STORAGE PROTEIN COMPOSITION OF WINTER WHEAT FROM ORGANIC FARMING*

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We tested the grain storage protein composition and wheat quality parameters in a set of varieties from different quality groups from organic farming during a two-year experiment. We also tested a set of varieties from conventional farming for orientation comparison of results. Our results show a noticeable influence of organic and conventional ways of growing on the wheat grain storage proteins composition and the technological quality characteristics, predicative partly of the storage protein quantity, partly of the protein complex quality (sedimentation index by Zeleny, rheology characteristics determination on pharinograph and the yield of bread). Varieties with higher content of HMW glutenins (varieties from conventinal growing systems and varieties from the elite (E) and high-quality (A) quality groups), which are the most suitable for baking utilization, reached higher values of sedimentation index, pharinographic characteristics predeterminig good baking quality and higher values of yield of the bread.Varieties from organic farming and from the C quality group (wheat unsuitable for baking utilization) were mainly characterized by the higher content of residual albumins and globulins, due to higher content of amino essential acids and higher nutritional quality of albumins and globulins we suppose, that this wheat is more suitable for feeding and also for human nutrition.

wheat storage protein composition; wheat quality; organic farming

INTRODUCTION

The wheat from organic farming has a number of differences in technological quality compared with the technological quality of wheat from conventional growing. The most significant differences between qualitative wheat parameters from organic and conventional growing are in the crude protein content in dry matter of grain 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. It is in organic farming with the absence of fast effect industrial fertilizers, that a nitrogen deficit and a lower accumulation of wheat storage proteins – gliadins and glutenins, are frequently experienced (Prugar, 1999). This adversely affects the wheat's food potential, mainly the baking utilization (Branlard et al., 1991).

However, the present studies indicate that the genetically determined differences, e.g. in the baking quality of wheat from conventional farming can also be observed in wheat from organic farming. Some high-quality varieties may give good baking utilization possibilities. Organic farming, due to the favourable quality of gluten therefore offers a satisfactory quality of dough rheology (Prugar, 1999; Capouchová, 2003).

Wheat flour ability to create viscoelastic properties of dough depends on the wheat protein character. The gluten quality for the specific final utilization depends on the combination of many physical and chemical properties of the protein complex and it is determined especially by the optimal storage protein combination – gliadins and glutenins. Each of them affects rheology in a unique way – viscosity is affected by gliadins and elasticity by glutenins (Bushuk, Bekes, 2002). Albumins and globulins have the highest nutritional quality in the way of amino acids composition. According to some authors they decrease the quality of gluten (Payne et al., 1987; Bushuk, 1989). Evaluation results of the wheat varieties complex protein provide important information for assessment of the technological wheat quality.

MATERIAL AND METHODS

During the harvest years of 2004 and 2005 the grain storage protein composition and baker quality were evaluated in a set of winter wheat varieties from different quality groups based on their baking quality (E – elite, the most suitable for baking utilization, A – high-quality, B – additional, suitable for use in a mixture, C – others, unsuitable for baking utilization) from organic farming at the Experimental Station of Plant production Department, Faculty of Agrobiology, Food and Natural Resources, Czech University of Agriculture in Prague-Uhříněves. For orientation comparison of results were used same varieties from conventional farming at the Stupice Breeding Station.

The experimental sites of the Stupice Breeding Station and the Uhříněves Experimental Station lie in nearly the same soil-climatic conditions (approx. 2 km apart) in the sugar-beet growing region of the central Bohemian area, with the elevation above sea-level 295 m, average annual

* Financial support by the Research Project of Czech University of Life Sciences in Prague No. 6046070901, grant MŽP NaV 1C/4/8/04 and grant MZe QG 50034.

temperature 8.4 °C and average annual precipitation total of 575 mm. There is a clay-loam brown soil with good reserves of all essential nutrients and with the arable land depths of 25–30 cm. The experiments were established according to the methods valid for performing the State Varietal Trials in the Czech Republic – using the method 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 fertiliser rate of 130 kg $N.ha^{-1}$, plus a herbicide, fungicide, insecticide, and a morphoregulator, the preceding crop was *Pisum sativum speciosum* L. 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 IFOAM (International Federation of Organic Agriculture Movements) and Methodical instruction for organic farming of the Ministry of Agriculture of the Czech Republic. The preceding crop was *Trifolium pratense* L. in both years and the N-total content in the soil was 21,7 $mg.kg^{-1}$ (medium reserve) in the year 2004 and 49,0 $mg.kg^{-1}$ (high reserve) in the year 2005. The harvest was on 10. 8. 2004 and 2. 8. 2005.

