QUALITY EVALUATION OF THE SELECTED TRITORDEUM LINES*

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Nowadays, the tritordeum as a wheat and wild Chilean barley cross represents a new crop, which could be in a decade potentially used in a baking industry. The article describes the results of comparative study of the six tritordeum lines and commercial wheat flour quality in a three-crop year period. Related to standard (i.e. wheat flour), the basic analytical characteristics showed comparable ash content as well as higher protein content with significantly lower quality (averagely about 40% in both cases). Non-fermented and fermented dough properties of tritordeum flours and their composites (50:50) with wheat one were tested by custom rheological tests. Technological times and dough volumes in single stages of the fermentation process were insignificantly shorter and higher, respectively. Laboratory baking test as a direct consumer's quality indicator was also performed, and its results revealed approx. 15% bread volume increase – it was statistically unimportant through three-crop testing. Statistic methods of ANOVA, PCA and CA used for evaluation of tritordeum samples and their origin effects confirmed higher importance of harvest year. Results of our study predicted possibility of tritordeum bakery usage in near future.

tritordeum; quality features; rheological characteristics; bread

INTRODUCTION

Tritordeum (X *Tritordeum* Ascherson et Graebner) was bred by crossing of the wild perennial barley (*Hordeum chilense* Roemer et Schultese, 2n = 2x = 14) with wheat (*Triticum* spp.). Hexaploid forms of the tritordeum (2n = 6x = 42) have a genom set $H^{ch}H^{ch}$AABB, created by the barley chromosomes (H^{ch}) and the wheat ones (A, B). The first report about this new cereal is dated to the year 1977 (M a r t i n et al., 1999). Nowadays, breeding of the plant continues in the Spain, where a range of the spring forms were established with satisfying genetic variability proper to further breeding. Genesis of this cereal was similar to the case of the triticale (X *Triticosecale* Wittmack), which is a product of wheat and rye crossing. Triticale is known over 100 years, while tritordeum is cultivated in the field tests from 80's of the last century.

According to genetic lines, the hexaploid tritordeum is characterised by higher protein content ranged from 19 to 22% for the primary forms, and around 16% for the secondary ones (consequence of over-breeding oriented to grain yield increase). Barley chromosomes could demonstrate themselves differently from the wheat ones − the latter are responsible to viscoelastic properties of gluten proteins. The tritordeum proteins thus show some characteristics, resulting (dependently on each bred line) into diverse bakery quality in comparison to wheat (M a r t i n e k, 2003).

Breeders' aim of gaining of the hexaploid tritordeum with bakery quality comparable to food wheat was not still accomplished (A l v a r e z et al., 1996). S i l l e r o et al. (1997) performed protein sequence extraction from the selected hexa- and octoploid tritordeum and their parent forms (*T. durum* and *T. aestivum*) and revealed, that quality likeness as the proportion of the single protein fractions (mainly gliadins and glutenins) is higher to the latter than the former wheat species. Flour extraction rate of the hexaploid tritordeum was lower compared to wheat milling test, and their rhelogical properties and bakery parameters were worse too. A large interspecies variability indicates, at new breeding methods employment, that there is a possibility to create spring tritordeum of improved bakery quality (A l v a r e z et al., 1995). Qualitative features are affected by a harvest year, nutrition dosage and farming regimes. A higher N-level in a soil increases protein content in grain of the tested genotypes as well as decreases thousand kernel weights. Tritordeum is characterised by lower grain hardness than wheat *T. durum* as proved A l v a r e z et al. (1992) by PSI method. Further, tritordeum genotypes are rich in yellow pigment compared to triticale. From the viewpoint of agricultural production, tritordeum reaches about 20–40% lower grain yield related to common wheat average − it is caused by later heading (M a r t i n et al., 1988). The important parameter conditioning industrial usage is equally to common wheat affected by a harvest year.

Present work is aimed at technological properties of the pure tritordeum flour monitoring. Composite flours formed as 50% substitution of the commercial wheat flour by the fine flour from the six selected tritordeum lines

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were also tested. Complex quality evaluation of all prepared samples from three-crop tests allows an assessment of the genom factor and the harvest year effects on the selected quality traits. The goal of this paper is a prediction of bakery usage possibility of the tritordeum.

MATERIAL AND METHODS

Quality analysis were performed with three sets of fine flour milled from the six tritordeum lines, grown in the Agricultural Research Institute Kroměříž, Ltd. (ARI) during a period of 2006–2008. Tested samples were HT135bDH (T1), HTC1331bDH (T2), HTC1323DH (T3), HTC1331DH (T4), HTC1331cDH (T5) and HTC1380 (T6). DH forms were derived from immatured (haploid) anthers at *in vitro* conditions. Samples T2, T4 a T5 represent different DH lines derived from the same initial genotype HTC1331, thus one to each other could be in closer genetic relation.

A complex procedure of quality analysis according to the internal method of the Cereal Laboratory of the Institute of Chemical Technology Prague (CL ICT) was applied differently for the mentioned samples. Quality description of the tritordeum fine flours (prepared on the Brabender's Junior laboratory mill in ARI) was done by analytical traits and by the alveograph test. Due to technical difficulties at behaviour testing of fermented dough prepared of the pure tritordeum (extreme stickiness), composite flour including 50% of bright fine wheat flour **(**M**)** were prepared. Composite flour quality from the six tritordeum lines was evaluated by 22 features covering flour viscoelastic and fermented dough behaviour and bread features from baking test of the CL ICT.

