of weed control and sowing rate (Table 1). Significantly highest values for both indicators were obtained for chemical weed control and the lowest sowing rate (43 g and 78.5 $kg \cdot hl^{-1}$, respectively). Comparative analysis of the mass of thousand grain weight showed that the highest value of this parameter was attained by the Oberkulmer Rotkorn spelt (Table 3). Higher values of these parameters indicate higher milling yield, while low values indicate poor endosperm development. Test weight is a very stable parameter, although it is influenced by habitat conditions, fertilisation and protection levels, the sowing rate and the sowing date. Data presented on the physical characteristics of the grains in this work are in most cases consistent with the literature data (Abdel-Aal et al., 1996; Capouchová, 2001; Marconi et al., 2002). The responses of cultivars and strains to the applied agricultural practices were similar.

Estimation of flour baking quality is based on determination of suitability for the purposes of the baking industry. Our results concerning baking quality are shown in Tables 2 and 3. A significant effect on quality parameters was exerted by weed control (W), sowing rate (R), and the strain (S) (Table 1).

The falling number is an indicator demonstrating the amylolytic activity of the flour which significantly influences the dough strength and crumb properties (Ostasiewicz et al., 2009). The data obtained in the present study (Table 1) show that the falling number varied significantly among cultivars, being significantly lowest in common wheat (134 seconds), while for spelt strains it ranged from 229 to 295 seconds. The tested flours from spelt grain had the optimal level of amylolytic activity (Capouchová, 2001). The falling number for the common wheat flour was below the level obtained by other authors (Grobelnik-Mlakar et al., 2009; Lemańczyk and Kwaśna, 2013; Ross et al., 2012).

Table 1. Significance of main effects - weed control (W), sowing rate (R), strains (S) and its interactions in ANOVA

Traits	Source of variability					
	W	R	S	W×R	W×S	R×S
Thousand grain weight (g)	*	*	**	ns	ns	ns
Test weight (kg·hl^{-1})	**	*	**	ns	ns	ns
Grain fractions (%): < 2.2	ns	ns	**	ns	ns	ns
2.2 – 2.5	ns	ns	**	ns	ns	ns
2.5 – 2.8	ns	ns	**	ns	ns	ns
> 2.8	ns	ns	**	ns	ns	ns
Falling number (s)	ns	*	**	ns	ns	ns
Protein (g/kg)	ns	**	**	ns	ns	ns
Zeleny test (cm^3)	**	ns	**	ns	ns	ns
Gluten content (%)	*	**	**	ns	ns	ns
Gluten weakening (mm)	ns	*	**	ns	ns	ns
Gluten index (%)	**	**	**	ns	ns	ns
Water absorption (%)	*	**	**	ns	ns	ns
Development time (min)	*	ns	**	ns	ns	ns
Dough stability (min)	ns	ns	**	ns	ns	ns
Degree of softening (10 min after begin) FU	ns	ns	**	ns	ns	ns
Degree of softening (ICC/12 min after max) FU	ns	ns	**	ns	ns	ns

**P≤0.01; *P≤0.05; ns – not significant.

Protein level was significantly influenced by the sowing rate (Table 2) and cultivar (Table 3). Differences in protein content amongst spelt cultivars ranged from 140 to 163 g. Common wheat contained significantly less protein (114 g) than all spelt cultivars. Many authors also report higher protein content in spelt compared to common wheat (Chrenková et al., 2000; Escarnot et al., 2012; Hofmanová et al., 2014). It should be noted, however, that those studies were conducted in different years and on different cultivars. Stallknecht et al. (1996), who studied 164 cultivars of spelt, showed a very high variability in grain protein content, depending on the genotype and location, i.e. agricultural technology and environmental conditions. Environmental conditions very clearly modify grain quality, including protein content. Taking into account the use of wheat flour by the baking industry, it should be noted that to be used in the production of flour, as grain for baking purposes, any cultivar should contain at least 11.5% protein in dry matter. Grain that may act as a source of dough enhancer in mixtures containing medium or low value grains should contain more than 14% protein in dry matter.