Weather pattern at the Prague-Uhříněves Experimental Station and at the Stupice Breeding Station in the years 2003–2005 and the long-time average are in Table 1.

After the harvest approx. 3 kg of grain samples were collected for the laboratory quality analysis. The grain samples were analyzed for the total crude protein content in dry matter of grain according to the ČSN ISO 1871 standard, wet gluten content in dry matter of grain (the ČSN ISO 5531 standard), the sedimentation index by Zeleny (the ČSN ISO 5529 standard), grain hardness (method PSI) AACC method 5530 and starch content in dry matter of grain (the ČSN ISO 56 0512-16 standard). The remaining part of the grain was milled on the Bühler laboratory mill (MLU-202 type). Following this procedure the individual components of the mixture corresponded to the T 550 common baker smooth flour. This was used for the analysis of the rheology quality on the pharinograph (ČSN ISO 5530-1 standard) and for baker test (methodology by the Mill and Baking Prague Research Institute: 300 flour, 12 g leaven, 3 g fat, 5,1 g salt, 4,5 g sugar, the dough consistence 550–650 B.j., 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 polyacrylamid gel electrophoresis analysis in dodecyl sulphate sodium (SDS-PAGE) of the storage proteins was used, the method according to Wrigley (1992). Quantitative evaluation of electrophoreograms was made using the Bio 1D software from the Vilber-Lourmat firm (France). Qualitative parameters of the wheat's technological quality were statistically evaluated by the analysis of variance in the Statgraphics Plus, Version 5.1 programme, with the references of the statistical coefficients demonstrated at the 0.05 significance level.

RESULTS AND DISCUSSION

From results of analysis of variance (Table 2) and following influence evaluation of selected factors on selected quality parameters it is noticeable the main influence of growing system (organic x conventional) on quality parameters of wheat grain and flour. The growing system influenced mainly amount of HMW (high molecular weight) glutenins and albumins and globulins, wet gluten content in grain and flour dray matter, starch content in grain and flour dry matter, ash content in grain dry matter, pharinographic water absorption, degree of dough softening and yield of bread. As well Capouchová (2003) on the basis of their results of evaluation selected set of winter wheat varieties from organic and conventional growing confirmed strong influence of growing system on wheat quality parameters.

Second important was the influence of the year – it mens the cours of the weather and others agroecological

Table 1. Weather pattern at the Prague-Uhříněves Experimental Station and at the Stupice Breeding Station in the years 2003–2005, and the long-time average

Month	Month average temperature (°C)			Sum of precipitation (mm)			Long-time average of temperature (°C)	Long-time average of precipitation (mm)
	2003	2004	2005	2003	2004	2005	1950–2000	1950–2000
January	–0.66	–2.93	1.77	29.4	54.8	30.9	–2.1	28
February	–2.70	2.70	–1.94	5.3	25.1	47.3	–0.8	27
March	5.40	4.25	3.17	7.9	42.4	14.2	3.4	31
April	9.05	10.27	10.71	22.2	15.9	19.5	8.2	46
May	16.55	12.73	14.78	72.8	54.8	52.5	13.4	65
June	20.97	17.04	17.86	30.9	90.2	62.4	16.3	74
July	21.00	18.91	19.32	76.0	35.4	137.8	18.2	74
August	21.82	19.82	17.20	26.5	56.6	68.5	17.5	72
September	14.48	14.39	15.64	37.3	43.2	50.0	14.0	49
October	6.46	10.01	10.22	30.1	20.5	11.0	8.6	41
November	5.18	4.68	3.16	7.2	68.7	15.7	3.2	34
December	0.91	0.78	0.35	33.2	12.6	38.2	–0.5	34

Table 2. Values of test criterion F for two-year results of selected quality parameters

Quality parameter / Factor	HMW glutenins		LMW glutenins + gliadins		Albumins + globulins	
Variety	4.75**	6%	0.28 n	7%	5.00**	6%
Growing system	77.67**	93%	1.28 n	34%	61.64**	77%
Year	0.98 n	1%	2.18 n	58%	13.14**	17%

