Changes in technological quality of food wheat in a four crop rotation

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ABSTRACT

The evaluation of technological characteristics of food wheat (*Triticum aestivum* L.), grown in a four crop rotation (corn, barley, pea, wheat) since 1994, is presented. Samples of grain, whole grain meals, and flours of the varieties Vlada and Samanta were analyzed. The samples originated from field trials at a research base near Nitra. All important methods of the assessment of the raw material technological quality (intended use for milling and baking) were applied. A total of 22 characteristics were evaluated (15 of them are shown in Table 1). The highest abundance of highly significant (significance levels being results of both parametric and nonparametric methods) changes ($\alpha \leq 0.01$) in quantity (grain and flour yield) and quality (gluten and its properties, water-binding capacity of flour, α-amylase activity) was observed between different years (7). The soil management methods (3; 2 + 1) had a significant ($\alpha \leq 0.05$) influence on the test weight (grain volume mass) and gluten content. In interaction with the year (as a factor), they significantly influenced gluten swelling number (Q-number) and highly significantly the activity of α-amylases. Highly significant differences were also found between varieties (2; 1/1), significant ones in interaction with soil management. Fertilization (3) and other interactions of factors were not statistically significant. Parameter means for factor levels (along with statistical significance of the influence of particular factors) and simple quality coefficients (used for the ranking of factor levels) are shown in Table 1.

Keywords: four crop rotation; food wheat; annual trends; soil management; fertilization; quality

The baker, as stressed by Hamer (1992), meets with a bunch of problems, the fundamental one being the variations of parameters in her/his main ingredient – wheat flour. The flours show batch-to-batch variations in protein and starch content, and enzymatic activity. This is reflected in the water-binding capacity (WBC), dough behavior during processing, curing and rising time, which affects the volume of products. As an example, starch amylolysis leads to the loss of bound water – a positive effect to some extent. Higher water losses commonly accompanied by an increased production of dextrins result in less favorable dough (Drapon and Godon 1987, etc.). Moreover, not every wheat grain yields flours of equal quality at equal milling conditions (Muchová 2001). Thus, wheat separation is the first necessary step towards quality flours. The isolation of individual passages provides millers with the ability to perform economical mixing of wheat that, together with the online control of middlings at critical points of technological operations and final products as well, substantially enhances the probability of obtaining a flour of requested fixed properties (Sugden 1997, 1999, Schäfer 1999). Consequently, we were interested in changes in the technological quality of food wheat grown (for a long-term) in a four crop rotation: corn – barley – pea – wheat.

The milling and bakery-processing simulations under laboratory conditions were performed by trial milling and baking.

MATERIAL AND METHODS

The investigation of changes in wheat technological quality was based on multi-factor field trials at an experimental base of the Slovak Agricultural University near Nitra (climatically warm, moderately arid region of corn production type; soil – Orthic Luvisol with good supply of accessible N, P, and K) in the period of 1994–2000. The factors investigated were as follows: 2 (1/1) varieties (Vlada, 1994–1998 and its replacement Samanta, 1999–2000), 3 (2 + 1) types of soil management (B1 – tillage to the depth of 0.2 m + surface cultivation of the soil, B2 – soil preparation by disk harrow and combined cultivator, B3 – combined cultivator and rotary plow; the last one since 1997), and 3 fertilization variants (0 – unfertilized, IF – industrial fertilizers with doses calculated by the balance method for planned yield of 6 t/ha, RIF – incorporation of all after-harvest plant remnants combined with doses of industrial fertilizers calculated by the balance method).

The evaluation methods included the common ones for determination of test weight (grain volume mass, TW [g/l]), thousand grain weight/mass (TGW [g]), percentage of complete grains (PCG [%]); special ones – trial milling with the determination of flour yield (fractions I and II, IaII [%]) and properties of the main milling fractions. From the chemical and physical analytical methods, we used standard methods of determination of the dry [%], gluten (G0, G30 [%]; 0 – in the whole grain meal, 30 – in flour), gluten swell-

The presented results were obtained during research on VEGA projects No. 1/1064/94 and 1/5131/98.

ing number (Q0, Q30 [ml]), and rapid assessment methods as SDS-test (SDS, SDSiF [ml]; iF – in flour) and falling number (FN, FNiF [s]); furthermore the determination of rheological properties (valorigraphic value VV among them) of the dough and trial baking were carried out.

