The effect of organic and conventional growing systems on quality and storage protein composition of winter wheat

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ABSTRACT

Protein composition of the grain storage proteins (evaluation using electrophoresis in polyacrylamide gel – the SDS-PAGE method) and selected parameters of bread-making quality in a set of 6 winter wheat varieties from organic and conventional growing in Central Bohemia (elevation 295 m a.s.l.) were evaluated during a two-year experiment (2004 and 2005). In comparison with the varieties from organic growing, wheat varieties from the conventional growing were characterized by twice the percentage of High Molecular Weight (HMW) glutenins, responsible for dough elasticity (conventional wheat in average 25.22%, organic wheat 12.71%). At the same time, varieties from conventional growing generally reached higher, more positive values of crude protein content and wet gluten content in grain dry matter, sedimentation index by Zeleny and yield of bread. On the other hand, wheat varieties from organic growing were mainly characterized by significantly higher percentage of nutritionally valuable albumins and globulins (organic wheat in average 17.69%, conventional wheat 7.33%). In both systems of growing the highest percentage of HMW glutenins was determined in varieties from the quality group E (elite, the most suitable for bread-making), while the varieties from the quality group C (wheat unsuitable for bread-making) reached the highest percentage of residual albumins and globulins.

Keywords: wheat; organic and conventional farming; storage protein composition; technological quality

The technological quality of wheat from organic farming differs in many aspects from the technological quality of wheat from conventional farming. The most significant differences are in the content of crude protein in the grain dry matter and in the parameters that characterize the wheat protein complex quality. Higher nitrogen levels require a later vegetation phase, when the grain is forming and maturing. In organic farming with absence of fast-effect industrial fertilizers, a nitrogen deficit and a lower accumulation of wheat storage proteins are frequently experienced (Prugar 1999).

Wheat storage (gluten) proteins create up to 80% from a total amount of wheat grain (Shewry et al. 2000). Technologically, glutenins and gliadins are the most important wheat storage proteins. Their proportion and amount in wheat grain is variable and changes with the total protein content, growing conditions, genetic disposition of variety and process of grain maturing (Branlard et al. 2000, Shewry et al. 2000). The gluten quality for the specific final utilization is determined especially by the optimal storage proteins combination. Each of them affects rheology in a unique way – dough viscosity and tensibility are affected by gliadins, elasticity by glutenins (Bushuk and Bekes 2002).

Gliadins create heterogeneous mixture of one-chain polypeptides; they are proteins with the lowest nutritional value in the way of amino-acid composition. Glutenins are not as heterogeneous as gliadins; depending on their electrophoretic mobility to the HMW and LMW (Low Molecular Weight) glutenins subunits could be distinguished. HMW glutenins subunits with the molecular weight of about 80 000–120 000 Da create circa 25–35% of

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the total glutenins, the rest is created with LMW glutenins subunits (Thompson et al. 1994, Shewry et al. 2000). Most studies in bread-making wheat focus on HMW glutenins, as they are the key factors in the bread-making process and they are easily identifiable by the electrophoresis.

LMW glutenins subunits with the molecular weight about 30 000–40 000 Da have been far less explored than the HMW glutenins. This is due to their difficult identification in one-dimension SDS-PAGE (overlaying gliadins and LMW glutenins).

Albumins and globulins are usually ranged to the so-called protoplasmatic proteins. As to the amino-acids composition, these proteins have the highest nutritional quality. Albumins are important for their enzymatic activity, globulins especially for their catalytic effect. However, it was determined, that they are functional also as storage proteins and they serve as a nutrient store for the embryo germination. Generally, albumins and globulins are not considered as proteins critical for the flour quality, even though a small significance was noticed (Schofield and Booth 1983). According to some authors they decrease the quality of gluten (Payne et al. 1987, Bushuk 1989).