Quality parameter / Factor	Crude protein content in grain DM		Wet gluten content in grain DM		Sedimentation index by Zeleny		Grain hardness		Starch content in grain DM		Falling number	
Variety	2.67 n	5%	3.42*	13%	5.20**	21%	40.47**	52%	1.23 n	10%	3.92*	58%
Growing system	21.87**	39%	17.44**	65%	8.88**	36%	33.39**	43%	8.61**	70%	2.20 n	33%
Year	31.04**	56%	5.97*	22%	10.57**	43%	4.06 n	5%	2.54 n	21%	0.61 n	9%

Quality parameter / Factor	Pharinographic water absorption		Dough development time		Dough stability time		Degree of dough softening		Yield of bread	
Variety	5.76**	31%	1.70 n	46%	2.93*	62%	0.90 n	33%	2.40 n	14%
Growing system	8.23*	44%	2.00 n	54%	1.71 n	36%	1.54 n	57%	13.26**	75%
Year	4.87*	26%	0.00 n	0%	0.07 n	1%	0.27 n	10%	1.98 n	11%

** statistically significant $\alpha = 0.01$, * statistically significant $\alpha = 0.05$, n – statistically nonsignificant

conditions during experiments. The influence of the year was the most important in crude protein content in grain dry matter, amount of LMW (low molecular weight) glutenins and gliadins, volume weight and falling number. The varienty influenced mainly grain hardness, falling number of grain and dough stability time.

The obtained results (Tables 3, 4 and 5) document the influence of organic and conventional ways of growing on the wheat grain storage proteins composition and technological quality characteristics, predicative partly of the protein quantity (total crude protein content and wet gluten content in the dry matter of grain), partly of the protein complex quality (sedimentation index by Zeleny, rheology characteristics determination on pharinograph and the yield of bread).

Regarding the contents of the LMW glutenins and gliadins we have uncovered considerable differences between those from organic and from conventional growing. Under the conditions of organic growing wheat was in its content a little bit higher compared with conventional wheat. In case of HMW glutenins, a considerably higher content was found in the conventionally growed wheat; while in case of organic wheat we recorded a considerably higher content of the most high-quality nutritional albumins and globulins. Our results of quantitative evaluation of storage protein electrophoretic analysis are in accordance with Petr et al. (2003). Authors analysed samples of *Triticum aestivum* L., Chinese Spring and *Triticum aestivum* L., Marquis. According to their resutls the percentage of HMW glutenins is c. 29%, percentage of LMW glutenins and gliadins is 48% and percentage of residual albumins and globulins is 22%.

These results are also in accordance with the conclusions of Prugar (1980) and Graveland (1996), who found that nitrogen application generally increases the part of the protein fractions typical for gluten – glutenins and gliadins. Increasing the amount of these fractions in the total protein content leads to an improvement in the technological, especially baking, wheat quality, but also to a decrease in the biological and nutritional value of proteins, due to the reduction in the amino-acids content.

Except for the differences in the wheat grain storage proteins composition from organic and conventional growing we have recorded certain differences in the protein composition among the single varieties groups of quality. In both the conventional and organic way of growing the highest contents of HMW glutenins and at the same time the lowest contents of albumins and globulins were found in the varieties from the quality group E – elite, and the A – high-quality, and the lowest in the varieties from the quality group C – other, which is unsuitable for baking utilization. This supports the results of some authors, according to which the changes in the ratio of single protein fractions are affected. Not only by the total proteins content in wheat grain, but also by the genotype and results of Prugar (1999) and Capouchová (2003), who show that the varieties from the quality groups E and A being observed, have genetically dependent differences in the characters of the baking quality and act as technologically better, superior, while also using an ecological way of growing. The differences in the wheat grain storage proteins composition reflect also at the level of the technological quality parameters.

We noticed, especially in the harvest year 2004, a relatively marked influence of the growing intensity (when comparing the organic and conventional ways). Overall, the lower levels of sedimentation index in the organically grown wheat are also mentioned by Petr et al. (1998) and Capouchová (2003) on the basis of their results.

