Bulgarian Journal of Agricultural Science, 22 (No 4) 2016, 604–610
Agricultural Academy

EFFECT OF WEED CONTROL AND SOWING RATE ON THE BAKING QUALITY OF SPELT IN COMPARISON WITH COMMON WHEAT

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Abstract

STANKOWSKI, S., S. PUŻYŃSKI, M. SOBOLEWSKA and W. BIEL, 2016. Effect of weed control and sowing rate on the baking quality of spelt in comparison with common wheat. *Bulg. J. Agric. Sci.*, 22: 604-610

In the experiment conducted in 2012–2013 the following factors were investigated: 7 strains and cultivars (winter spelt: cv. Oberkulmer Rotkorn and five Polish 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. Agricultural factors (weed control and sowing rate) had not significant influence for quality traits. Positive effect of chemical weed control was observed only for physical parameter of grain. There was no interaction between agronomical factors and strains and cultivars. Quality parameters were better for spelt strains than for common wheat, especially in protein and gluten content. Quality of gluten, expressed as gluten index was much lower. Spelt flour dough had longer stability times and smaller dough weakening than wheat, which means that they require to be mixed for longer than wheat flour dough. Obtained result indicate, that spelt could be a good material for bread production.

Key words: grain quality; new breeding lines; sowing rate; *Triticum aestivum* ssp. *spelta*; *Triticum aestivum* ssp. *vulgare*; weed control

Introduction

Spelt (*Triticum aestivum* ssp. *spelta* L.) is one of the oldest cereals used by man. It was cultivated for more than 7000 years in western part of Asia. To Europe was brought probably from Iran. In 19th century in some European countries production of spelt was conducted on the biggest area among all cereals. Later was substituted by higher yielding cultivars of common wheat. Lately we can observe come back of this plant. The lower 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, 2010; Pospišil et al., 2011). Nutritional value of spelt, in comparison to wheat, is better because of more total fat, vitamins, microelements, macroelements and high-value protein content (Schober et al., 2006; Abdel-Aal et al., 2007; Pruska-Kedzior et al. 2008; Spychaj-Fabisiak et al., 2014).

Spelt has more total protein and greater gluten yield, but its rheological properties make spelt flour less useful for standard baking methods (Zieliński et al., 2008; Kohajdová and Karovicová, 2009). Spelt flour dough has a lower stability and elasticity with greater extensibility and viscosity compared to wheat flour dough (Kohajdová and Karovicová, 2008; Coda et al., 2010). Spelt bread usually has a smaller volume than wheat bread (Bonafaccia et al., 2000) and differs in taste and smell (Campbell, 2010). Although there are consumers who accept its flavor. However, the prevalence of spelt is low due to difficulties associated with production

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and processing of the grain (Ruibal-Mendieta et al., 2005). Recently are carried some project to improve spelt quality and minimize problems with processing.

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

Materials and Methods

The material for investigation were grain samples obtained from an experiment conducted in 2011–2012 and 2012–2013 years at the Lipnik Agricultural Experimental Station (53º12′ N, 14º27′ E), Poland on good rye complex soil. The experimental factors in were: 2 methods of weed control (organic harrowing and the use of Legato Plus herbicide 1.25 l/ha), 3 sowing rates (300, 400 and 500 grains/m) and 7 cultivars and strains variants: winter spelt German cultivar Oberkulmer Rotkorn and 5 Polish strains (STH 8, STH 11, STH 28-4609, STH 28-4614, STH 28-4619) from the Strzelce Plant Breeding centre and for comparison, common winter wheat (cultivar Tonacja).

