Baking quality of genetics resources of hulled wheat species, grown in organic farming

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Abstract: As organic farmers are searching for new market and sale opportunities, the organic farming system may grow and process a wider range of species than the conventional farming system. Concerning wheat, there are so called hulled wheat species (einkorn, emmer wheat, spelt wheat) comprising parts of collections of the world gene banks. Our paper aims at presenting the results of the study and the assessment of spring wheat forms, four einkorn cultivars, eight emmer wheat cultivars, seven spelt wheat cultivars in particular, as compared to modern bread wheat variety. Small-plot trials were established at organic farming research area of University of South Bohemia in Ceske Budejovice in 2009 and 2012. The results of the trials show that the grains are characterised by a high proportion of protein in grain (up to 18.1%). Higher content is in einkorn and emmer – but this species have bad baking quality (low sedimentation and gluten index values). However, they may be difficult to use for common baking. Different situation is in spelt wheat – some varieties had good yield level, lower protein content but suitable sedimentation and gluten index. Moreover, new food products demonstrating a different technological quality of the hulled wheat species have to be launched on the market. The food products will be suitable for regional marketing.

Key words: organic farming, hulled wheat, einkorn, emmer wheat, spelt wheat

Introduction

In 2011, organic cereals were grown on the area of 1,800,000.00 hectares in Europe. Bread wheat (*T. aestivum* L.) is one of the most significant crops, being grown in accordance with the organic farming principles. Spelt wheat (*T. spelta* L.) is the second most significant cereal species [17]. Einkorn (*Triticum monococcum* L.) and emmer wheat (*T. dicoccon* Schrank) are also important. The area of einkorn and emmer wheat is, however, smaller. Hulled wheat species used to be widespread. They used to be elementary and essential parts of everyday human diet. They have become significant again recently, as they have returned back to human diet [14].

Nowadays, einkorn is only grown in montane areas [19]. As Wieser et al.[16] state, it is mostly grown in Western Turkey, on the Balkan Peninsula, in Italy, Spain, Switzerland, Germany and Austria. It is popular among farmers and consumers because its seeds have favourable nutritional values. It can adapt to low-input farming conditions very well. It is highly disease and pest resistant [19]. Emmer wheat is a tetraploid species. It has been grown in Israel, Jordan, Lebanon, Syria, Turkey and Iran. As far as the European countries are concerned, the largest area can be found in Italy. Emmer wheat is a popular wheat species thanks to high protein content in grain and a suitable protein composition [8].

It is not clear how spelt wheat was born [13]. It is a young hexaploid species, younger than bread wheat. Nowadays, it is mostly grown in Central and Western Europe, in Germany, Switzerland, Austria, in the Czech Republic and Hungary in particular [15]. It is partly grown in the USA and Canada as well. Spelt wheat contains more proteins and more soluble fibres than bread wheat. It can be grown in less fertile soil than bread wheat. Spelt wheat contains similar amino acids to bread wheat [1].

It is very important to breed more land races and cultivate their characteristics, as there are a few hulled wheat species. Organic farmers have

been searching for more stable species and varieties, greater genetic diversity and the varieties adaptable to various climatic conditions. Brand new varieties have to be more competitive, disease and pest resistant [4]. Important will be also reduction of negative impact on environment, because of growing more resistant varieties [10,11]. Hulled wheat species are considered valuable resources of genes which can improve and enhance wheat characteristics and features, and nutritional values as well. Low yield rate and fierce competition between spelt wheat and bread wheat are major big disadvantages of spelt wheat varieties [19].

Hulled wheat species have become more attractive to farmers and producers recently. Requirements for diversity and good quality have been increasing [18]. Therefore, organic farmers are seeking after the varieties with high nutritional value and the varieties suitable for product processing. They aim at making the range of regional foodstuff wider [12]. These are unique wheat species which gain and have a competitive advantage on the market [5]. Lachman et al. [7] also agree with the hulled wheat species having a considerable food potential. They have favourable nutritional characteristics. Lachman et al. [7] also state hulled species are a good healthy diet.

This article aims at evaluating particular significant characteristics and quality of hulled wheat species belonging to a genetic resources collection.

