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Baking Quality of Hulled Wheat Species in Organic Farming

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***Abstract*—**The organic farmers use wider range of crop varieties than the conventional farming. Bread wheat is the most favorite and the most common food crop. The organic bread wheat is usually of worse technological quality. Therefore, it is supposed to be an attractive alternative to the hulled wheat species (einkorn, emmer wheat and spelt). Twenty-five hulled bread wheat varieties and control bread wheat ones were grown on the certified organic parcel in České Budějovice (the Czech Republic) between 2009 and 2012. Their baking quality was measured and evaluated with standard methods, and in accordance with ICC. The results have shown that the grain of hulled wheat varieties contain a lot of proteins in grains (up to 18 percent); even the organic hulled bread wheat varieties are characterized by such good baking quality. Einkorn and emmer wheat are of worse technological quality of proteins (low values of gluten index and Zeleny test), which is a disadvantage of these two wheat species. On the other hand, spelt wheat is of better technological quality and is similar to the control bread wheat varieties. Mixtures consisting of bread wheat, among others, are considered good alternatives; they may contribute to wider range of use of the hulled wheat species. It is one of the possibilities which may increase the proportion of proteins in bread wheat grains; the nutrition-rich hulled wheat grains may be also used in such way at the same time.

***Keywords*—**Baking quality, organic farming, einkorn, emmer wheat, spelt.

I. Introduction

WHEAT (*Triticum* L.) is one of the most important crops for the organic farming system [1]. It was initially grown and processed by people 10,000 years ago as part of the "Neolithic revolution". Nowadays, bread wheat (*Triticum aestivum* L.) is a dominant cereal species worldwide [1]. *Triticum monococcum* L., *Triticum dicoccum* (Schrank) Schuebl. and *Triticum spelta* L. used to belong to the oldest domesticated species and they were also widespread [2]. Einkorn (*Triticum monococcum* L.) is an obsolete cereal species being evidenced by archeologists 10,000 years ago [3]. It spread to Europe in the neolithic period [4]. Nowadays, einkorn is grown on a limited area in Western Turkey, on the Balkan peninsula, in Italy, Spain, Switzerland, Germany [3] and Austria. Emmer wheat [*Triticum dicoccum* (Schrank) Schuebl] belongs to the hulled wheat species. It has been traditionally grown and used as a part of the human diet [5]. It is still grown as a minor crop in Ethiopia, India, Italy [6] or in Turkey [7]. Spelt wheat (*Triticum spelta* L.) is considered to be an obsolete cultural European wheat species. It used to grow widespread in Central Europe in the past as it was (is) resistant to cold and is able to provide a sufficient yield rate even though it grows from weak soil [8]. However, it has extended towards Central and Western Europe, Germany, Switzerland, Austria, the Czech Republic and Hungary in particular [9].

The information on positive as well as negative features technological quality of the hulled wheat landraces is a crucial factor determining their use in the breeding process, growing and processing in the sustainable farming systems (organic farming, low-input farming). Regarding the increasing requirements for diversity and quality of foodstuffs, the hulled wheat species have become more interesting and attractive [10]. Therefore, organic farmers look for the cultivars characterized by a higher nutritive grain value and suitability for the processing and production of a wide range of regional products as well as providing a competitive advantage as unique products for these organic farmers.

This paper aims at providing information on baking quality traits of the hulled wheat genetic resources which can be valuable and important for the sustainable farming systems. Objectives of study are: a) an evaluation of the basic parameters of the technological (baking) quality; b) an analysis of flour improving by mixture of hulled wheat species and high quality bread wheat.

II. Material and Methods

Used varieties: The varieties came from the Gene bank of the Crop Research Institute in Prague-Ruzyně (Czech Republic). Genetic resources of einkorn (*Triticum monococcum* L.), emmer wheat [*Triticum dicoccum* (Schrank) Schuebl], spelt wheat (*Triticum spelta* L.), bread wheat - intermediate form and bread wheat - control varieties (*Triticum aestivum* L.) were chosen (Table I).