Nitrogen percentage of grain was determined based on the Kjeldahl method, followed by colorimetric reading using a Büchi B-324 (Switzerland). Cereal protein concentration was calculated by multiplying N by 6.25. The following grain parameters were determined: thousand grain weight (4 × 250 grains), test weight (kg/hl) and grain fractions (%). The following flour traits was estimated by ICC standard methods: Hagberg-Perten falling number using an SWD-83 camera (Poland), sedimentation rate, gluten content, gluten weakening in mm, gluten index (%). Also the rheological properties of the dough were determined: flour water absorption (%), stability (min), developed time (min) and degree of softening (FU), using a Brabender farinograph (Duisburg, Germany) according to the standard method (AACC, 2003). The number of replications n = 2.

The results were statistically overworked using a three-way analysis of variance without replications. For testing the effects in ANOVA mean square of the highest interaction was used. LSD values for multiple comparisons were calculated using the Tukey's test at a significance level $p = 0.95$. For the comparison of group means, the following orthogonal contrasts (using the Scheffe method) were calculated:

$$C_1 = (x_A + x_B + x_C + x_D + x_E)/5 - x_G;$$

$$C_2 = (x_A + x_B + x_C + x_D + x_E)/5 - x_F; C_3 = x_F - x_G,$$

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.

Results and Discussion

Agricultural factors used in the experiment – two methods of weed control (mechanical and chemical) and 3 sowing

Table 1
Significance of main effects – weed control, sowing rate, strains

Traits	Source of variability					
	W	R	S	W × R	W × S	R × S
Thousand grain weight (g)	**	ns	**	ns	ns	ns
Test weight (kg/hl)	**	*	**	ns	ns	ns
Grain fractions (%):						
< 2.2	ns	**	**	ns	ns	ns
2.2–2.5	**	ns	**	ns	ns	ns
2.5–2.8	**	ns	**	ns	ns	ns
> 2.8	**	ns	**	ns	ns	ns
Falling number (s)	**	*	**	ns	ns	ns
Protein (g/kg)	ns	**	**	ns	ns	ns
Zeleny test (cm^3)	ns	ns	**	ns	ns	ns
Wet gluten content (%)	ns	ns	**	ns	ns	ns
Gluten weakening (mm)	ns	ns	**	ns	ns	ns
Gluten Index (%)	ns	ns	**	ns	ns	ns
Water absorption (%)	ns	ns	**	ns	ns	ns
Development time (min)	ns	ns	**	ns	ns	ns
Stability (min)	ns	ns	**	ns	ns	ns
Degree of softening (FU) after 10 min	ns	ns	**	ns	ns	ns
Degree of softening (FU) after 12 min	ns	ns	**	ns	ns	ns

Note. Data represent the mean from 2012–2013, W: weed control, R: sowing rate, S: strains; ** $P \leq 0.01$, * $P \leq 0.05$, ns: not significant

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)			Mean	$LSD_{0.05}$	
	M	CH	300	400	500		W	R
Thousand grain weight (g)	42.9	44.5	44.1	43.8	43.3	43.7	0.69	ns
Test weight (kg/hl)	74.5	76.2	75.7	75.4	75.0	75.4	0.41	0.61
Grain fractions (%):								
< 2.2	2.8	3.0	3.2	2.9	2.6	4.7	ns	0.31
2.2–2.5	9.7	8.8	9.6	9.3	9.0	9.2	0.64	ns
2.5–2.8	31.5	28.2	29.3	30.0	30.4	29.8	0.77	ns
> 2.8	56.1	59.9	58.3	58.0	57.7	58.0	1.54	ns
Falling number (s)	275	266	263	281	278	270	ns	14.0
Protein (g/kg)	118	123	121	120	119	120	1.10	1.49
Zeleny test (cm^3)	14.2	14.8	14.8	14.4	14.4	14.5	ns	ns
Wet gluten content (%)	31.1	31.0	31.2	31.1	30.9	31.1	ns	ns
Gluten weakening (mm)	1.21	1.24	1.38	1.19	1.12	1.22	ns	ns
Gluten Index (%)	62.8	64.0	61.6	64.6	64.0	63.4	ns	ns
Water absorption (%)	52.3	52.5	52.3	52.5	52.3	52.4	ns	ns
Development time (min)	2.23	2.18	2.28	2.13	2.20	2.20	ns	ns
Stability (min)	3.55	3.44	3.61	3.55	3.63	3.50	ns	n.s
Degree of softening (FU) after 10 min	98.4	93.4	95.2	98.1	94.4	95.9	ns	ns
Degree of softening (FU) after 12 min	126	119	121	122	125	122	ns	ns

