NARDI FUNDULEA, ROMANIA
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ROMANIAN AGRICULTURAL RESEARCH, NO. 35, 2018
Print ISSN 1222–4227; Online ISSN 2067–5720

EVALUATION OF THREE WHEAT SPECIES (*TRITICUM AESTIVUM* L., *T. SPELTA* L., *T. DICOCCUM* (SCHRANK) SCHUEBL) COMMONLY USED IN ORGANIC CROPPING SYSTEMS, CONSIDERING SELECTED PARAMETERS OF TECHNOLOGICAL QUALITY

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ABSTRACT

A recent interest in the usage of different wheat species for organically grown healthy food has led to resurgence in cultivation not only of hulled wheat, but also of coloured-grain wheat, which contains a large number of nutrients that have vital importance for human feed. The study was aimed to determine and compare the technological properties of *Triticum spelta* L., *Triticum dicoccum (*Schrank) Schuebl and coloured-grain wheat (*Triticum aestivum* L.). The research was based on field experiment carried out at the Agronomy experimental station of National University of Life and Environmental Sciences of Ukraine (Kyiv region) during the period 2014-2016. The data were analyzed using ANOVA method. The difference of weather conditions among experimental years did not have significant influence on examined parameters. On the other hand quality parameters significantly depended on the wheat species. The results obtained indicated that the highest protein content was testified in emmer wheat 20.8 %, but the highest wet gluten yield (30.8 %) and as a result better rheological dough properties was determined in spelt wheat. Significantly the least values for such key parameters as flour strength (W), water absorption, sedimentation value were found examining *T. aestivum* (coloured). Overall it should be noted that all three examined wheat species had poor technological properties for bread producing in most characteristics, except protein content.

Key words: organic cropping system, breadmaking, weather conditions, *Triticum spelta* L.*, Triticum dicoccum* (Schrank) Schuebl.

INTRODUCTION

Wheat production in Eastern Europe countries is particularly dependent on synthetic nitrogen fertilizers because the use of animal manure is very limited, many of the soils are naturally low in levels of soil organic matter and there are only few legumes present in main crop rotations that could supply symbiotically fixe nitrogen (Biel et al., 2016; Piergiovanni et al., 1996)

Therefore, continuous wheat and wheat-fallow systems in Eastern Europe are facing challenges from environmental and economic perspectives, especially with higher than normal fertilizer nitrogen cost and relatively low wheat prices.

Globally there is increasing interest in using organic farming system and maximizing grain production in low-input scenarios. Organic residues are being employed as fertilizers and plant breeding in being used to develop new cultivars that are specifically adapted to organic and/or low-input systems. Old or “neglected” crops are receiving more attention from growers and processors seeking a niche product, while consumers are seeking potential nutritional, sensory and health benefits by eating food from more traditional sources (Trckova et al., 2005; Buntaru et al., 2003). On the other hand, interest of consumers in natural, unconventional and nutritional foods led to the development of new specialty food products. One of the main resources for it is so-called

Received 30 March 2017; accepted 15 January 2018. First Online: March, 2018. DII 2067-5720 RAR 2018-9.

"ancient wheats". The main wheat species grown in Ukraine under organic agriculture systems are spelt, emmer and wheat with coloured grain.

Hulled wheats are often grown in marginal hill and mountain areas in organic farms, where they are considered suitable crops for sustainable farming systems. Despite a number of defects, such as plant height, low grain yield and low pasta- and bread-making quality, spelt and emmer have been recovered in modern times thanks to their adaptability to poor soils and unfavourable climatic conditions (Hajnalová & Dreslerová, 2010).

Consumer interest in spelt grain (*Triticum spelta* L.) is believed to be due to its rich flavour, described as sweet and nutty, agreeable texture in baked products, and good nutritional profile. The grain may have higher contents of protein and fibre, minerals, β-carotene and retinol equivalent, than common bread wheat. Spelt is used to make a wide range of consumer products; the most popular is leavened bread (Capouchova, 2001; Piergiovanni et al., 1996).