Table 2. Effect of weed control and sowing rate on physical properties, quality and farinograph traits of winter spelt grain

Trait	Weed control		Sowing rate(grains·m^{-1})			Mean	$LSD_{0.05}$	
	M	CH	300	400	500		W	R
Thousand grain weight (g)	41.6	42.7	43.0	41.8	41.6	42.2	0.9	1.34
Test weight (kg·hl^{-1})	77.3	78.5	78.5	77.5	77.6	77.9	0.6	1.24
Grain fractions (%): < 2.2	4.6	4.9	4.8	4.8	4.6	4.7	ns	ns
2.2 – 2.5	13.8	13.2	13.2	13.5	13.9	13.5	ns	ns
2.5 – 2.8	32.7	32.9	33.1	33.6	31.7	32.8	ns	ns
> 2.8	48.3	49.0	48.9	48.2	48.9	48.6	ns	ns
Falling number (s)	248	252	259	244	246	250	ns	14.4
Protein (g·kg^{-1})	143	143	146	142	142	143	ns	2.50
Zeleny test (cm^3)	18.4	19.9	19.5	19.1	18.9	19.2	1.2	ns
Gluten content (%)	40.0	39.0	40.7	39.7	38.1	39.5	0.8	1.16
Gluten weakening (mm)	3.1	2.7	3.0	3.0	2.7	2.9	ns	ns
Gluten index (%)	44.3	49.8	45.1	47.9	48.3	47.1	1.54	2.31
Water absorption (%)	54.5	54.1	54.9	54.1	53.8	54.4	ns	0.62
Development time (min)	3.57	3.17	3.60	3.25	3.26	3.37	0.37	ns
Dough stability (min)	4.37	4.58	5.06	4.05	4.31	4.48	ns	n.s
Degree of softening (10 min after begin) FU	78.1	73.0	67.4	83.5	75.9	75.6	ns	ns
Degree of softening (ICC/12 min after max) FU	111.9	107.8	109.3	112.3	107.9	109.8	ns	ns

M-mechanical; CH-chemical; LSD-the least significant difference; GI-gluten index; ns-not significant.

Table 3. Physical properties, quality and farinograph traits

Trait	Strain/cultivar							$LSD_{0.05}$
	A*	B	C	D	E	F	G	
Thousand grain weight (g)	38.6	43.5	42.4	38.5	44.7	46.2	41.1	2.70
Test weight (kg·hl^{-1})	81.8	78.9	79.4	69.0	80.8	74.7	80.8	1.82
Grain fractions (%): < 2.2	8.3	3.1	3.5	7.8	2.7	3.7	4.05	0.63
2.2 – 2.5	22.3	7.7	12.2	25.0	10.4	6.5	10.4	3.32
2.5 – 2.8	40.7	28.8	31.5	34.5	31.8	36.3	26.1	5.96
> 2.8	28.8	60.3	52.9	32.7	55.1	53.4	57.4	5.37
Falling number (s)	276	295	275	281	229	258	134	28.8
Protein (g·kg^{-1})	145	148	149	142	140	163	114	5.02
Zeleny test (cm^3)	15.9	21.3	19.2	19.7	22.8	16.7	18.6	3.25
Gluten content (%)	44.4	42.9	44.6	37.0	35.1	44.8	27.9	2.32
Gluten weakening (mm)	2.8	1.7	2.8	3.4	3.4	5.3	1.0	1.17
Gluten index (%)	40.3	58.1	43.5	36.9	49.6	19.3	81.8	4.63
Water absorption (%)	59.0	56.2	56.8	51.2	49.2	54.1	53.4	1.25
Development time (min)	4.58	5.83	3.84	3.32	1.86	2.45	1.70	1.10
Dough stability (min)	5.38	7.98	4.23	3.92	4.78	2.53	2.51	2.30
Degree of softening (10 min after begin) FU	60.1	44.3	69.7	77.5	71.9	116.7	89.1	40.3
Degree of softening (ICC/12 min after max) FU	111.6	75.7	105.4	106.4	102.9	148.4	118.3	46.9

*Strains and cultivars: A-STH 8; B-STH 11; C-STH 28-4609; D-STH 28-4614; E-STH 28-4619; F-Oberkulmer Rothkorn, G-common wheat Tonacja; GI-gluten index.