As noted previously, protein composition of the wheat grain is influenced by genotype, as well as by cultivation system and environmental conditions. There is not much information available about protein composition of wheat from organic farming. Hence, the aim of our work was to evaluate protein composition and selected parameters of technological quality of winter wheat from organic and conventional growing, and to determine the effect of variety, experimental year and way of farming on the evaluated characteristics.

MATERIAL AND METHODS

During the experimental years of 2004 and 2005 the grain protein composition was evaluated in a set of six winter wheat varieties Sulamit (E), Samanta (A), Apache (B), Meritto (B), Mladka (C), Rapsodia (C) from different quality groups based on their bread-making quality (E – elite, the most suitable for bread-making; A – high-quality; B – additional, suitable for use in a mixture; C – others, unsuitable for bread-making); wheat from conventional farming was grown at the Stupice Breeding Station, organic farming was used at the Experimental Station of Department of Plant Production, Faculty of Agrobiology, Food and Natural Resources, Czech University of Life Sciences in Prague-Uhříněves.

Both experimental sites lie in nearly the same soil-climatic conditions (approx. 2 km apart) in Central Bohemia, with the elevation of 295 m a.s.l., average annual temperature of 8.4°C and average annual precipitation of 575 mm. The soil is a clay-loam brown soil with good reserve of all essential nutrients and with the depth of arable land of 25–30 cm. The experiments were established according to the methods valid for performing the State Varietal Trials in the Czech Republic – using random blocks, in 4 replicates, and with the size of experimental plots of 10 m^2. The experiments at the Stupice Breeding Station were established with the use of the total N fertilizer rate of 75 kg N/ha, with herbicide, fungicide, insecticide, and growth regulator; pea was used as forecrop in both years.

At the Experimental Station in Prague-Uhříněves the experiments were carried out in an organic growing system according to the principles of the International Federation of Organic Agriculture Movements and the Methodical Instruction for organic farming of the Ministry of Agriculture of the Czech Republic, without mineral fertilizers and pesticides. The forecrop was trifolium in both years.

As for the weather conditions, the period of grain formation and maturing in 2004 was dry with average temperatures; experimental year 2005 was warm and very wet (according to the classification of World Meteorological Organization).

After the harvest, approximately 3 kg of grain samples were collected for the laboratory quality analysis. The grain samples were analyzed for the total content of crude protein in dry matter of grain according to the ISO 1871 standard, content of wet gluten in dry matter of grain (ISO 5531 standard) and the sedimentation index by Zeleny (ISO 5529 standard). Remaining grains were milled on the Bühler laboratory mill (MLU-202 type). After this procedure the individual components of the mixture corresponded to the T 550 common baker flour. It was used for the baker test (methodology by the Mill and Baking Prague Research Institute: 300 g flour, 12 g leaven, 3 g fat, 5.1 g salt, 4.5 g sugar, proofing 45 min in 30°C, next proofing 50 min in 30°C, baking 14 min in 240°C).

For the classification of wheat grain storage protein composition the polyacrylamide gel electrophoresis in dodecyl sulphate sodium (SDS-PAGE) was used, according to the method of Wrigley (1992). Percentage of individual protein subunits

[High Molecular Weight (HMW) glutenins, Low Molecular Weight (LMW) glutenins and gliadins, residual albumins and globulins] was calculated on the basis of denzitometric evaluation of electrophoreograms using the Bio 1D software from the Vilber-Lourmat firm (France).

Qualitative parameters of the wheat technological quality and results of the protein composition were statistically evaluated by the analysis of variance (ANOVA) in the programme Statgraphics Plus, Version 5.1, with determination of the test criterion *F* values. Significance of differences among the evaluated varieties, experimental years and cultivation systems were demonstrated using the LSD test at the 0.05 significance level.

RESULTS AND DISCUSSION

The obtained results document the influence of organic and conventional growing on the wheat grain storage proteins composition and other evaluated technological quality parameters, characterized amount, quality and properties of the protein complex.