M: mechanical, CH: chemical; LSD: the least significant difference, ns: not significant

rate had not very strong effect on physical properties of grain. Significant effects in the thousand grain weight, test weight and share of grain fraction were obtained for methods of weed control (Table 1). Higher values of above mentioned traits were noticed for chemical weed control than for mechanical, however the range of differences not exceeding in most of them 5% indicate low practical importance (Table 2).

The significant effect of sowing rate was noticed only for test weight and the smallest grain fraction <2.2 mm. Data presented on the physical characteristics of the grains in this work are in most cases consistent with the literature data (Capouchová, 2001; Zieliński et al., 2008; Mayer et al., 2012). There were no interaction between weed control, sowing rates and cultivars that indicate the responses of cultivars and strains to the applied agricultural practices were similar. Much bigger differences were observed for strains and cultivars used in the investigation (Table 3). Significant effect was noticed for every of physical traits estimated in the experiment. Comparative analysis of thousand grain weight showed the great variation between spelt strains and cultivars.

The highest values of this parameter were obtained by the cv. Oberkulmer Rotkorn and STH 28-4619 and the lowest by STH 8 strain. In general higher values of thousand grain weight are negatively correlated with grain test weight. The share of grains with diameter > 2.8 was observed for common wheat and STH 28-4619 strain. Comparison of mean groups contrast C_1 (Table 4) indicate that new strains has lower thousand grain weight and test weight than common wheat. Higher values of these parameters indicate higher milling yield, while low values indicate poor endosperm development.

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 significance of the effects on quality parameters caused by weed control (W), sowing rate (R), and the strain (S) are presented in Table 1. Agronomic factors have no effect on quality parameters except falling number and protein content. There is also no interaction between them and cultivars or strains.

The falling number is very important factor of the flour which significantly influences the dough strength and crumb properties (Ostasiewicz et al., 2009). The data obtained in the present study (Table 3) show that the falling number varied significantly among cultivars, being significantly lowest in common wheat (188 seconds), while for spelt strains it ranged from 260 to 308 seconds. Capouchová (2001) indicate that values obtained in the experiment are on the optimal level of amylolytic activity. The falling number for Tonacja was lower than obtained by other authors (Grobel-

nik-Mlakar et al., 2009; Ross et al., 2012; Lemańczyk and Kwaśna, 2013).

Protein level was significantly influenced by weed control and sowing rate (Table 2), but the difference was 5 and 2 g, respectively. Differences in protein content among spelt cultivars ranged from 116 to 132 g (Table 3). Common

Table 3
Physical properties, quality and farinograph traits

Traits	Strain/cultivar							$LSD_{0.05}$
	A	B	C	D	E	F	G	
Thousand grain weight (g)	37.5	42.2	44.2	43.6	46.7	47.1	44.3	1,18
Test weight (kg/hl)	78.8	76.0	76.1	69.1	78.6	71.6	77.4	1.22
Grain fractions (%):								
< 2.2	7.0	1.5	1.9	3.4	1.7	1.5	3.4	0.60
2.2–2.5	20.7	6.8	7.2	15.2	5.0	5.9	4.1	1.91
2.5–2.8	43.8	28.3	27.7	44.1	19.8	31.8	13.8	2.32
> 2.8	28.8	63.5	63.3	37.5	74.4	59.6	78.9	4.60
Falling number (s)	298	308	297	283	262	260	188	28.0
Protein (g/kg)	122	122	124	116	118	132	107	3,0
Zeleny test (cm^3)	13.0	12.7	13.5	15.4	17.5	14.6	14.9	2.41
Wet gluten content (%)	34.8	30.6	33.8	27.5	31.2	34.6	24.8	3.22
Gluten weakening (mm)	1.40	0.56	1.06	1.19	1.67	1.94	0.77	0.52
Gluten Index (%)	48.7	83.4	58.1	59.1	62.8	41.2	90.5	9.40
Water absorption (%)	55.2	52.2	52.7	50.2	50.5	53.1	52.7	0.99
Development time (min)	2.88	2.39	2.60	1.93	1.77	2.34	1.51	0.885
Stability (min)	3.87	4.88	4.29	3.67	3.58	2.81	2.09	1.44
Degree of softening (FU) after 10 min	91.2	74.5	85.9	82.6	99.6	108.4	129.2	29.8
Degree of softening (FU) after 12 min	129	102	117	104	117	135	154	40.3