The vast majority of Ukrainian spelt production is organic, because the much higher prices paid for the organic product offsets the reduced yield. The reduced yield is a result of three factors: 1) poorly adapted genotypes; 2) the inherently lower-yielding capacity of the organic, low-input system; 3) spelt produces hulled grain which requires additionally processing before flour milling resulting in quite big losses due to chipping and splitting. Commercially-available spelt in Ukraine is presently restricted to a few poorly-adapted genotypes (Morgun et al., 2015). Evidence for poor adaptation is limited, but it suggests that the grain yield of current genotypes, including the predominant commercial variety Zorya Ukraini is low relative to standard bread wheats. It is known that wheat under an organic system can yield from 14 to 44% less then under a high-input system (Abdel-Aal et al., 1995; Escarnot et al., 2012).

The tetraploid emmer wheat – *Triticum dicoccum* (Schrank) Schuebl is one of the crops considered suitable for low-input farming system, where modern conventional varieties are not able to develop their yielding potential at a good level. Emmer is one of the hulled wheat species which has been grown and used as a part of human diet for a very long time. As people are paying more attention to the diversity and good quality of food products, they have become more interested in these wheat species. Emmer wheat landraces have a number of advantages, which assure them an important role in the interest of farmers and consumers: they are resistant and tolerant to drought, the root system is able to better absorb nitrogen (Konvalina et al., 2010; Piergiovanni et al., 1996).

Unless using hulled wheats, bio-enhanced breeding such as genetic breeding method was used to improve the nutrient value of wheat. Researches show that coloured-grain wheat (*Triticum aestivum* L.) contains a large number of needsed nutrients. Particularly, it is rich in anthocyanins that have many functions such as antioxidant, antibacterial, anticancer and reduction of the incidence of cardiovascular disease (Abdel-Aal et al., 2006; Li et al., 2003; Knielev et al., 2009). Therefore, coloured-grain wheat becomes more interesting for producers and consumers, especially in organic production.

However very few publications that discus the question of using the grain of these wheat species can be found in the literature. This is a question which has vital importance now. The current study was aimed to evaluate the technological properties of selected advanced wheat species to identify their suitability for further processing.

MATERIAL AND METHODS

Description of the experimental site. Field experiment was carried out in a certified ecological field at the Agronomy experimental station of National University of Life and Environmental Sciences of Ukraine (Kyiv region) during 2014-2015. The soil of the experimental site is clay loam (Luvic Chernozems, Cl) with a humus content of 4.3-4.5%, pHKCl 6.8-7.0, P_2O_5 176-187 mg kg^{-1}, K_2O 440-454 mg kg^{-1}.

In our research we used the samples of the wheat species from collection of Ukrainian

Institute of Plant Variety Examination, particularly spelt variety Zorya Ukrainy, emmer wheat variety Golikovska and coloured-grain soft wheat variety Chornobrova. All of them are Ukrainian breeding and recommended to be cultivated in Forest-Step zone of Ukraine. The wheat preceding crop was clover in both experimental years. Crops were grown under the organic agriculture system. In this system only organic fertilizers (20 t ha^{-1}) were applied in crop rotation, without any mineral fertilizers and pesticides. In a breakdown, about 17 t/ha^{-1} of this fertilizing was dunged on other cultures in crop rotation and for wheat there were no less than 7 t ha^{-1} stubbly remains (like clover or corn residues). In particular, by the wheat cultivation there was only seed processing by a biological fertilizer before sowing (Azofit). Exclusively, mechanical and biological means were used against pests, diseases and weeds.

Meteorological conditions. Description of the weather conditions was based on the data from the meteorological site of the Agronomy experimental station. Spring 2014 was rather secured by rainfall and had higher temperatures compare to average multiannual data (Figure 1). As a result sprouting and growth of wheat were quite intensive. But after third decade of May rainfall became rare during all the summer. That is why crop formation was faster than usual.

In 2015 the average decade temperature was higher than multiannual rate, except third decade of June and second decade of July; in conjunction with sporadic rains it was the reason of plant development under drought and stress conditions (Figure 1).

Laboratory analyses. Estimation of technological properties of wheat species grain and flour was done in grain-milling laboratory of Institute of Food Resources NAAS Ukraine and then carried on in University of Environmental and Life Sciences in Wrocław, Department of Fruit, Vegetable and Cereal Technology.

Wheat flour was obtained by milling in a Buhler automatic mill MLU-202. Flour samples that correspond to Ukrainian State Standard (46.004.99) requirements were used.