A significant effect of the cultivation system (organic × conventional) on the percentage of HMW glutenins is evident from the values of the test criterion *F* (Table 1). The effect of variety on the percentage of HMW glutenins was substantially lower; the effect of the experimental year was insignificant.

The evaluation of statistical significance of differences among individual varieties, experimental years and organic and conventional growing by the LSD test (Table 2) shows significant differences in percentage of HMW glutenins between organic and conventional growing – varieties from conventional growing were characterized by twice the percentage of HMW glutenins in comparison with varieties from organic growing. Statistically significant differences in percentage of HMW glutenins were documented also among the individual varieties, while the difference between the experimental years was insignificant.

It is evident from the results in the Table 2 that differences in the percentage of LMW glutenins and gliadins among experimental years, varieties, and ways of growing were statistically insignificant.

The percentage of residual albumins and globulins was influenced, as well as the percentage of HMW glutenins, especially by the system of growing; the effects of variety and experimental year were important, though not so significantly (Table 1). A highly significant effect of organic and conventional growing is evident from the evaluation of differences by the LSD test – varieties from the organic growing were characterized by twice the percentage of albumins and globulins in comparison with conventionally grown varieties (Table 2).

Obtained results are in accordance with the conclusions of Prugar (1999) and Graveland et al. (1996), who found that the application of nitrogen fertilizers, usually used in the conventional farming, generally increases the part of protein fractions typical for gluten, i.e. glutenins and gliadins. An increase of the percentage of these fractions in the total protein leads to an improvement in the technological, especially bread-making, wheat

Table 1. ANOVA, values of the test criterion *F* for two-year results of selected quality parameters of winter wheat

	Quality parameter		
Factor	HMW glutenins	LMW glutenins + gliadins	albumins + globulins
Variety	4.75**	0.28 n	5.00**
Growing system	77.67**	1.28 n	61.64**
Year	0.98 n	2.18 n	13.14**

	crude protein content in grain dm	wet gluten content in grain dm	sedimentation index by Zeleny	yield of bread
Variety	2.67 n	3.42*	5.20**	2.40 n
Growing system	21.87**	17.44**	8.88**	13.26**
Year	31.04**	5.97*	10.57**	1.98 n

**statistically significant α = 0.01; *statistically significant α = 0.05; n – statistically insignificant

Table 2. Quantitative evaluation of SDS-PAGE electrophoretic analysis of the winter wheat storage proteins (LSD, α = 0.05)

Parameter		HMW glutenins (%)			LMW glutenins + gliadins (%)			Residual albumins + globulins (%)		
		$\bar{x}$	d_{min}	significance	$\bar{x}$	d_{min}	significance	$\bar{x}$	d_{min}	significance
Growing system	conventional	25.22	3.01	b	67.18	4.62	a	7.33	2.80	a
	organic	12.71		a	69.65		a	17.69		b
Variety	Apache	19.82	5.21	bc	70.15	8.01	a	10.05	4.84	a
	Meritto	17.47		ab	70.11		a	12.23		ab
	Mladka	13.58		a	68.39		a	17.44		c
	Rapsodia	16.98		ab	67.13		a	15.99		bc
	Samanta	21.57		bc	66.95		a	11.50		ab
	Sulamit	24.36		c	67.78		a	7.86		a
Year	2004	18.26	3.01	a	66.80	4.62	a	14.92	2.80	b
	2005	19.67		a	70.03		a	10.10		a

$\bar{x}$ = average values of the percentage of individual protein subunits (%) in evaluated varieties, experimental years and growing systems; d_{min} = least significant difference

quality, but also to a decrease in the biological and nutritional value of proteins, due to a reduction in the content of essential amino-acids, occurring mainly in the albumins and globulins (Bushuk 1989).