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 – wheat Tonacja

Table 4
Significance of contrasts for comparisons of mean group's value (by Scheffe test)

Traits	Contrast		
	C_1	C_2	C_3
Thousand grain weight (g)	-1.46	-4.26	2.8
Test weight (kg/hl)	-1.68	4.12	-5.8
Grain fractions (%):			
< 2.2	-0.3	1.6	-1.9
2.2–2.5	**6.8**	**5.8**	1.8
2.5–2.8	**18.9**	0.9	**18.0**
> 2.8	-25.4	-6.1	-19.3
Falling number (s)	102	30	72
Protein (g/kg)	13	-12	25
Zeleny test (cm^3)	-0.5	-0.2	-0.3
Wet gluten content (%)	**6.8**	3.0	**9.8**
Gluten weakening (mm)	0.41	-0.76	1.17
Gluten Index (%)	**-28.1**	21.2	**-49.3**
Water absorption (%)	-0.54	-0.94	0.40
Development time (min)	0.80	0.03	0.83
Stability (min)	**1.97**	**1.25**	0.72
Degree of softening (FU) after 10 min	**-42.4**	-21.6	-20.8
Degree of softening (FU) after 12 min	**-40.2**	-21.2	-19.0

$C_1 = (x_A + x_B + x_C + x_D + x_E)/5 - x_G$, $C_2 = (x_A + x_B + x_C + x_D + x_E)/5 - x_F$, $C_3 = x_F - x_G$; bold letters = significance at 0.05 level

wheat contained significantly less protein (107 g) than all spelt cultivars. Many authors also indicate for higher protein content in spelt as compared to common wheat (Escarnot et al., 2012). Grain protein content could be modified by genotype, agronomic factors – especially nitrogen fertilization – and environmental conditions (Pierre et al., 2008; Fuertes-Mendizábal et al., 2010). For spelt there is no relationship between grain protein content and grain yield (Jablonskytė-Raščė et al., 2013). This analysis proved grain protein content to be a strong, rather stable genetic trait for spelt.

Taking into account the use of wheat flour by the baking industry, it should be noted that each of the examined cultivars may be used in the production of flour, as grain for baking purposes 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.

The quantity and quality of gluten are considered the most important quality parameters of wheat flour. 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 production. The minimum gluten content for wheat in bread making is 17.6% (Kohajdová and Karovicová, 2009). 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.

Gluten Index Method is a rather new method for determining gluten quantity and quality in wheat semolina and flour. It is centrifuged to force wet gluten through a specially constructed sieve under standardized conditions. The percentage of wet gluten remaining on the sieve after centrifugation is defined as the Gluten Index. If the gluten is very weak all of the gluten may pass through the sieve, the Gluten Index is zero (0). When nothing passes through the sieve, the Gluten Index is 100. The agronomical factors as weed control and sowing rate did not change the gluten index, but it was strong differentiated by cultivar and strains. The highest value of the index was observed for wheat (90.5%) and one of new strain from Strzelce Breeding Station (83.3%). The significantly lowest value was found for Oberkulmer Rotkorn (41.2%) and spelt strain STH 8 (48.7%). A gluten index of 50–60% is best for baking purposes, flour with an index of less than 50% is more difficult to obtain good bread (Mikos and Podolska, 2012).