We determined physical and biochemical characteristics of grain by the following methods: moisture (ISO 712-6540), test weight (ISO 7971-2), structural and mechanical properties of dough by Farinograph (ISO 5530-1), protein content (ISO 20483), falling number by Perten method (ISO 3093), Alveograph by ISO 27971, wet gluten by hand washing ISO 21415-1, sedimentation value by ISO 5529.

Statistical analyses. The significance of the experimental data was estimated by the analysis of variance (two-factor ANOVA) by evaluating the standard deviation and the least significant difference LSD05. To define the compounds and relationship between the parameters, the results were exposed to the analysis of simple correlation and equations of linear regression were calculated.

RESULTS AND DISCUSSION

Analysis of the physical properties of the grains showed their suitability for milling. It is well-known that the higher the thousand grain weight, the higher the flour extraction rate. In our study, both the thousand grain weight and the test weight were influenced by the wheat specie and weather conditions. Higher values for both indicators were obtained in 2014 (0.15-0.25 g and 0.6-0.9 kg·hl^{-1} respectively). Both these parameters were stable divided up to wheat species.

Data presented on the physical characteristics of the grain studied in this work are in majority of cases consistent with literature data (Abdel-Aal et al., 1995; Jablonskyte-Rasce et al., 2013; Guo et al., 2012).