Spelt grain is characterised by a significantly higher amount of gluten compared to wheat, which is confirmed by Mikos and Podolska (2012). This parameter determines the quality of the grain and its usefulness for bread flour. The minimum gluten content for wheat in bread making is 25% (Bojňanská and Frančaková, 2002). Pruska-Kędzior et al. (2008) reported that gluten content in wholemeal flour from spelt amounted to about 42% and was significantly higher than in common wheat.

The gluten index is another parameter characterising the suitability of flour for baking, defining the relationship between the quality and quantity of gluten, and predicts the ability of the dough to retain gas as well as its resistance to mechanical processing. The closer the gluten index is to 0, the lower the gluten quality. Highly significantly, the highest value of the index was observed for wheat (82). The average gluten index level for the tested spelt samples was above 40, while the significantly lowest value was found for Oberkulmer Rotkorn (19.3). A gluten index of 50–60 is best for baking purposes, flour with an index of less than 50% is more difficult to process, the dough is sticky, and is mainly suitable for biscuits, with a potential application, for example, in two-layer flat breads (Mikos and Podolska, 2012).

The sedimentation rate (Zeleny test) is a measure of the quality and amount of structure-building substances. It defines both the quality and quantity of gluten. The higher the result of the analysis, the higher the gluten protein content in the flour, and in particular high-molecular glutenin, which has a good swelling ability and ensures a good baking value. In the present study, the value of this ratio was significantly influenced by the weed control method (W) and the strains (S). Indeed, the lowest value of this ratio was obtained for STH 8 strain (15.9 cm^3) and the Oberkulmer Rotkorn cultivar (16.7 cm^3). For the rest of the examined spelt strains the sedimentation ratio was higher than for common wheat (18.6 cm^3).

In literature, Zeleny sedimentation rates found for spelt flour usually indicate that the flour, in spite of a higher content of protein and better gluten quality in comparison with wheat, has a worse baking value. The swelling ability of the protein, expressed by the sedimentation rate for the majority of spelt flours, is lower than in wheat flour (Piergiovanni et al., 1996; Tang Yong-Lu et al., 2012).

Bojňanská and Frančaková (2002) observed that spelt flour in an extremely dry year had higher protein content, increased wet gluten yield and a higher falling number. Other authors have noted that an increase in protein content and wet gluten yield leads to a deteriorated gluten quality, which in turn affects the usefulness of the flour in baking (Peterson et al., 1998; Capouchová, 2001).

The study of rheological characteristics of dough using instrumental methods makes it possible to determine the behaviour of dough during kneading and fermentation, as well as enables the evaluation of flour water absorption (Walker and Hazelton, 1996). The farinograph test is one of the most commonly used methods for assessing dough behaviour. It is well known that the better the quality of the protein, the higher the water absorption, the longer the duration of dough development, the longer the stability time, and the lesser the degree of dough softening. All the farinographically tested characteristics were significantly influenced by cultivar/strain (Table 1). The highest waterabsorption was observed for STH 8 (59%). The next highest water absorption was exhibited by STH 11 and STH 28-4609 flours (56% and 57%, respectively), with the flours from the remaining spelt strains and common wheat less water-absorptive, in the range 53.4–54.1% (Table 3). Bojňanská and Frančaková (2002) reported that water absorption in spelt cultivars varied between 53 and 64.4%. Ceglińska (2003) reported that the studied spelt flours showed 65% waterabsorption.

Doughs made from the spelt flours examined in this study (except for STH 28-4619) had a much longer duration of development (2.45-5.83 minutes) than common wheat flour dough (1.7 minutes). In contrast, Marconi et al. (2002) obtained shorter development time for spelt dough (1-3 minutes). Spelt doughs had significantly longer stability times (exception - Oberkulmer Rotkorn) than wheat dough. Marconi et al. (2002) studied spelt flours which showed shorter stability times in our study (i.e. below 4 minutes). Cieglińska (2003) reported long stability times of spelt flours (9.5 min). The sum of the development and stability time indicates the resistance of the dough to mixing. The higher the sum, the longer the dough should be mixed. Therefore, spelt dough requires kneading that is longer than wheat flour dough.