Field Trials: Varieties were sown in a randomized, complete block design on the organic certified research area in České Budějovice (48°58'N, 14°27'E) during 2009 and 2012. The seeding rate was adjusted for a density of 350 germinable grains per m^2. The crop stands were treated in compliance with the European legislation (the European Council

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Regulation (EC) No. 834/2007, the European Commission Regulation (EC) No. 889/2008.

Characteristics of the Trial Station: The University of South Bohemia in České Budějovice (USB): Mild warm climate, soil type – pseudogley cambisols, kind of soil – loamy sand soil, altitude of 388m. Agrochemical soil characteristics: pH ($CaCl_2$) – 6,29; N-NH_4 – 8,96mg.kg^{-1}; N-NO_3 – 7.7mg.kg^{-1}; P – 116mg.kg^{-1}; K – 76mg.kg^{-1}; Ca – 1630mg.kg^{-1}; Mg – 122mg.kg^{-1}.

Laboratory analyses - baking quality: The following parameters were tested after the harvest and dehulling of the grains by The International Association for Cereal Chemistry (ICC) methods: crude protein content (ICC 105/2); wet gluten content (ICC 106/2); gluten index (ICC 155); SDS test (ICC 151); Zeleny test (ICC 116/1) and falling number (ICC 107/1).

Statistical Data Processing: Data were processed by the Statistica 9.0 (StatSoft. Inc., Tulsa, USA) program. Regression and correlation analyses provided the evaluation of interdependence. The comparison of varieties and their division into statistically different categories were provided by the Tukey HSD test.

TABLE I
LIST OF USED VARIETIES

Variety/Accession	Origin[1]	Taxon[2]
Einkorn (*T. monococcum* L.)		
T. monococum 38	GEO	*hohensteinii* FLAKSB.
T. monococum 44	ALB	*vulgare* KOERN.
No. 8910	DNK	*macedonicum* PAPAG.
Schwedisches Einkorn	SWE	*vulgare* KOERN.
Emmer wheat [*T. diccocum* (Schrank) Schuebl.]		
Rudico	CZE	*rufum* SCHUEBL.
Weisser Sommer	DEU	*dicoccum*
May-Emmer	CHE	*dicoccum*
T. dicoccon (Brno)	CZE	*rufum* SCHUEBL.
T. dicoccon (Dagestan)	RUS	*serbicum* A. SCHULZ
T. dicoccon (Palestine)	ISR	*serbicum* A. SCHULZ
Tapioszele	-	*semicanum* KOERN.
T. dicoccum (Tabor)	-	*rufum* SCHUEBL.
Spelt (*T. spelta* L.)		
T. spelta (Ruzyne)	CZE	*arduini* (MAZZ.) KOERN.
T. spelta (Tabor 22)	-	*duhamelianum* KOERN.
T. spelta (Tabor 23)	-	*duhamelianum* KOERN.
Spalda bila jarni	CZE	*album* (ALEF.) KOERN.
VIR St. Petersburg	CZE	*album* (ALEF.) KOERN.
T. spelta (Kew)	-	*caeruleum* (ALEF.) KOERN.
T. spelta No. 8930	-	*album* (ALEF.) KOERN.
Intermediate form of bread wheat (*T. aestivum* L.)		
Postoloprtská	CZE	milturum (ALEF.) MANSF.
Kaštická	CZE	milturum (ALEF.) MANSF.
Rosamova	CZE	milturum (ALEF.) MANSF.
Červená perla	CZE	milturum (ALEF.) MANSF.
Bread wheat – control (*T. aestivum* L.)		
SW Kadrilj	SWE	*lutescens* (ALEF.) MANSF.
Jara	CZE	*lutescens* (ALEF.) MANSF.

[1]Abbreviations of countries comply with ISO 3166-1 alpha-3;
[2]Clasification according: V. F. Dorofeev, A. A. Filatenko, E. F. Migušova, "*Opredelitel pšenicy*," Leningrad, 1980.