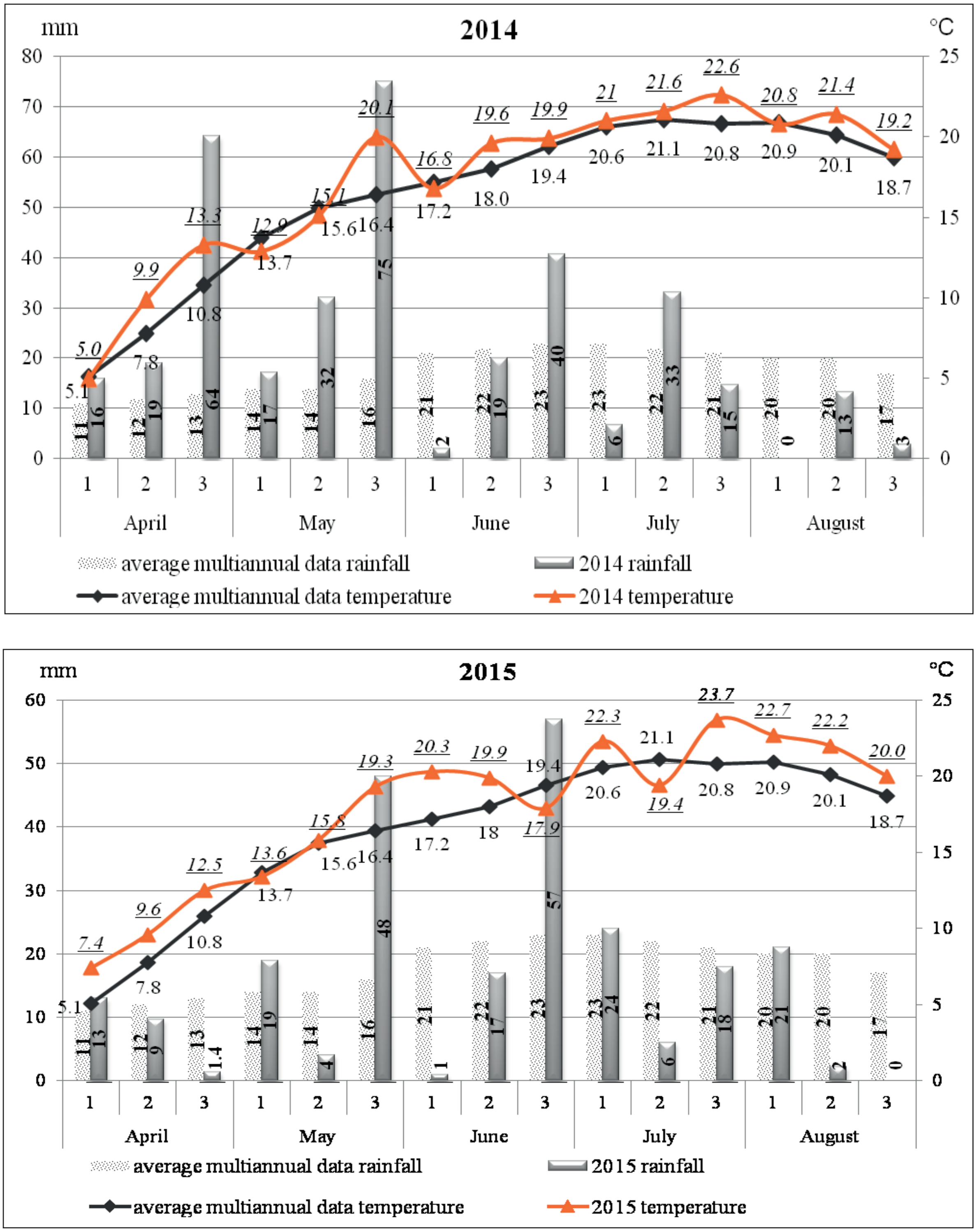

Figure 1. Rainfall and temperature distribution during the growing season

Test weight is characterized as one of the most important indices for estimating the usability of grain in different ways. Comparative analyses of the test weight showed that the lowest value of this parameter was attained by the spelt. But on the other hand this qualitative parameter was significantly different only for T. aestivum (coloured) in comparison to other species.

Thousand grain weight of emmer wheat was by 2 times lower than spelt wheat. A considerable difference was found between all three species (Table 1, Figure 2). Higher values of mentioned parameter indicates higher milling yield, while low values indicate poor endosperm development which was typical for emmer. Konvalina et al. (2008) found the same ratio; the authors indicated that mass of thousand grains for emmer landraces was between 27 and 36 g and emphasized it to be influenced by the genotype and environment conditions.

The falling number is an indicator demonstrating the amylolitic activity of the grain that significantly influences the dough strength and the crumb properties, which has vital importance for bread making. The data obtained in our study show that the mentioned index varied mostly significantly among species, being significantly the highest in emmer wheat, while for spelt and *T. aestivum* (coloured) it ranged from 287 to 322 seconds. The tested meal from all three studied species had the suitable level of amylolitic activity (Petrenko et al., 2015).

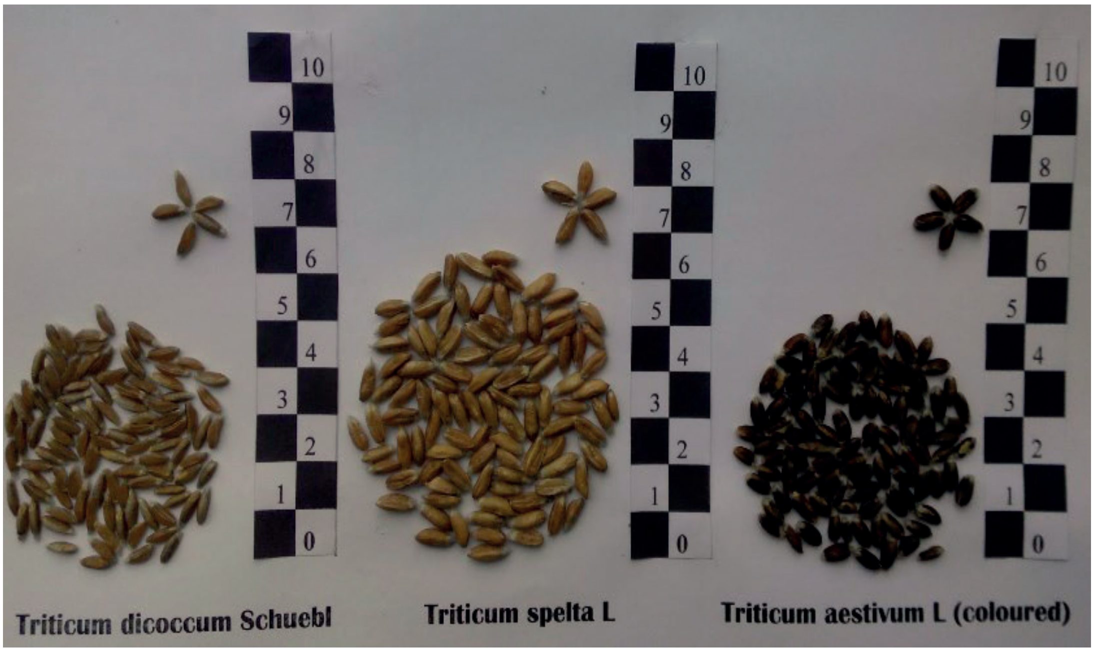

Figure 2. Visual appearance and grain size of studied wheat species (100 kernels)