The pharinographic data characterize the flour quality, for example the dough and dough tolerance on mechanical

Table 3. Electrophoretic analysis of storage proteins of wheat from the organic and conventional farming – harvests in 2004 and 2005

Year	Growing system	Quality groups	HMW glutenins (%)	LMW glutenins + gliadins (%)	Residual albumins and globulins (%)
2004	Organic	E	15.40	71.16	13.44
		A	10.66	69.86	18.81
		B	10.92	68.76	20.28
		C	7.73	67.71	24.50
	Conventional	E	28.74	67.19	4.06
		A	25.85	66.59	8.10
		B	25.82	69.07	5.11
		C	24.77	59.88	15.35
2005	Organic	E	17.52	70.56	11.92
		A	14.78	69.90	14.02
		B	14.20	70.98	14.87
		C	10.88	70.78	18.40
	Conventional	E	34.90	62.34	2.75
		A	30.05	64.22	5.67
		B	23.60	70.51	5.53
		C	20.13	70.65	8.43

Values in the Table are statistical means

Table 4. Selected qualitative parameters of wheat from the conventional and organic farming – harvests in 2004 and 2005

Growing system	Quality groups	Crude protein content in grain DM (%)	Wet gluten content in grain DM (%)	Sedimentation index by Zeleny (ml)	Grain hardness (% PSI)	Starch content in grain DM (%)	Falling number of grain (s)
Organic	E	10.09	19.74	26	11.15	70.32	278
	A	9.61	19.86	28	27.35	71.42	324
	B	9.45	16.92	24	17.08	72.54	275
	C	8.86	15.06	15	27.23	73.53	262
Conventional	E	10.74	22.98	32	8.90	69.91	317
	A	11.63	27.05	34	21.70	69.23	344
	B	11.54	26.07	27	13.45	71.69	301
	C	10.86	20.77	23	21.13	69.81	287

Values in the Table are statistical means

Table 5. Pharinographic parameters and yield of bread of wheat varieties from the conventional and organic farming – harvests in 2004 and 2005

Growing system	Quality groups	Pharinographic water absorption (%)	Dough development time (min)	Dough stability time (min)	Degree of dough softening (FU)	Yield of bread (ml/100g of dough)
Organic	E	53.50	1.25	2.54	140	293
	A	43.88	1.09	2.96	134	291
	B	52.13	1.03	2.29	153	247
	C	50.87	0.99	1.99	161	245
Conventional	E	59.38	1.38	3.75	98	350
	A	53.87	1.25	3.34	114	331
	B	42.80	1.38	3.79	119	298
	C	50.23	1.19	1.94	132	271

Values in the Table are statistical means straining on the basis of the consistence change monitoring at plasticization under standard conditions. In pharinographic classification the conventionally grown wheat was better, and compared with organic wheat it reached a higher water absorption, longer time of dough stability and a lower degree of dough softening. Better rheology characteristics of the conventionally grown wheat features are also mentioned by Capouchová (2003).

The baking test is the final direct indicator of the wheat baking quality. The higher yield of bread in both harvests years reached varieties from conventional growing system.

In organic and also in conventional growing system reached higher yield of bread varieties from the E and A quality groups. Lower and slower nitrogen input to plant in organic growing system bounds often possibility of protein and that may negatively influenced bake properties while following processing (Prugar, 1999).

As well as Petr et al. (1999) found out differences in yields o bread between varieties from organic and conventional growing system, varieties from organic farming reached about 30 ml lower yield of bread in comparing with wheat from conventional growing system.

Prugar (1999) showed, that high quality varieties reched often even while lower content of proteins very good yield of bread due to excellent properties of gluten and satisfying rheology properties of dough. This trend confirmed also our result, varieties with elite (E) and high quality (A) baking quality reached even in conditions of organic farming satisfying yields of bread.

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Received for publication on July 2, 2007
Accepted for publication on October 31, 2007

KREJČÍŘOVÁ, L. – CAPOUCHOVÁ, I. – BICANOVÁ, E. – FAMĚRA, O. (Česká zemědělská univerzita, Fakulta agrobiologie, potravinových a přírodních zdrojů, Praha, Česká republika):

Skladba zásobních bílkovin pšenice z ekologického způsobu pěstování.

Scientia Agric. Bohem., *39*, 2008: 6–11.

K nejvýraznějším rozdílům mezi kvalitativními ukazateli obilovin vypěstovaných v konvenčním a ekologickém způsobu pěstování patří rozdíly v obsahu N-látek a mokrého lepku. To zhoršuje možnosti potravinářského, zvláště pekárenského zpracování.

Výsledky hodnocení skladby zásobního bílkovinného komplexu zrna odrůd pšenice lze tedy považovat za důležitou informaci pro hodnocení technologické jakosti pšenice.