Material and methods

Used varieties

The varieties came from the Gene bank of the Crop Research Institute in Prague-Ruzyně. Genetic resources of einkorn (*Triticum monococcum* L.), emmer wheat [*Triticum dicoccum* (Schrank) Schuebl], spelt wheat (*Triticum spelta* L.) and one bread wheat variety (*Triticum aestivum* L.) were chosen (Table 1).

Field Trials

Varieties were sown in a randomized, complete block design on the organic certified research area in České Budějovice 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 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 388 m.

Analyse

A) Before harvest there were taken 30 plants from every repetition. After the harvest we measured grain yield and calculated protein yield per hectar. From the plants were measured harvest index and make spike productivity analysis.

B) 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); index of sedimentation - SDS test (ICC 151); wet gluten content (ICC 106/2) and gluten index (ICC 155).

Statistical Data Processing

Data were processed by the Statistica 9.0 (StatSoft. Inc., 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.

Results and Discussion

The Table No. 2 shows the lowest content of proteins and wet gluten in bread wheat grains, whereas the highest content of proteins in emmer and spelt wheat grains. As stated by Mondini et al. [9], the content of proteins varies from 13.7 to 15.9 percent in spelt wheat grains. The content of proteins exceeds 15.9 percent in grains of four particular varieties (for more details, see the Table No. 3). The content of proteins may rise up to 20 percent in emmer wheat grains. However, it usually gets to 18 percent [9]. We have found a variety containing more than 18 percent of proteins (*Triticum dicoccon* - Palestine). According to Mondini et al. [9], the wet gluten content varies from 37.0 to 56.6 percent. It is much higher in hulled wheat grains than in bread wheat ones. After Zeleny test we have found the lowest wet gluten content in einkorn and emmer wheat grains, whereas the highest wet gluten content in bread wheat ones. The wet gluten content

measurement results have been very similar to the gluten index measurement results. Bread wheat grains have the highest gluten index values and emmer wheat grains have the lowest ones. The lowest einkorn and emmer wheat values originate from their genetic codes. As stated by Corbellini at al. [2], einkorn dough is not ideal for baking, as einkorn gluten is not drawable enough. Einkorn bread does not rise very well. Moreover, consumers do not like how einkorn bread looks like. However, einkorn biscuits are thinner and bigger than bread wheat ones [2]. According to Konvalina et al. [6], emmer wheat grains are valuable materials. A lot of proteins are concentrated in them. Their characteristics are suitable for no-bake products, e.g. pasta, biscuits, muesli, puree, etc. Fares et al. [3] also agree with emmer wheat grains, being suitable for pasta production, as they contain a lot of proteins. Emmer wheat pasta may be consumed by anyone, without any restrictions.

Table 1 List of used varieties

Name of Variety/Accession	Identifier[1]	Origin[2]	Botanical Variety[2]
***Triticum monococcum* L.**			
Triticum monococcum 38	01C0204038	GEO	*hohensteinii* FLAKSB.
Triticum monococcum 44	01C0204044	ALB	*vulgare* KOERN.
No. 8910	01C0204542	DNK	*macedonicum* PAPAG.
Schwedisches Einkorn	01C0204053	SWE	*vulgare* KOERN.
***Triticum diccocum* (SCHRANK) SCHUEBL**			
Rudico	01C0200948	CZE	*rufum* SCHUEBL.
Weisser Sommer	01C0203993	DEU	*Dicoccum*
May-Emmer	01C0203990	CHE	*Dicoccum*
Triticum dicoccon (Brno)	01C0204022	CZE	*rufum* SCHUEBL.
Triticum dicoccon (Dagestan)	01C0204016	RUS	*serbicum* A. SCHULZ
Triticum dicoccon (Palestine)	01C0201261	ISR	*serbicum* A. SCHULZ
Triticum dicoccon (Tapioszele)	01C0201280	-	*semicanum* KOERN.
Triticum dicoccum (Tabor)	01C0204318	-	*rufum* SCHUEBL.
***Triticum spelta* L.**			
Triticum spelta (Ruzyne)	01C0201257	CZE	*arduini* (MAZZ.) KOERN.
Triticum spelta (Tabor 22)	01C0204322	-	*duhamelianum* KOERN.
Triticum spelta (Tabor 23)	01C0204323	-	*duhamelianum* KOERN.
Spalda bila jarni	01C0200982	CZE	*album* (ALEF.) KOERN.
VIR St. Petersburg	01C0204865	CZE	*album* (ALEF.) KOERN.
Triticum spelta (Kew)	01C0200984	-	*caeruleum* (ALEF.) KOERN.
Triticum spelta No. 8930	01C0204506	-	*album* (ALEF.) KOERN.
***Triticum aestivum* L. – control**			
SW Kadrilj	01C0104877	SWE	*lutescens* (ALEF.) MANSF.