Table 1. Quality indices of studied wheat species

Specie	Test weight (kg hl^{-1})			Mass of thousand grains (g)			Falling number (sec)		
	2014	2015	Average	2014	2015	Average	2014	2015	Average
T. spelta	72.5	71.4	72.0	56.74	56.53	56.64	287.0	303.0	295.0
T. dicoccum	73.6	73.0	73.3	28.20	27.95	28.07	466.3	427.7	447.0
T. aestivum (coloured)	79.9	78.9	79.4	38.47	38.24	38.36	322.7	309.3	316.0
$LSD_{0,05}$	1.57	2.63	1.62	0.35	0.26	0.27	15.11	22.4	14.01

Estimation of suitability of wheat grain for any kind of processing is based on determination its technological value, which usually depends on the concentration of total protein and the gluten content. Compared to soft wheat, emmer and spelt have significantly more total protein that translates into higher gluten content (Bojnanska & Francakova, 2002; Escarnot et al., 2012). Protein level was significantly influenced by the wheat species. The overall measurement results are summarized in Table 2.

Table 2. Protein and gluten characteristics of studied wheat species

Specie	Protein content (%)			Wet gluten (%)			Sedimentation value (mm)		
	2014	2015	Average	2014	2015	Average	2014	2015	Average
T. spelta	18.9	18.5	18.7	31.7	30.8	31.2	59.7	52.3	56.0
T. dicoccum	20.9	20.8	20.8	30.4	29.4	29.9	79.3	75.3	77.3
T. aestivum (coloured)	13.0	13.2	13.1	23.3	23.8	23.5	40.0	38.0	39.0
$LSD_{0,05}$	0.92	0.58	0.57	1.91	2.4	1.57	2.92	5.59	4.39

Proteins are a source of energy and provide essential amino acids for human consumption. In our research the highest crude protein content had emmer wheat in both experimental years. Significantly the lowest protein content among studied species had *T. aestivum* (coloured). The few data available in the literature on protein content of coloured wheat show a great variability of this parameter. Samples examined by Chapek et al. (2010) had a middle protein level ranged from 9.5 up to 14% calculated on dry basis. On the contrary Gregova et al. (2011) found high mean values of 16 % in several Asian *T. aestivum* landraces with black, blue, pink or purple grains. The same we could say for emmer and spelt – species, protein content varies widely in the different studies. But if all analyses were performed by Kjeldahl method, the variability among species could be explained by the growing conditions (environment and nitrogen fertilizers) and genetic background that influenced the protein content (Dupont et al. 2003). In the research presented here, a significant influence of weather conditions on protein content was not detected. These results are consistent with other studies, which have shown that compared to common soft wheat, spelt and emmer are more resistant to any natural disasters (Konvalina et al., 2008; Giacintucci et al., 2009).

In our study, spelt and emmer grain was characterized by a significantly higher amount of gluten compared to *T. aestivum* (coloured). This parameter determines the quality of the grain and its usefulness for bakery and some other ways of processing. The highest indices of this quality parameter belonged to spelt wheat, despite the fact that protein content was lower on 2-2.3% than for emmer wheat. Biel et al. (2016) reported that gluten content in wholemeal spelt flour amounted to about 35 % which was confirmed by our data.

The sedimentation value (Zeleny test) is a measure of the quality and amount of structure building substances. It estimates both the quantity and quality of wheat 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 good swelling ability and ensures good physical properties of dough (Biel et al., 2016). In the present study, the value of this index was significantly influenced by the wheat species. Indeed the lowest value was obtained, as for previous parameters, for *T. aestivum* (coloured). For the rest of examined species, the sedimentation value was quite high, that confirm the data of other researchers (Galterio et al., 2003; Lacko-Bortosova & Curna, 2015).

In order to understand better the technological properties of mentioned wheat species, we performed alveograph testing. The alveograph parameters give information about the elasticity, extensibility and dough strength. The dough strength, that is used to estimate the dough behaviour during the baking process, presented significant differences for all examined species. But the mean value of the dough strength obtained for the studied wheat was very low, 29 (10^{-4}J) for *T. aestivum* (coloured); the results for 2 other species were also poor; in order to get a good bread quality W must range from 250 to 300. The same we can say for other alveograph parameters – dough elasticity (P) and extensibility (L).