Except for the differences in the grain storage proteins composition from organically and conventionally grown wheat, we have recorded certain differences in the storage protein composition among the individual varieties from the different quality groups. In both the conventional and organic system of growing the highest percentage of HMW glutenins and at the same time the lowest percentage of residual albumins and globulins were found in Sulamit variety (quality group E – elite) and the lowest percentage of HMW glutenins and the highest percentage of residual albumins and globulins in Mladka and Rapsodia varieties (quality group C – others), unsuitable for bread-making (Figures 1–3). These results were recorded in both systems of growing.

This supports the results of Michalík (1992), according to which the changes in the ratio of individual protein fractions are affected not only

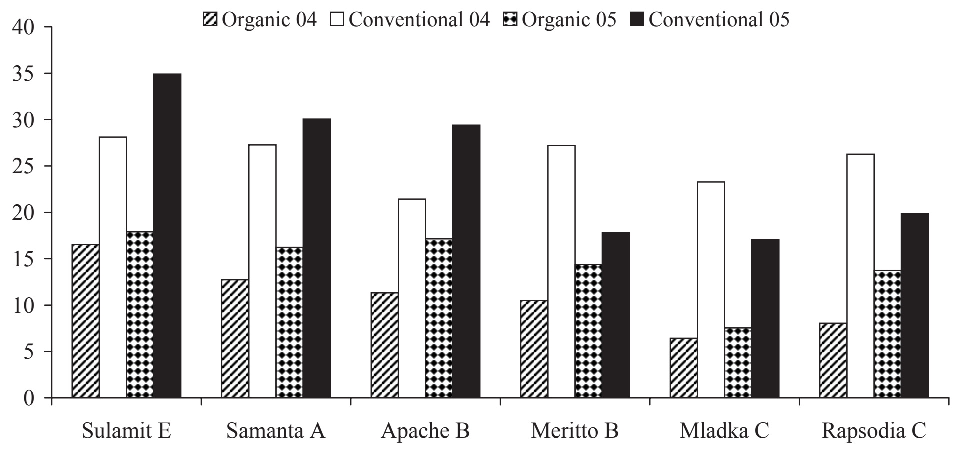

Figure 1. Quantitative evaluation of SDS-PAGE electrophoretic analysis of the winter wheat storage proteins, percentage of HMW glutenins

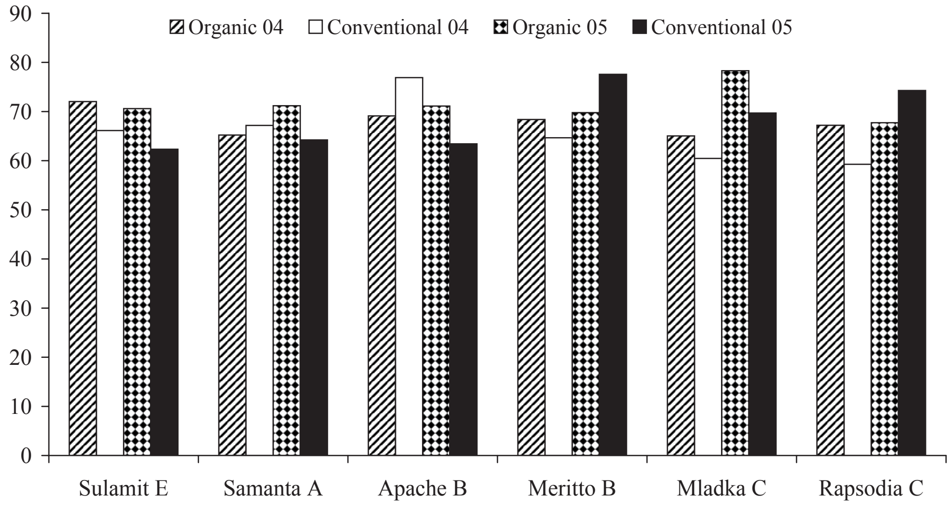

Figure 2. Quantitative evaluation of SDS-PAGE electrophoretic analysis of the winter wheat storage proteins, percentage of LMW glutenins + gliadins

by the total protein content in the wheat grain, but also by the genotype. Similarly, Prugar (1999) shows that the varieties from the quality groups E and A observe their genetically dependent differences in the characters of the bread-making quality and act as technologically better and superior, also while using an organic system of growing.