III. RESULTS AND DISCUSSION

Crude protein content in grain is a significant technological quality indicator [11]. The bread wheat landraces contain much more proteins than the modern bread wheat varieties [12]. Foreign literary sources even mention that the hulled wheat grains consist of a lot of proteins [5]. Considering the group of varieties we studied and evaluated (see Table II), the mean proportion of proteins ranged from 15.30 percent in the einkorn grains, through 16.33 percent in the emmer wheat grains to 16.13 percent in the spelt wheat grains. Whereas the control wheat grains consisted of 13.56 percent of proteins. We also detected higher proportion of wet gluten in all the hulled wheat species (einkorn – 40.26 percent; emmer wheat – 39.28 percent; spelt wheat – 42.63 percent). The control wheat varieties consisted of 33.44 percent of wet gluten. The highest proportion of proteins was detected in grains of *T. dicoccon* (Palestine) (18.41 percent), as well as *T. monococum* 44 (16.62 percent). Reference [13] detected even higher proportion of proteins in the einkorn grains – 22.8 percent, and the winter emmer wheat grains – 24.8 percent. Both the einkorn and the emmer wheat were grown in favorable conditions.

Not only the proportion of proteins, but also the characteristics of gluten are significant technological quality indicators. Viscoelastic character of gluten may be studied and evaluated, and the gluten index values indicate the strong gluten or the weak gluten. The gluten index makes a positive correlation to the gluten quality and the Zeleny test values (see Table III). Very high values of the gluten index indicate the strong gluten; it might be quite difficult to process the strong gluten. On the other hand, low values of the gluten index indicate the weak gluten; such gluten is not suitable for any baking purposes. Minor wheat species consisted of the weak and dispersive gluten. Einkorn varieties can compare to emmer wheat ones in the gluten index values (16, respectively 14). Therefore, the dough is sticky, it is hard to work it and the produced baking products have a small volume [14]–[16]. Spelt wheat is characterized by middle values of the gluten index (36). On the other hand, control wheat varieties consist of hard and solid gluten (66). There are minimum differences between the varieties belonging to particular species.

Zeleny test and SDS test indicate, whether the particular material is suitable or unsuitable for the baking process. Zeleny test resulted in the proportion of sediments of 11ml in the diploid einkorn plants and 14ml in the emmer wheat plants. On the other hand, the hexaploid spelt wheat plants were of better baking quality – the proportion of sediments reached high values in the spelt wheat plants (31ml), as well as the control wheat plants (42ml). The careful selection of varieties may provide some spelt wheat varieties which are suitable for common baking [17]. Most of the hulled wheat genotypes are hardly processed, as they consist of weak gluten elements. However, they may be used in mixtures (where the genotypes are mixed with bread wheat ones) and baked. Table 4 shows several examples of the flour mixtures. Zeleny test provides much better results, if the einkorn or emmer wheat flour mixtures consist of much bread wheat – if 80% of the mixtures consist of bread wheat (see Table IV). Spelt wheat does not require such high percentage of bread wheat in order to achieve good baking quality; it tolerates lower percentage

of bread wheat in the flour mixtures (40 – 60%). If the hulled wheat grains are mixed with the bread wheat ones, such mixture is enriched with proteins (the proportion of proteins is usually lower in the organic bread wheat plants).

Falling number has become the most common criterion and indicator of the wheat grain endosperm reserves which are damaged and hit, before being harvested, by the spike grains entering the germination process [18]. Minor wheat species do not usually face any problems with the falling number – einkorn (335 s.); emmer wheat (308 s.); spelt wheat (332 s.); control varieties (269 s.). There are minimum differences between the varieties, except for *T. dicoccon* (Dagestan), an emmer wheat variety which is characterized by much lower falling number than the other wheat varieties.