Concerning the dough elasticity specific to the studied wheat species, the mean value was 52 mm (Figure 3). The P values of standard wheat range from 92 to 100 mm that signify a very good quality of wheat (Escarnot et al., 2012). The extensibility for studied grain samples was not so bad, ranging from 76 to 112 mm for emmer and spelt wheat respectively, except for coloured wheat with very low index; the extensibility of 100 mm is considered as being optimum. The P/L ratios obtained in all variants were close to optimum, ranging from 0.6 to 1.3.

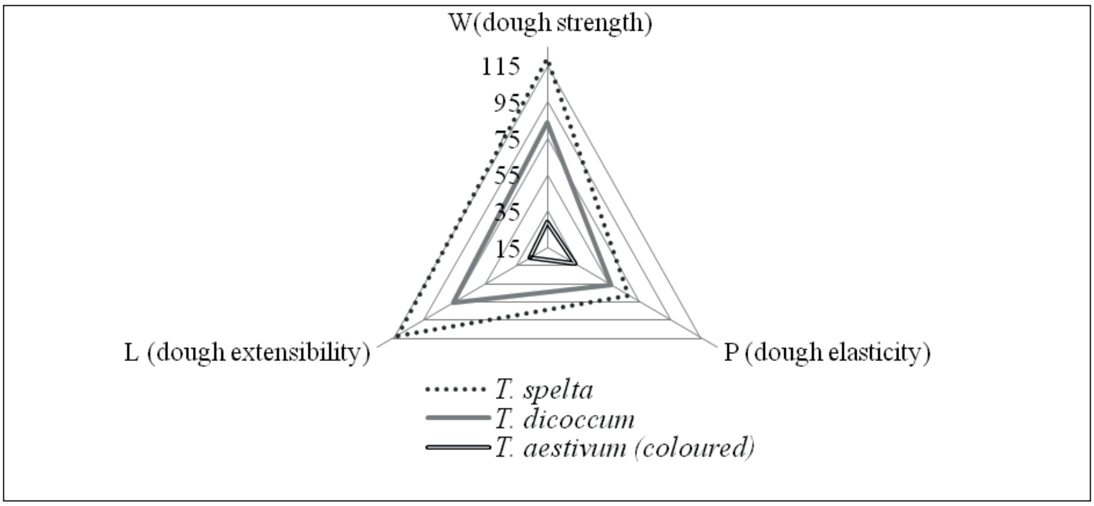

Figure 3. Alveograph indices of examined wheat species

The study of rheological characteristics of dough using instrumental methods makes it possible to determine the behaviour of dough during kneading and fermentation process, as well as enables the evaluation of flour water absorption (Walker & Hazelton, 1996). The farinograph test is one of the most popular methods for assessing dough behaviour. It is commonly known that the better 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.

In our research all the characteristics tested by farinograph were significantly influenced by wheat species. The highest index of water absorption was peculiar to spelt wheat (61.7%), while coloured wheat had quite lower index – 58%. The emmer wheat exhibited a medium result – 60.1%. Bojnanska & Francakova (2002) reported that water absorption in spelt cultivars varied between 54 and 63%.

On the other hand, Chapek et al. (2010) reported that the studied flour from coloured landraces showed up to 66% water absorption that runs counter to our data.

Notwithstanding the foregoing dough produced from spelt wheat examined in this study had the same duration of development as *T. aestivum* (coloured), on average three and a half minute, instead of 5 minutes and 40 seconds for emmer wheat. Our data is in accordance with reports of other emmer wheat researchers (Galterio et al., 2003; Lacko-Bortosova & Curna, 2015).

The emmer dough had significantly longer stability time compared to other examined species. The sum of development and stability time indicates the resistance of the dough to mixing. The higher the sum, the longer the dough should be mixed. Therefore emmer dough requires kneading that is longer than spelt and *T. aestivum* (coloured) dough.

Degree of softening in doughs made from the examined flours differed significantly among the studied wheat species. Wheat with good baking parameters should be characterised by a degree of softening not higher than 120 FU. In our research only emmer had that softening degree – 85 FU. Both spelt and *T. aestivum* (coloured) doughs raised the optimum level – 122 and 156 FU accordingly. In the performed research, higher water absorption was correlated with higher gluten content (Figure 4).