Ve dvouletých pokusech (2004, 2005) jsme hodnotili skladbu zásobních bílkovin zrna a parametry mlynářské a pekařské jakosti u souboru odrůd ozimé pšenice z různých skupin jakosti (E – elitní, A – kvalitní, B – doplňkové, C – ostatní, nevhodné pro pekárenské využití) vypěstovaných ekologickým způsobem pěstování na pokusné stanici katedry rostlinné výroby FAPPZ ČZU v Praze-Uhříněvsi. Pro orientační porovnání sledovaných ukazatelů jsme použili stejné odrůdy vypěstované konvenčním způsobem na šlechtitelské stanici Stupice. Pokusné plochy stanice Uhříněves i šlechtitelské stanice Stupice leží v takřka shodných půdně-klimatických podmínkách. Pokusy byly zakládány podle

zásad platných pro vedení Státních odrůdových pokusů v ČR. Pokusy byly vedeny na ŠS Stupice s použitím mořeného osiva, celková dávka dusíku byla 130 kg $N.ha^{-1}$ a byl použit herbicid, fungicid, morforegulátor a insekticid podle potřeby. Předplodinou byla v obou letech peluška jarní. Na pokusné stanici v Uhříněvsi byly pokusy vedeny podle zásad platných pro ekologické zemědělství, předplodinou byl v obou letech jetel luční, sklizeň proběhla 10. 8. 2004 a 2. 8. 2005. U vzorků zrna byl stanoven obsah N-látek (ČSN ISO 1871), obsah mokrého lepku (ČSN ISO 5531), Zelenyho sedimentační test (ČSN ISO 5529), tvrdost zrna (metodou PSI) AACC metoda 5530 a obsah škrobu v sušině zrna (ČSN ISO 56 0512-16), reologické vlastnosti na farinografu (ČSN ISO 5530-1), pekařský pokus (metodika VÚ MPP Praha), elektroforetická analýza zásobních bílkovin – metoda SDS-PAGE.

V zastoupení LMW (nízkomolekulárních) gluteninů a gliadinů jsme nezaznamenali výrazné rozdíly mezi ekologickým a konvenčním způsobem pěstování. V případě HMW (vysokomolekulárních) gluteninů bylo zjištěno výrazně vyšší zastoupení u konvenčně vypěstované pšenice; u ekologické pšenice jsme naproti tomu zaznamenali podstatně vyšší zastoupení zbytkových albuminů a globulinů, které se vyznačují příznivým aminokyselinovým složením a vysokou nutriční hodnotou.

Z výsledků jsou dále patrné rozdíly ve skladbě zásobního bílkovinného komplexu ve vztahu k vybraným parametrům technologické jakosti pšenice. Odrůdy s vyšším obsahem HMW gluteninů se vyznačovaly vyšší technologickou, pekárenskou jakostí. Byly u nich zpravidla zaznamenány příznivější hodnoty ukazatelů předurčující dobrou pekařskou kvalitu: vyšší hodnoty Zelenyho sedimentačního indexu, vyšší farinografická vaznost, delší doba stability těsta, nižší pokles konzistence těsta a vyšší hodnoty měrného objemu vyrobeného pečiva. Výsledky potvrdily známou skutečnost, že vysokou vazností vody moukou se vyznačují odrůdy s výbornou pekařskou jakostí.

V ekologickém i konvenčním způsobu pěstování bylo zjištěno nejvyšší zastoupení HMW gluteninů a současně nejnižší zastoupení zbytkových albuminů a globulinů u odrůd zařazených do jakostní skupiny E – elitní a A – kvalitní a nejnižší u odrůd zařazených do jakostní skupiny C – ostatní, nevhodné pro pekárenské zpracování. Odrůdy z jakostní skupiny C se vyznačovaly nejvyšším zastoupením zbytkových albuminů a globulinů. Z důvodů vysoké nutriční hodnoty albuminů a globulinů lze usuzovat, že tyto odrůdy jsou díky vysokému zastoupení albuminů a globulinů nejvhodnější pro krmení hospodářských zvířat a jsou vhodné i pro lidskou výživu (speciální mlýnsko-pekárenské výrobky, müsli atd.).

Závěrem lze říci, že naše výsledky potvrdily, že u pšenice vypěstované ekologickým způsobem lze jen velmi obtížně dosáhnout parametrů potravinářské pekárenské jakosti. Díky vyššímu zastoupení albuminů a globulinů lze však považovat ekologickou pšenici za kvalitnější z pohledu výživové hodnoty.

skladba zásobních bílkovin pšenice; kvalita pšenice; ekologický způsob pěstování

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