If we compare the results of evaluation of the grain storage protein composition with the results of evaluated selected quality characters of winter wheat, it is possible to observe (Table 3) that the values of the yield of bread as a direct parameter of the wheat bread-making quality best corresponded with the percentage of HMW glutenins. These results are in accordance with the conclusions of Branlard et al. (2000) and Shewry et al. (2000), who found that HMW glutenins and their relative percentage in the total wheat grain protein affect bread-making quality of wheat in a decisive way. However, in varieties with higher percentage of HMW glutenins generally more favourable values were determined also in the indirect parameters, characterizing good bread-making quality – higher values of the crude protein content and wet gluten content in the grain dry matter and higher values of the sedimentation index by Zeleny.

Evaluation of the storage protein composition may be taken as an important completion of the general view on the quality of wheat for different ways of utilization – not only for food, bread-mak-

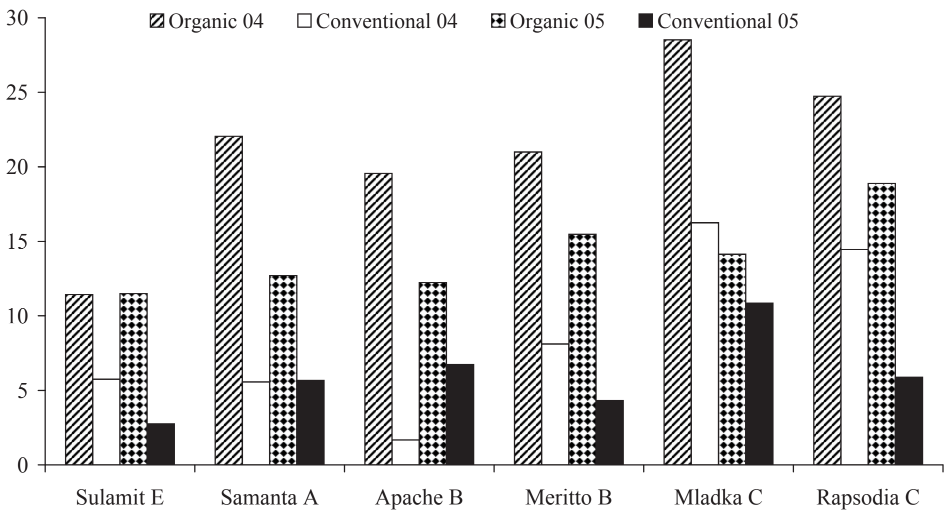

Figure 3. Quantitative evaluation of SDS-PAGE electrophoretic analysis of the winter wheat storage proteins, percentage of residual albumins + globulins

Table 3. Selected quality parameters of winter wheat (LSD, α = 0.05)

Parameter		Total crude protein content in grain dm (%)			Wet gluten content in grain dm (%)			Sedimentation index by Zeleny (ml)			Yield of bread (ml/100 g of dough)		
		$\bar{x}$	d_{min}	significance	$\bar{x}$	d_{min}	significance	$\bar{x}$	d_{min}	significance	$\bar{x}$	d_{min}	significance
Growing system	conventional	11.04	0.71	b	24.03	2.76	b	27.67	3.91	b	311.42	31.15	b
	organic	9.48		a	18.59		a	22.17		a	257.92		a
Variety	Apache	10.59	1.22	ab	21.82	4.78	ab	26.25	6.78	bcd	287.50	53.96	abc
	Meritto	9.65		a	21.67		ab	23.00		abc	263.50		ab
	Mladka	9.51		a	19.82		a	20.50		ab	252.00		a
	Rapsodia	10.04		a	17.14		a	18.50		a	272.00		ab
	Samanta	11.30		b	26.15		b	31.50		d	326.00		c
	Sulamit	10.47		ab	21.27		a	29.75		cd	307.00		bc
Year	2004	9.33	0.71	a	19.72	2.76	a	21.92	3.91	a	295.00	31.15	a
	2005	11.19		b	22.90		b	27.92		b	274.33		a