Grain of spelt obtain in good weather conditions have generally higher protein content, increased wet gluten yield and a higher falling number, which resulted in higher value of the flour in baking process (Capouchová, 2001; Kohajdová and Karovicová, 2009; Li et al., 2013).

The sedimentation rate according to Zeleny test describes the degree of sedimentation of flour suspended in a lactic acid solution during a standard time interval and this is taken as a measure of the baking quality. Swelling of the gluten fraction of flour in lactic acid solution affects the rate of sedimentation of a flour suspension. Both higher gluten content and a better gluten quality give rise to slower sedimentation and higher Zeleny test values. The value of this quality indicator was not influenced by the weed control method and sowing rate. The significant effect was only observed for strains and cultivars. The highest value of this trait was obtained for STH 28-4619 strain (17.5 cm^3). For the rest of the examined spelt strains the sedimentation ratio was similar as obtained for common wheat (14.9 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 (Tang et al., 2010; Lacko-Bartošová and Korczyk-Szabó, 2011).

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 farinographic test is one of the most commonly used methods for assessing dough quality. Higher protein and gluten content could increase the water absorption, the duration of development time, the stability time, and the degree of softening.

All the farinographically tested characteristics were not affected by agronomical factors (Table 1). Differences were observed only for strains and cultivars. The highest water absorption was observed for STH 8 (55.2%). The water absorption for the rest of strains and cultivar was between 53.1–50.2%, (Table 3). Ceglińska (2003) reported that water absorption in spelt cultivars varied between 53% and 64.4%. It could be affected by environmental condition, also.

Dough made from the spelt flours used in this study (except for STH 28-4619) had a longer duration of development time (1.9–2.9 minutes) than common wheat flour dough (1.5 minutes). Spelt strains doughs had significantly longer stability times (exception – Oberkulmer Rotkorn) than wheat dough. Results obtained by Ceglińska (2003) indicated for high variability in development time – from for 4 to 9 minutes. In general we can conclude that spelt need longer time of mixing than common wheat. 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 dough were characterised by a low degree of softening (10 min. after begin) within the interval 74.5–108.4. Wheat with

good baking parameters should be characterised by a degree of softening not higher than 120 farinograph units (FU). Higher value was observed only for common wheat (129.2 FU).

Comparisons of group means (Table 4) indicate that Polish spelt strains had a lower value of physical parameters than wheat (C_1). Quality characteristics of spelt cultivars were also better, only gluten gluten index was much lower. Comparing Polish strains with common wheat Tonacja only the dough stability was better for spelt. For the remaining characters was no difference or wheat was better. The results of new strains were better in gluten index and dough stability than in the older non-modified cv. Oberkulmer Rothkorn (C_2). Comparison of Oberkulmer Rotkorn with Tonacja wheat (C_3) indicates its lower gluten index, test weight and share of grain fraction > 2.8 mm. Higher was gluten content and thousand grain weight. Farinograph characteristics showed no significant differences between the cvs. Oberkulmer Rotkorn and Tonacja.

Conclusions

Agricultural factors (weed control and sowing rate) had not significant influence for quality traits. Positive effect of chemical weed control was observed only for physical parameter of grain. There was no interaction between agronomical factors and strains and cultivars.

Quality parameters were better for spelt strains than for common wheat, especially in protein and gluten content. Quality of gluten, expressed as gluten index was much lower.

Spelt flour dough had longer stability times and smaller dough weakening than wheat, which means that they require to be mixed for longer than wheat flour dough.

Obtained result indicate, that spelt could be a good material for bread production.

Acknowledgements

This study was supported by the Polish Ministry of Science and Higher Education (MNiSW) of Poland (project no. NN 310436938) in 2010-2013.

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Received July, 16, 2015; accepted for printing June, 17, 2016