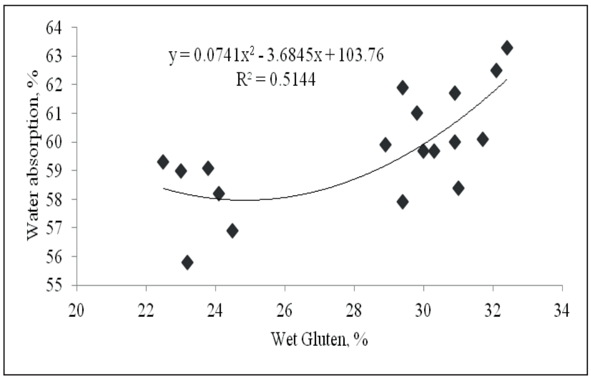

Figure 4. Relationships between mean of water absorption (by farinograph) and wet gluten content

With the exception of emmer and spelt wheat, better physical properties of dough during kneading process were also associated with higher gluten content, because of the positive association of water absorption with other primary wheat grain quality factor, protein content.

The results of correlation analyses of technological parameters of three different wheat species showed a complex relationship between them. In emmer wheat it is important to point out that the correlation coefficients between flour strength (W) and sedimentation value, as well as between flour strength (W) and water absorption were relatively high (r=0.89 & r=0.81 respectively). In spelt wheat we reported relatively high correlation coefficients between flour strength (W) and sedimentation value, the same as between sedimentation value and wet gluten content (r=0.82 & r=0.74 respectively), that is similar with the previous species. The most unrepresentative among studied wheat species was *T. aestivum* (coloured). As shown in Table 3, in the mentioned wheat we did not find so high correlation relationships between examined parameters as in the other species. Only sedimentation value and wet gluten content had a quite strong relationship, which is in agreement with data of other researchers (Zeven, 1991).

Table 3. Correlation between technological parameters in examined wheat species

Parameter	Means	Standard deviation	Wet gluten (%)	Sedimentation value (mm)	Protein content (%)	W, points	Water adsorption (%)
Triticum dicoccum (Schrank) Schuebl							
Wet gluten (%)	29,9	0,72	–	0,15	-0,06	-0,14	-0,21
Sedimentation value (mm)	77,3	2,73	0,15	–	0,42	0,89	0,61
Protein content (%)	20,8	0,32	-0,06	0,42	–	0,39	0,65
W, points	81,8	5,03	-0,14	0,89	0,39	–	0,81
Water adsorption (%)	59,4	1,11	-0,21	0,61	0,65	0,81	–
Triticum spelta L.							
Wet gluten (%)	31,2	1,08	–	0,74	-0,02	0,38	0,28
Sedimentation value (mm)	56,0	4,60	0,74	–	0,27	0,82	0,05
Protein content (%)	18,6	0,32	-0,02	0,27	–	0,47	0,08
W, points	121,3	10,91	0,38	0,82	0,47	–	-0,29
Water adsorption (%)	61,5	1,31	0,28	0,05	0,084	-0,29	–
Triticum aestivum L. coloured							
Wet gluten (%)	23,5	0,74	–	-0,67	-0,013	-0,52	-0,34
Sedimentation value (mm)	39,0	2,44	-0,67	–	0,01	0,65	-0,07
Protein content (%)	13,1	0,23	-0,01	0,01	–	-0,47	0,24
W, points	35,0	8,87	-0,52	0,65	-0,47	–	-0,30
Water adsorption (%)	58,0	1,41	-0,34	-0,07	0,24	-0,30	–

CONCLUSIONS

From the research that was performed, it is possible to conclude that the examined wheat species are poor in their technological properties in comparison to common soft wheat. On the other hand the nutritional parameters, first of all protein content of three studied wheat species grown under organic farming in central part of Ukraine were quite remarkable. Also it must be noted that examined parameters were not significantly influenced by weather conditions, only by species.

Our results confirmed that only spelt wheat had poor acceptable rheological properties determined by alveograph and farinograph for bread producing. Emmer and *T. aestivum* (coloured) are not suitable for bread making as main ingredient. But doubtless flour from studied wheat species could be used as conditioner to common soft wheat producing bread and bakery products. However, there are quite a lot of other ways to use mentioned wheat species in our diurnal nutrition.

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