$\bar{x}$ = average values of the crude protein content in dm (%), wet gluten content in dm (%), sedimentation index by Zeleny (ml), yield of bread (ml/100 g of dough); d_{min} – least significant difference

ing, but also for feeding. Our results confirm that as for the storage protein composition, the wheat from organic growing was generally characterized by worse technological, bread-making quality, but better feeding quality than wheat from conventional growing. These results are in accordance with Petr et al. (2004), who found that the wheat from organic growing showed better results in biological tests and the diets based on the organic wheat were preferred by the model animals (laboratory rats) compared to the diets based on the conventionally grown wheat.

However, despite the worse bread-making quality of wheat from the organic growing, it is not possible to say that it is unsuitable for bread-making. Favourable bread-making quality can be ensured in the organic production as well, partly by the modification of bread-making technologies, partly by the choice of suitable varieties with genetically defined excellent bread-making quality.

REFERENCES

Branlard G., Dardevet M., Saccomano R., Lagoutte F., Gourdon J. (2000): Genetic diversity of wheat storage proteins and bread wheat quality. Wheat in Global Environment. In: Proc. 6th Int. Wheat Conf., Budapest, Hungary.

Bushuk W. (1989): Wheat Proteins: Aspects Structure that Determine Breadmaking Quality. Protein Quality and the Effects of Processing. Marcel Dekker, Inc., New York, Basel.

Bushuk W., Bekes F. (2002): Contribution of protein to flour quality. In: Proc. ICC Conf. Novel Row Materials, Technologies and Products – New Challenge for the Quality Control, Budapest, Hungary.

Graveland A., Henderson M.H., Paques M., Zandbelt P.A. (1996): Composition and functional properties of gluten proteins. In: Proc. 6th Int. Gluten Workshop, in association with 46th Australian Cereal Chemistry Conf., Sydney, Australia.

Michalík I. (1992): Influence of agroecological conditions on formation of wheat grain protein complex. Rostl. Výr., *38*: 643–649. (In Slovak)

Payne P.I., Nightingale M.A., Krattiger A.F., Holt L.M. (1987): The relationship between HMW glutenin subunit composition and the bread-making quality in British-grown wheat varieties. J. Sci. Food Agric., *40*: 51–65.

Petr J., Kodeš A., Stehlíková K., Hubert D., Svobodová P. (2004): Feeding quality of wheat from conventional and ecological farming. Sci. Agric. Bohemica, *35*: 74–78.

Prugar J. (1999): The Quality of Plant Production from Organic Farming. Study Information – Plant Production. ÚZPI, Praha. (In Czech)

Schofield J.D., Booth M.R. (1983): Wheat proteins and their technological significance. Dev. Food Proteins, *2*: 1–65.

Shewry P.R., Tatham A.S., Fido R., Jones H., Bercelo P., Lazzeri P.A. (2000): Improving the end use properties of wheat by manipulating the grain protein composition. Wheat in Global Environment. In: Proc. 6th Int. Wheat Conf., Budapest, Hungary.

Thompson S., Bishop D.H.L., Tatham A.S., Shewry P.R. (1994): Exploring disulphide bond formation in a low molecular weight subunit of glutenin using a baculovius expression system. In: Gluten Proteins. Assoc. Cereal Res., Detmold: 345–355.

Wrigley C.W. (1992): Identification of cereal varieties by gel electrophoresis of grain proteins. In: Linskens H.F., Jackson J.F. (eds.): Seed Analysis. Springer-Verlag, Berlin, New York: 17–41.

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