Parametric and nonparametric methods (exact or estimated significance levels were computed) were used (individual analysis of variance, Kruskal-Wallis and Friedman tests followed by the analysis of contrasts – *t*-tests, Wilcox test; correlation analysis by Spearman, Kendall, and Pearson methods; normality assumptions for parametric methods were checked, as well as the applicability of each method) in the process of statistical evaluation (see e.g. Honerkamp 1990; R-Core Team, 2000–2002 and references therein) of the results. The means for factor levels of the investigated parameters are presented in Table 1 along with the significance of factors for each of the 15 quality characteristics (appropriate significance levels were chosen by a conservative approach – in the case of doubt the output of the method giving the worst values was taken). The data in Table 1 are rounded means (to reproduce/verify the grand mean, if wanted, up to rounding error, it is necessary to calculate weighted average according to the experimental design above, i.e. for year means: 1994–1996 must be multiplied by product 1*2*3, for 1997–2000 by 1*3*3 before summing up and dividing by 54 – the total number of combinations/data points for a parameter; for variety means: Vlada by 3*2*3 + 2*3*3, Samanta by 2*3*3; for soil management means: B1 and B2 by 1*7*3, B3 by 1*4*3; for fertilization means: all by 1*3*2 + 1*4*3; the numbers in preceding weights are in the following order: varieties*years*soil-management*fertilization – the actual factor used to calculate the grand mean is, of course, always skipped and the summing-up and dividing-step is shared by all factors), but all the calculations were performed with the exact raw values; such data sets can effectively be represented by graphical means like scatterplots (R-Core Team, 2000–2002 and references therein) if desired (see e.g. Muchová 2001 for examples with similar, large data-sets).

We also performed some simple quality calculations. The quality measure was designed to represent a deviation (relative difference) from the chosen optimal values for particular parameters. Total quality (K) was calculated by taking the arithmetic mean of the individual deviations, i.e. K = SUM(DEV)/COUNT(DEV). A deviation (DEV) for a parameter, say P, is given by:

– DEV = D(ABS((MEAN(P) – TO_POINT(reference_for_P)))/SCALE_for_P.

The MEAN in the last expression is the arithmetic one, and ABS means absolute value. The TO_POINT function equals:

– to the reference value for P if it is point-wise, e.g. reference_for_P = 230, then TO_POINT(reference_for_P) = 230
– to the lower bound if the reference is minimum-like, e.g. reference_for_P: min. 40, then TO_POINT(reference_for_P) = 40
– to the upper bound if the reference is maximum-like, e.g. reference_for_P: max. 160, then TO_POINT(reference_for_P) = 160
– the arithmetic mean (this leads to apparent stretching of values close to but not quite equal to the reference ones, thus allowing for their separation) of the lower and upper bound if the reference was given as an interval, e.g. reference_for_P: min. 40 – max. 160, then TO_POINT(reference_for_P) = (40 + 160)/2 = 100.

The function D returns:

– its argument, e.g. D(ABS(5–100)) = 95, if MEAN(P) is not in the reference interval, it does not equal the reference value if it is point-wise, or the argument is not bigger than the TO_POINT(reference_for_P)
– zero if the MEAN(P) is in the reference interval (i.e. no deviation), e.g. ABS(45–100) = 55 but 45 > 40 also D = 0
– TO_POINT(reference_for_P) if the argument of D is bigger than TO_POINT(reference_for_P), this represents the values far off optimum, e.g. ABS(1000–100) = 900 > 100 hence D = 100 – i.e. nothing can be worse than absolutely unacceptable.

The parameter SCALE_for_P ensures that all deviations are relative and thus comparable – bound to the interval <0,1>. With the above choices SCALE_for_P can be set equal to TO_POINT(reference_for_P), i.e. SCALE_for_P = TO_POINT(reference_for_P).