[1] EVIGEZ (http://genbank.vurv.cz/genetic/resources/asp2/default_c.h); [2]Abbreviations of countries comply with ISO 3166-1 alpha-3; [2]Clasification according: Dorofeev VF, Filatenko AA, Migušova EF (1980). Opredelitel pšenicy, Leningrad, 105 p.

Table 2 Baking quality of evaluated species (2009-2012) – Means with the same letter are not significantly different at P<0.05 according to the Tukey´s HSD test

Species	Protein content (%)	Wet gluten content (%)	Zeleny test (ml)	Gluten index	Falling number (s)
Einkorn	15.29_{b}	37.03_{b}	12_{a}	19_{a}	333_{b}
Emmer	16.34_{c}	38.39_{b}	15_{a}	19_{a}	308_{b}
Spelt	16.13_{bc}	42.62_{c}	36_{b}	39_{b}	330_{b}
Control variety SW Kadrilj	12.82_{a}	29.02_{a}	50_{c}	74_{c}	245_{a}

Table 3 Baking quality of evaluated varieties (2009-2012) – Means with the same letter are not significantly different at P<0.05 according to the Tukey´s HSD test

Variety	Protein content (%)	Wet gluten content (%)	Zeleny test (ml)	Gluten index	Falling number (s)
Einkorn					
Triticum monococum 38 – J1	15.68_{abc}	37.70_{abcde}	14_{a}	22_{abcd}	314_{abc}
Triticum monococum 44 – J2	16.63_{bc}	35.50_{abc}	13_{a}	18_{a}	329_{abc}
No. 8910 - J4	14.65_{ab}	37.40_{abcde}	10_{a}	18_{ab}	343_{bc}
Schwedisches Einkorn – J6	14.20_{ab}	37.53_{abcde}	11_{a}	20_{abc}	349_{bc}
Emmer					
Rudico	16.22_{bc}	39.72_{cde}	18_{ab}	20_{abc}	321_{abc}
Weisser Sommer – D11	15.97_{bc}	41.34_{cde}	18_{ab}	21_{abc}	338_{abc}
May-Emmer – D12	16.52_{bc}	39.07_{bcde}	18_{ab}	26_{abcd}	337_{abc}
Triticum dicoccon (Brno) – D13	14.70_{ab}	30.39_{ab}	15_{a}	15_{a}	292_{abc}
Triticum dicoccon (Dagestan) – D14	16.05_{bc}	36.25_{abcd}	12_{a}	17_{a}	238_{a}
Triticum dicoccon (Palestine) – D17	18.41_{c}	44.36_{cde}	15_{a}	20_{abc}	301_{abc}
Triticum dicoccon (Tapioszele) – D18	16.89_{bc}	37.78_{abcde}	13_{a}	15_{a}	325_{abc}
Triticum dicoccum (Tabor) – D19	15.96_{bc}	38.18_{bcde}	15_{a}	14_{a}	319_{abc}
Spelt					
Triticum spelta (Ruzyne) – SP1	15.99_{bc}	42.45_{cde}	31_{bc}	42_{bcd}	318_{abc}
Triticum spelta (Tabor 22) – SP2	15.89_{bc}	41.63_{cde}	40_{d}	43_{cd}	356_{c}
Triticum spelta (Tabor 23) – SP3	16.30_{bc}	41.77_{cde}	37_{cd}	36_{abcd}	332_{abc}
Spalda bila jarni - SP7	15.58_{abc}	40.25_{cde}	31_{bc}	32_{abcd}	335_{abc}
VIR St. Petersburg – SP6	16.72_{bc}	45.41_{e}	37_{cd}	37_{abcd}	330_{abc}
Triticum spelta (Kew) – SP8	15.75_{abc}	42.00_{cde}	42_{cd}	45_{d}	304_{abc}
Triticum spelta No. 8930 – SP9	16.70_{bc}	44.80_{de}	33_{c}	36_{abcd}	338_{abc}
***Triticum aestivum* L. – control**					
SW Kadrilj	12.82_{a}	29.02_{a}	50_{d}	74_{e}	245_{ab}