TABLE II
YIELD RATE AND QUALITY (MEAN OF THREE LOCATIONS AND TWO YEARS)

Variety/Accession	Crude protein content (%)	Wet gluten content (%)	Gluten Index	SDS (ml)	Zeleny test (ml)	Falling number (s)
Einkorn (*T. monococcum* L.)						
T. monococum 38	15.70^{ab}	39.96^{abcd}	19^{ab}	28^{ab}	13^{a}	318^{a}
T. monococum 44	16.62^{ab}	40.57^{abcd}	11^{a}	28^{ab}	13^{a}	327^{a}
No. 8910	14.67^{ab}	40.26^{abcd}	17^{ab}	20^{a}	7^{a}	346^{a}
Schwedisches	14.20^{ab}	40.26^{abcd}	15^{ab}	25^{a}	9^{a}	349^{a}
Emmer wheat [*T. diccocum* (Schrank) Schuebl.]						
Rudico	16.21^{ab}	39.45^{abcd}	15^{ab}	38^{abc}	18^{ab}	321^{a}
Weisser Sommer	15.95^{ab}	41.34^{abcd}	16^{ab}	39^{bc}	15^{a}	336^{a}
May-Emmer	16.52^{ab}	40.22^{abcd}	17^{ab}	41^{bcd}	18^{ab}	339^{a}
T. dicoccon (Brno)	14.70^{ab}	30.87^{a}	13^{a}	27^{ab}	14^{a}	289^{a}
Dagestan	16.04^{ab}	35.99^{abcd}	12^{a}	21^{a}	10^{a}	235^{a}
Palestine	18.41^{b}	46.56^{d}	17^{ab}	27^{ab}	13^{a}	301^{a}
Tapioszele	16.89^{ab}	39.56^{abcd}	12^{a}	24^{a}	10^{a}	325^{a}
Tabor	15.94^{ab}	40.27^{abcd}	13^{a}	28^{ab}	14^{a}	320^{a}
Spelt (*T. spelta* L.)						
T. spelta (Ruzyne)	15.99^{ab}	42.53^{abcd}	40^{cd}	45^{bcd}	29^{c}	320^{a}
Tabor 22	15.90^{ab}	41.40^{abcd}	41^{cd}	62^{ef}	33^{c}	356^{a}
Tabor 23	16.29^{ab}	41.62^{abcd}	33^{c}	62^{ef}	34^{c}	332^{a}
Spalda bila jarni	16.73^{ab}	45.49^{cd}	34^{c}	60^{ef}	29^{c}	330^{a}
VIR St. Petersburg	15.57^{ab}	40.18^{abcd}	29^{c}	51^{cde}	27^{bc}	341^{a}
T. spelta (Kew)	15.75^{ab}	41.76^{abcd}	42^{cd}	64^{ef}	36^{cd}	307^{a}
T. spelta No. 8930	16.71^{ab}	45.41^{bcd}	32^{c}	54^{cde}	29^{c}	337^{a}
Intermediate form of bread wheat (*T. aestivum* L.)						
Postoloprtská	13.63^{a}	31.95^{ab}	34^{c}	57^{def}	32^{c}	300^{a}
Kaštická	13.29^{a}	32.59^{abc}	39^{cd}	55^{cde}	31^{c}	305^{a}
Rosamova	14.08^{a}	34.95^{abcd}	39^{cd}	58^{def}	36^{cd}	306^{a}
Červená perla	13.33^{a}	33.50^{abcd}	47^{cde}	59^{def}	35^{c}	319^{a}
Bread wheat – control (*T. aestivum* L.)						
SW Kadrilj	12.71^{a}	29.30^{a}	69^{e}	74^{f}	46^{d}	249^{a}
Jara	14.41^{ab}	37.57^{abcd}	63de	63^{ef}	38^{cd}	289^{a}
Year						
2009	17.52^{c}	42.33^{c}	25^{a}	43^{a}	24^{a}	286^{a}
2010	15.57^{b}	40.92^{bc}	36^{a}	48^{a}	24^{a}	298^{ab}
2011	14.38^{ab}	34.95^{a}	29^{a}	46^{a}	25^{a}	337^{bc}
2012	14.32^{a}	37.56^{ab}	26^{a}	40^{a}	22^{a}	343^{c}
Wheat species						
Einkorn	15.30^{ab}	40.26^{a}	16^{a}	25^{a}	11^{a}	335^{a}
Emmer wheat	16.33^{b}	39.28^{a}	14^{a}	31^{a}	14^{a}	308^{a}
Spelt	16.13^{b}	42.63^{a}	36^{b}	57^{b}	31^{b}	332^{a}
Intermediete wheat	13.58^{a}	33.25^{b}	40^{b}	57^{b}	34^{b}	308^{a}
Bread wheat	13.56^{a}	33.44^{bc}	66^{c}	69^{c}	42^{c}	269^{a}