The individual relative deviation (e.g. reference_for_P: min. 40 – max. 160, MEAN(P) = 5, D = 95, SCALE_for_P = TO_POINT(reference_for_P) = 100, then DEV = 0.95) is a normalized distance from a given value(s) indicating how far the actual parameter is from the desired state (0 or 0% is equivalent to optimum, 1 or 100% is equivalent to something like absolutely unacceptable result). One individual relative deviation can be represented graphically (if desired) by a ray in a starplot, or by a cell in a table. The sum of all rays (divided by their number to bind K to the interval <0,1>) or the shape of a star is equivalent to the above defined total quality – we sometimes call it star quality coefficient K. Star quality coefficient K can be understood as the equivalent portion (percentage) of criteria not met (see also Ivanová 2002 for a similar approach to a different topic), or as an average relative deviation of each parameter (the closer to one/hundred the worse, see above), e.g. K = 0.20 would mean in our case – 15 parameters that the quality is as if three of the criteria were unacceptably missed or that the deviation of all criteria from their respective references is on average 20%. The interpretation is thus straightforward 0 – excellent quality, 1 – bad quality, values in-between accordingly (as a classification system that can be different for different purposes). In this contribution, reference values are chosen to represent the desired optima (yield → min. 8 t/ha, TGM → min. 45 g, GVM → min. 780 g/l, PCG → min. 85%, G0 → min. 25%, Q0 → min. 12 ml, SDS → min. 45 ml, G30 → min. 30%, Q30 → min. 15 ml, SDSiF → min. 80 ml, FN → 220–250 s, FNiF → 250–280 s, IaII → min. 69%, WBC → 58–64%, VV → min. 70 points). The quality coefficients are summarized in Table 1. They are used to establish the ranking of lev-

Table 1. Means for factor levels of investigated parameters and total quality/star quality coefficient (K)

Year	Yield^{++} t/ha	TGW^{++} g	TW^{++} g/l	PCG %	G0^{+} %	Q0 ml	SDS^{++} ml	G30^{++} %	Q30^{++} ml	SDSiF ml	FN s	FNiF^{+} s	IaII^{++} %	WBC^{++} %	VV points	Quality K
1994	8.15	40.12	794.67	87.43	23.35	16.33	34.23	32.72	20.33	87.62	361.50	427.83	67.67	63.00	60.17	0.115
1995	6.82	40.03	815.33	75.47	29.22	13.00	49.42	40.97	13.83	88.37	391.67	423.00	70.17	61.90	52.82	0.130
1996	7.58	39.07	791.33	60.93	35.68	10.00	51.82	42.18	21.17	76.83	311.50	357.83	55.00	61.00	77.65	0.104
1997	8.11	42.56	778.89	83.85	23.98	13.26	40.30	27.76	21.89	84.41	138.93	175.15	51.44	61.02	40.78	0.114
1998	6.93	42.36	784.70	85.40	18.45	12.33	35.96	19.83	22.78	94.59	320.07	276.81	50.39	60.80	54.24	0.123
1999	5.23	43.98	770.85	87.97	21.11	12.74	42.22	23.15	22.30	87.48	330.82	284.59	56.83	58.74	43.72	0.124
2000	4.62	46.67	794.04	76.55	25.85	16.04	58.37	27.68	22.07	88.56	365.52	383.44	42.44	52.83	62.72	0.148
Variety	yield^{++} t/ha	TGW^{++} g	TW^{++} g/l	PCG %	G0 %	Q0^{+} ml	SDS^{++} ml	G30^{+} %	Q30^{+} ml	SDSiF ml	FN^{+} s	FNiF s	IaII^{++} %	WBC^{++} %	VV points	Quality K
Vlada	7.52	41.10	791.12	79.62	25.32	12.95	41.64	31.21	20.39	86.89	292.19	314.44	57.60	61.44	55.53	0.072
Samanta	4.92	45.33	782.44	82.26	23.48	14.39	50.30	25.42	22.19	88.02	348.17	334.02	49.64	55.79	53.22	0.132
Soil management	yield t/ha	TGW g	TW^{+} g/l	PCG %	G0^{+} %	Q0 ml	SDS ml	G30^{+} %	Q30 ml	SDSiF ml	FN s	FNiF s	IaII %	WBC %	VV points	Quality K
B1	6.93	42.01	792.06	78.74	27.18	12.97	46.68	31.94	20.29	87.50	327.17	340.41	56.31	60.15	59.77	0.085
B2	6.85	42.55	791.44	80.60	24.16	13.44	43.77	29.76	20.79	87.17	311.89	330.00	56.40	59.91	52.79	0.088
B3	5.82	43.31	775.89	83.40	21.32	14.22	42.08	23.78	22.56	87.03	280.47	271.11	50.00	57.90	49.45	0.104
Fertilization	yield t/ha	TGW g	TW g/l	PCG %	G0 %	Q0 ml	SDS ml	G30 %	Q30 ml	SDSiF ml	FN s	FNiF s	IaII %	WBC %	VV points	Quality K
O	6.43	42.43	787.48	82.20	23.54	13.74	43.12	28.17	21.52	87.66	304.87	311.41	55.39	59.34	54.44	0.089
IF	6.96	42.58	788.22	79.25	25.43	12.89	44.99	29.90	20.70	87.10	318.50	324.65	54.25	59.54	54.68	0.084
RIF	6.57	42.52	788.98	80.05	25.14	13.67	45.47	29.75	20.74	87.03	309.18	326.83	55.19	59.78	55.16	0.084
Grand mean*	6.65	42.51	788.23	80.50	24.71	13.43	44.53	29.28	20.99	87.26	310.85	320.96	54.94	59.56	54.76	
References (optimal values) for the named parameters (below)																
	yield	TGW	TW	PCG	G0	Q0	SDS	G30	Q30	SDSiF	FN	FNiF	IaII	WBC	VV	
	min. 8	min. 45	min. 780	min. 85	min. 25	min. 12	min. 45	min. 30	min. 15	min. 80	220–250	250–280	min. 69	58–64	min. 70	