Conclusions

We compared four wheat species experimentally. We have found out there is a considerable difference in the baking quality between bread wheat and hulled wheat varieties. Bread wheat varieties have better baking quality, they are more suitable for bread baking and leavened bakeries production (the gluten characteristics). Hulled wheat species are more suitable for unleavened products (they contain more proteins, wet gluten, they attain lower Zeleny test values and gluten index values as well). Products made of hulled wheat species may be considered interesting alternatives by small and mid-size producers. Thanks to them, they can respond to an increasing demand for nature-friendly regional products.

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References:

[1] Bonafaccia G, Galli V, Francisci R, Mair V, Skrabanja V, Kreft I, Characteristics of spelt wheat products and nutritional value of spelt wheat-based bread. *Food Chemistry* [online]. 2000, vol. 68, issue 4, s. 437-441 [cit. 2014-09-26]. DOI: 10.1016/S0308-8146(99)00215-0. Available from: http://linkinghub.elsevier.com/retrieve/pii/S0308814699002150.

[2] Corbellini M, Empilli S, Vaccino P, Brandolini A, Borghi B, Heun M, Salamini F, Einkorn Characterization for Bread and Cookie Production in Relation to Protein Subunit Composition. *Cereal Chemistry* [online]. 1999, vol. 76, issue 5, s. 727-733 [cit. 2014-10-01]. DOI: 10.1094/CCHEM.1999.76.5.727. Available from: http://cerealchemistry.aaccnet.org/doi/abs/10.1094/CCHEM.1999.76.5.727

[3] Fares C, Codianni P, Nigro F, Platani C, Scazzina F, Pellegrini N, Processing and cooking effects on chemical, nutritional and functional properties of pasta obtained from selected emmer genotypes. *Journal of the Science of Food and Agriculture* [online]. 2008, vol. 88, issue 14, s. 2435-2444 [cit. 2014-10-01]. DOI: 10.1002/jsfa.3350. Available from: http://doi.wiley.com/10.1002/jsfa.3350

[4] Finckh MR, Integration of breeding and technology into diversification strategies for disease control in modern agriculture. *Sustainable disease management in a European context* [online]. Dordrecht: Springer Netherlands, 2008, s. 399 [cit. 2014-09-25]. DOI: 10.1007/978-1-4020-8780-6_19. Available from: http://link.springer.com/10.1007/978-1-4020-8780-6_19

[5] Konvalina P, Capouchová I, Stehno Z, Genetic resources of hulled wheat species in Czech organic farming. *Tagung der Vereinigung der Pflanzenzüchter und Saatgutkaufleute Österreichs 2012*, Lehr- und Forschungszentrum für Landwirtschaft Raumberg-Gumpenstein, Lehr- und Forschungszentrum für Landwirtschaft Raumberg-Gumpenstein, ISBN: 978-3-902559-74-6, pp. 81-86.

[6] Konvalina P, Capouchová I, Stehno Z, Moudrý J sr., Baking Quality and High Molecular Weight Glutenin Subunit Composition of Emmer Wheat, Old and New Varieties of Bread Wheat 2013. *Romanian Agricultural Research*, 30: 83-89, ISSN 1222-4227.