Within column values followed by the same letter are not significantly different at $P < 0.05$ (*Tukey HSD* test); the letters are given in alphabetical order with an increasing level of parameters.

TABLE III
RESULTS OF THE ANALYSIS OF CORRELATION OF TECHNOLOGICAL QUALITY TRAITS

Factor		1	2	3	4	5
Crude protein (%)	1					
Wet gluten (%)	2	0.74***				
Gluten Index	3	-0.32**	-0.16^{ns}			
SDS (ml)	4	-0.21*	-0.09^{ns}	0.79***		
Zeleny test (ml)	5	-0.26*	-0.18^{ns}	0.81***	0.94***	
Falling number (s)		-0.26**	0.03^{ns}	-0.17^{ns}	-0.05^{ns}	-0.10^{ns}

Statistically significant * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$; ^{ns} = statistically not significant

TABLE IV
POSSIBILITIES OF HULLED WHEAT BAKING PARAMETERS IMPROVING BY MIXING WITH HIGH QUALITY BREAD WHEAT (SW KADRILJ)

Wheat species	Share in mixture (%)[1]	Crude protein content (%)	Gluten Index	Zeleny test (ml)	Falling number (s)
Einkorn	100	17,09	20	15	318
	80	16,34	34	22	333
	60	15,29	45	29	317
	40	14,86	46	36	298
	20	13,77	50	43	293
Emmer wheat	100	16,49	15	16	353
	80	16,08	11	23	322
	60	15,33	16	30	320
	40	14,68	30	36	326
	20	14,02	50	44	328
Spelt	100	17,81	36	35	431
	80	17,06	40	38	383
	60	16,25	66	41	410
	40	15,06	92	44	403
	20	14,41	98	47	352
Bread wheat	100	13,30	77	50	381

[1]20-80% = SW Kadrilj

IV. CONCLUSION

Hulled wheat landraces are interesting alternatives to bread wheat, in the organic farming system in particular. Organic bread wheat grains usually consist of less protein, which is provoked by growing unsuitable varieties and lower proportion of nutrients in the soil. On the other hand, most of the einkorn genotypes, emmer wheat genotypes and the spelt wheat ones, grown under the organic farming conditions and not fertilized with any nitrogenous fertilizers, contain a lot of proteins and nitrogenous elements in their grains and dry matter. Particular genotypes contain 16 – 18 percent of nitrogenous elements in their grains. Einkorn and emmer wheat are characterized, nevertheless, by low values of gluten index and Zeleny test of sedimentation. Their grains are hardly processed in the baking industry. They have to be used in a different way. A production of mixtures is one possibility of their application (e.g. high proportion of proteins in emmer wheat varieties together with high sedimentation rate values in bread wheat varieties). Moreover, there are a lot of products made from the hulled wheat species, e.g. pasta, non yeast bread, biscuits, etc. On the other hand, a lot of spelt wheat genotypes are of good baking quality (they are even of better baking quality than the bread wheat genotypes). Grown under favorable land and climatic conditions, they also reach very high values of Zeleny test without any problems (over 30ml). There is a wide range of alternatives, how spelt wheat may be

processed and used – in the baking industry, as an ingredient of bakeries, pasta, etc.

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