$^{++}$ highly significant influence of the factor ($\alpha \leq 0.01$); $^{+}$ significant influence of the factor ($\alpha \leq 0.05$); * included for the sake of completeness only

Factors: year (7), variety (Vlada from 1994 – replaced by Samanta in 1999–2000), soil management (B1 and B2 since 1994 – B3 added in 1997), fertilization (3)

Parameters: grain yield, thousand grain weight/mass, test weight (grain volume mass), percentage of complete grains, gluten content (G0, G30), gluten swelling number (Quellzahl – Q0, Q30), SDS, SDS in flour, falling number, falling number in flour, flour yield (IaII), water-binding capacity, valorigraphic value

All values in this table are rounded means only, however, the calculations/tests were performed with the exact raw data sets (more than 800 data points total). Please see the text in Material and Methods and Results and Discussion for more details (abbreviations, experimental/factor layout* – must be taken into account to reproduce the grand mean, methods used, interpretation).

els for particular factors by objective means in this paper (see also e.g. Hušek and Maňas 1989, R-Core Team 2000–2002 for more details on the multicriterional evaluation of variants).

RESULTS AND DISCUSSION

The grain yield (yield), thousand grain weight/mass, test weight (grain volume mass), flour yield, gluten content in flour and its swelling number, water-binding capacity and sedimentation were influenced highly significantly ($\alpha \leq 0.01$) by the annual dynamics; gluten content in grain and α-amylases activity in flour only significantly ($\alpha \leq 0.05$), see also Table 1. The highest mean grain yield (highly significant) was achieved in the years 1994 (8.15 t/ha) and 1997 (8.11 t/ha); the lowest one in the year 2000 (4.62 t/ha), see Table 1. A significant difference in grain yield was observed for most of the combinations of year pairs (15 of 21).

For the formation of technological quality (gluten properties, rheological properties of dough, results of baking trials), the year 1996 was the most beneficial one (Table 1; $K \cong 0.104$, equivalent portion of 10.4% criteria, i.e. almost two, were not met or deviation of each parameter was on average off the optimum by this value).

The different soil management systems (see also Table 1) exerted a significant influence on the test weight (grain volume mass) and gluten content only (in both flour and whole grain meal). The highest values of those parameters were recorded for the B1 variant. Highly significant differences between this variant and the B3 one (see also Table 1) were also observed for the valorigraphic value in addition to the mentioned (characteristics) and significant ones for flour yield, activity of α-amylases and gluten swelling in flour. The differences between B2 and B3 (Table 1) are highly significant for test weight (grain volume mass), gluten content and swelling number in flour, significant for flour yield and the α-amylase activity in flour. According to the total quality (the portion of requested criteria not met/the average relative deviation from optimum), the ranking (Table 1) of soil management systems is as follows: B1, B2, B3 (values of K being ~ 0.085, 0.088, and 0.104, respectively).

Vlada/Samanta varieties' differences were highly significant for the grain yield, thousand grain weight/mass, seditest in the whole grain meal, water-binding capacity of flour, flour yield, and significant for test weight (grain volume mass), gluten content and swelling number (determined) in flour, and the activity of α-amylases mainly favoring Vlada (see also Table 1). The influence of the interaction with the used soil management type appeared to be significant for SDS-tests in the whole grain meals.