[7] Lachman J, Hejtmánková K, Kotíková Z, Tocols and carotenoids of einkorn, emmer and spring wheat varieties: Selection for breeding and production. *Journal of Cereal Science* [online]. 2013, vol. 57, issue 2, s. 207-214 [cit. 2014-09-26]. DOI: 10.1016/j.jcs.2012.05.011. Available from: http://linkinghub.elsevier.com/retrieve/pii/S0733521012001075

[8] Margiotta, B, Colaprico G, Urbano M, Polymorphism of high M-r glutenin subunits in wild emmer Triticum turgidum subsp. dicoccoides: chromatographic, electrophoretic separations and PCR analysis of their encoding genes. *Genetic Resources and Crop Evolution* [online]. 2014, vol. 61, issue 2, s. 331-343 [cit. 2014-09-26]. DOI: 10.1007/s10722-013-0037-6. Available from: http://link.springer.com/10.1007/s10722-013-0037-6

[9] Mondini L, Grausgruber H, Pagnotta MA, Evaluation of European emmer wheat germplasm for agro-morphological, grain quality traits and molecular traits. *Genetic Resources and Crop Evolution* [online]. 2014, vol. 61, issue 1, s. 69-87 [cit. 2014-10-01]. DOI: 10.1007/s10722-013-0016-y. Available from: http://link.springer.com/10.1007/s10722-013-0016-y

[10] Moudrý J jr., Jelínková Z, Moudrý J, Bernas J, Kopecký M, Konvalina P, Influence of farming systems on production of greenhouse gas emission within cultivation selected crops. 2013, *Journal of food, agriculture & environment* 11 (3-4): 1015-1018

[11] Moudrý J jr., Jelínková Z, Plch R, Moudrý J, Konvalina P, Hypšler R, The emissions of greenhouse gases produced during growing and processing of wheat products in the Czech Republic. 2013, Journal of food, agriculture & environment 11 (1): 1133-1136

[12] Moudrý J jr., Jelínková Z, Jarešová M, Plch R, Moudrý J, Konvalina P, Assessing greenhouse gas emissions from potato production and processing in the Czech Republic. 2013, *Outlook on Agriculture* 42: 179-183

[13] Padulosi S, Hammer K, Heller J, Hulled Wheat. Rome, Italy: *International Plant Genetic Resources Institute*, 1996. ISBN 92-9043-288-8.

[14] Piergiovanni AR, Laghetti G, Perrino P, Characteristics of meal from hulled wheats (Triticum dicoccum Schrank and T. spelta L.): An evaluation of selected accessions. *Cereal Chem*. 1996, vol. 73, issue. 6, s. 732-735.

[15] Troccoli A, Codianni P, Appropriate seeding rate for einkorn, emmer, and spelt grown under rainfed condition in southern Italy. *European Journal of Agronomy* [online]. 2005, vol. 22, issue 3, s. 293-300 [cit. 2014-09-26]. DOI: 10.1016/j.eja.2004.04.003. Available from: http://linkinghub.elsevier.com/retrieve/pii/S1161030104000449

[16] Wieser H, Mueller KJ, Koehler P, Studies on the protein composition and baking quality of einkorn lines. *European Food Research and Technology* [online]. 2009, vol. 229, issue 3, s. 523-532 [cit. 2014-09-26]. DOI: 10.1007/s00217-009-1081-5. Available from: http://link.springer.com/10.1007/s00217-009-1081-5

[17] Willer H, Kilcher L, The world of organic agriculture: statistics and emerging trends *2012*. [12th ed.]. Bonn: IFOAM, 2012. ISBN 978-394-0946-904.

[18] Zaharieva M, Ayana NG, Hakimi AA, Misra SC, Monneveux P, Cultivated emmer wheat (Triticum dicoccon Schrank), an old crop with promising future: a review. *Genetic Resources and Crop Evolution* [online]. Dordrecht: Springer Netherlands, 2010, vol. 57, issue 6, s. 937-962 [cit. 2014-09-25]. DOI: 10.1007/s10722-010-9572-6. Available from: http://link.springer.com/10.1007/s10722-010-9572-6

[19] Zaharieva M, Monneveux P, Cultivated einkorn wheat (Triticum monococcum L. subsp. monococcum): the long life of a founder crop of agriculture. *Genetic Resources and Crop Evolution* [online]. 2014, vol. 61, issue 3, s. 677-706 [cit. 2014-09-25]. DOI: 10.1007/s10722-014-0084-7. Available from: http://link.springer.com/10.1007/s10722-014-0084-7