Degree of softening made from the examined flours differed significantly among the studied spelt cultivars and strains, and between spelt and wheat (Table 3). The studied doughs were characterised by a high degree of softening (10 min. after begin) (60.1-116.7 FU) (exception: STH 11-44.3 FU). Wheat with good baking parameters should be characterised by a degree of softening not higher than 120 FU.

Farinograph characteristics also did not differ among the studied spelt cultivars and strains, and between spelt and wheat, in response to the applied agricultural practices. There were also no interactions between the methods of weed control and sowing rates.

Table 4. Significance of contrasts for comparisons of mean groups value (by Scheffe test)

Trait	Contrast		
	C1	C2	C3
Thousand grain weight (g)	0.44	**-4.66**	**5.10**
Test weight ($kg \cdot hl^{-1}$)	**-2.82**	**3.28**	**-6.10**
Grain fractions (%): < 2.2	1.03	1.38	-0.35
2.2 – 2.5	**5.12**	**9.02**	-3.90
2.5 – 2.8	**7.36**	-2.84	**10.20**
> 2.8	**-11.44**	**-7.44**	-4.00
Falling number (s)	**137.20**	13.20	**124.00**
Protein ($g \cdot kg^{-1}$)	**30.80**	**-18.20**	**49.00**
Zeleny test (cm^3)	1.18	3.08	-1.90
Gluten content (%)	**12.90**	**-4.00**	**16.90**
Gluten weakening (mm)	**1.82**	**-2.48**	**4.30**
Gluten index (%)	**-36.12**	**26.38**	**-62.50**
Water absorption (%)	1.08	0.38	0.70
Development time (min)	**2.19**	**1.44**	0.75
Dough stability (min)	**2.75**	**2.73**	0.02
Degree of softening (10 min after begin) FU	**-24.40**	**-52.00**	27.60
Degree of softening (ICC/12 min after max) FU	**-17.90**	**-48.00**	30.10

$C1=(x_A+x_B+x_C+x_D+x_E)/5-x_G$, $C2=(x_A+x_B+x_C+x_D+x_E)/5-xF$, $C3=x_F-x_G$; Bold letters – significance at 0,05 level.

Comparisons of group means (Table 4) indicate that Polish spelt strains had a lower loose packed density of grain and a smaller share of grain fractions >2.8 mm than wheat (C_1). Quality characteristics of spelt cultivars were also much better, apart from the gluten index. Farinograph characteristics were also better, except for the degree of softening.

The results of new strains were worse than the older non-modified Oberkulmer Rothkorn cultivar (C_2). Only the gluten index was higher in the new strains. Comparison of Oberkulmer Rotkorn with Tonacja wheat (C_3) indicates its lower susceptibility to fouling and higher protein and gluten content, with a worse gluten quality. Farinograph characteristics showed no significant differences between the Oberkulmer Rotkorn and To*n*acja wheats.

CONCLUSION

The parameters of nutritional, milling and baking values in most cases significantly differed between the tested spelt strains/cultivars and common wheat. The results indicate that Polish spelt strains had a lower loose packed density (test weight) and a smaller share of grain fractions >2.8 % than common wheat. Meanwhile, most quality characteristics were much better, with the exception of the gluten index. The spelt strains had a higher total protein content and wet gluten yield than wheat. The falling number showed that spelt flour had a moderate or low activity of amylolytic enzymes, which is detrimental to the fermentation of dough. However, it is worth noting that the majority of surveyed strains had better results in sedimentation test than wheat (respectively: 19.2-22.8 cm^3 and 18.6 cm^3). Spelt flour doughs had longer development and stability times than wheat, which means that they require to be mixed for longer than wheat flour dough.

In most characteristics, the tested cultivars and strains did not show significantly different responses to the applied agricultural practices, which is important from the point of view of organic farming and may suggest a reduced expenditure on the prevention and reduction of weed infestation.

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