The types of fertilization did not show any statistically significant effect. The quality ranking in this case would be RIF, IF, O (Table 1, values of K being ~ 0.0841, 0.0845, 0.089).

After 7 years, the soil structural state improved, Mucha (2001), compared with the initial one (1994). The positive agronomic influence of the (mainly) water-resistant soil structure seems to be confirmed. Such (favorably structured) soil releases the reserves of water and nutrients more efficiently than the soil with high percentage of micro-aggregates.

The calculated correlation tests show that the grain gluten content appears to have a highly significant, positive relation to gluten content in flour, seditest value in the whole grain meal, low activity of α-amylases in flour, and a negative one to seditest and gluten swelling number in flour.

Considering the gluten content in flour, there were found similar, highly significant, negative correlations as above; additional positive correlations to flour yield and water-binding capacity of flour appeared. Highly significant, negative correlations were observed between the Q-number values and the α-amylase activity in both flour and whole grain meal, the flour yield and the water-binding capacity of flour.

The relations between the water-binding capacity of flour and the other rheological characteristics – dough rising and stability times [minutes], its softening [FU] – were in favor of Vlada in the case of high water-binding capacity values (58–62%): dough rising and stability in excess of 4 minutes, softening degree after 12 minutes under 60 FU.

Products with a higher volume (more than 455 ml/100 g of flour), uniformly porous and elastic crumb were obtained in baking trials.

The presented results suggest that the conventional soil management (B1) combined with incorporation of after-harvest remnants + use of well dosed industrial fertilizers (RIF) can lead to a decrease in the variety differences for some characteristics (grain volume mass, flour yield, gluten content) but the specific properties (water-binding capacity of flour during dough production, its stability and body) were better for the variety Vlada with the agro-technical interventions being not really significant, but in combination with the varying weather conditions in individual years.

The facts presented in this contribution are in a good agreement with those found for a broader pool (10) of varieties in 1986–1990, for 3 fertilization variants (not identical with the mentioned ones) after the same pre-crop – pea (Muchová 1992). The varieties Ilona and Hana gave the best results that time. These varieties, accompanied by Vlada, have been replaced by new, more productive, but lower-quality ones in recent years.

A certain promise of the better structure of varieties used in future – as a base of the production of sufficient amounts of quality food wheat in the SR, also taking into account unstable weather conditions – is the modification of the technical standard for food wheat (STN 461100-2, 2000) requiring the following 4 class grading according to quality and intended use: E (elite), A (good quality), B (standard), P (for baker's goods, biscuits).

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ABSTRAKT

Změny technologické kvality potravinářské pšenice ve čtyřhonném osevním postupu

Byly hodnoceny změny jakostních znaků technologické kvality potravinářské pšenice (*Triticum aestivum* L.), pěstované od roku 1994 ve čtyřhonném osevním postupu (kukuřice, ječmen, hrách, pšenice). Byly analyzovány vzorky zrna, celozrnných šrotů a mouk odrůd Vlada a Samanta z polních pokusů na výzkumně-experimentální bázi nedaleko Nitry. K hodnocení byly použity všechny důležité metody pro posouzení technologické kvality suroviny pro mlýnsko-pekařské využití. Celkem bylo vyhodnoceno 22 znaků (15 z nich je prezentováno v tab. 1). Nejvíce vysoce významných (hladiny významnosti jsou výsledkem jak parametrických, tak i neparametrických metod) změn ($\alpha \leq 0{,}01$) v kvantitě (úroda zrna, výtěžnost mouk) i kvalitě (lepek a jeho vlastnosti, vaznost vody moukou, aktivita α-amyláz) bylo zjištěno mezi ročníky (7). Rozdílné způsoby obdělávání půdy (3; 2 + 1) významně ($\alpha \leq 0{,}05$) ovlivnily objemovou hmotnost zrna a množství lepku, v interakci s ročníkem rovněž bobtnání lepku a vysoce významně aktivitu α-amyláz. Vysoce významné rozdíly byly zjištěny rovněž mezi odrůdami (2; 1/1), významné v interakci s obděláváním půdy. Hnojení (3) a další interakce se statisticky významně neprojevily. Průměry hodnot parametrů na hladinách faktorů (spolu s významností vlivu faktorů) a jednoduché koeficienty kvality (použity na určení pořadí podle kvality) jsou uvedeny v tab. 1.

Klíčová slova: čtyřhonný osevní postup; potravinářská pšenice; roční trendy; obdělávání půdy; hnojení; kvalita

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