Analytical traits of fine tritordeum flour were mineral compounds (ash) and protein contents (according to ČSN 56 05 12). Protein baking quality was tested in agreement with Zeleny's sedimentation method (ČSN ISO 55 29) with the help of Sedi-tester apparatus (ZZN Strakonice, Czech Republic). Falling Number (ČSN ISO 30 93) was measured by usage of the Falling Number apparatus (type 1400, Perten, Sweden) and viscosity behaviour of composite flour suspension according to the standard ICC 126/1 on the Amylograph (Brabender, Germany). Viscoelastic properties of non-fermented dough were assessed in correspondence to ČSN ISO 55 30-4 by the Alveograph (Chopin, France). Dough behaviour during deformation is usually described by elasticity, extensibility, their ratio and by energy integrated as an area under a curve measured.

In a laboratory scale, fermentation process was simulated adequately to three technological phases – leavening, proofing and the first baking step. Fermented dough for all three custom tests was prepared on the Farinograph (Brabender, Germany) to constant consistency of 600 Brabender's unit (BU). The first fermentation phase is in the CL ITC observed on the Fermentograph (SJA, Sweden), the second on the Maturograph and the third on the Oven rise recorder (Ofentriebgerät, OTG; both apparatuses Brabender, Germany) according to the internal methods published earlier (e.g. Švec, Hrušková, 2003; Švec et al., 2004). During the single fermentation stages, both dough volume changes and time intervals immanent to these changes are recorded – e.g. reaching of the dough volume maximum (leavening time – fermentograph; proofing time, dough resistance – maturograph). Measurement by way of the mentioned laboratory apparatuses was completed by a direct evaluation of bakery quality – by a baking test. Final bakery product was characterised by the specific bread volume and by the shape ratio height/diameter. Consumer's quality was further depicted by 9-point sensory analysis and crumb penetration measurement. Transverse cut bread halves were scanned and from black-white prints the bread cut area was measured by use of the digital planimeter Plancom (Koizumi, Japan). With the help of the Lucia G 3.52 software (Laboratory Imaging, Czech Republic) and the optical repro-set Kaiser (Germany), bread crumb parameters as the mean cell area and the number of cell/cm^2 were evaluated.

A statistical model used for worth appraisement of the harvest year and tritordeum line factors included variance and cluster analyses as well as principal component method (program Statistica 7.1, StatSoft, USA). The cited model was for food wheat quality monitoring verified in the previous work (Švec et al., 2009).

RESULTS AND DISCUSSION

Technological quality of the tritordeum flour

Baking quality features of the tritordeum fine flours are given into Table 1. Pooled over harvests 2006-2008, their average values are not significantly different in minerals and protein contents. Compared to the flour M analytics, the protein one is about 39.4–45.5% higher. Its quality according to the Zeleny's test oscillates and in all cases it is lower than is required for standard bakery processing. ANOVA of the protein quality did not confirmed congeneric relation of the lines T2, T4 a T5, because T4 sample had in observed harvest years the highest mean Zeleny's index. In regard to the Falling Number, reflecting starch damage stage, samples T6 and T3 were provably diverse. Such low Falling Number values predict a higher dough stickiness, which was already detected at a dough preparation and treatment.

Table 1. Tritordeum line effect on analytical traits of pure flour (harvest year 2006–2008 average)

Sample	Ash content (%)	Protein content (%)	Zeleny's test (ml)	Falling Number (s)
T1	0.60 a	15.7 a	31 a	237 ab
T2	0.61 a	15.5 a	29 ab	231 ab
T3	0.66 a	15.7 a	25 ab	189 a
T4	0.60 a	16.3 a	33 a	316 b
T5	0.60 a	15.5 a	27 ab	235 ab
T6	0.66 a	15.5 a	22 b	167 a
M	*0.56*	*11.2*	*45*	*339*

a, b – means in columns followed by the same letter are not significantly different ($P < 0.05$)

Viscoelastic dough properties from tritordeum at the alveograph test (during biaxial deformation) were different one line from each other as well as related to wheat dough (Table 2). The dough extensibility L for the single lines ranges into the broadest interval (68–120 mm), thus ANOVA divided tested samples into three statistically independent groups. According to the parameter P/L, all samples with value lower than 0.50 could be marked as bakery weak. This fact confirms also alveograph energy W with values under $100·10^{-4}$ J. From a comparison with the wheat flour M alveograph data, an unequivocal dissimilarity all six tritordeum lines resulted – the standard reached nearly twofold both elasticity and energy.

Composite flour quality (wheat:tritordeum = 1:1)

Viscous behaviour of composite flour suspensions at heating describe amylograph characteristics summarised into Table 3. Recorded results correspond with amylases activity measured by screening method (Falling Number). As showed results in Table 1, samples T3 and T6 reached the lowest values. Temperature of gelatinisation beginning was for all samples approximately the same, extent of 2.5 °C testify similar starch grain structures between tritordeum lines. Average amylograph curve maxima oscillated between 240–803 amylograph units (AU) and temperatures of gelatinisation maxima between 75.8–92.8 °C. For data fluctuation caused by the harvest year effect, any statistically provable differences were not revealed; the mean absolute values signify similar behaviour of flour suspension of the sample groups T3–T6 and T1–T2–T5. In all three investigated harvest years, the closest relation to wheat standards had the line T4 − its mean amylograph maximum was 803 AJ and temperature of gelatinisation maximum 92.8 °C (Table 3).

Fermented dough behaviour of composite flours was monitored during the three technological steps of fermentation process − leavening is described by the fermentograph, proofing by maturograph and the first baking step by OTG test. With the exception of the final dough volume feature, dough behaviour from six lines composite flour during a leavening period was diverse minimally. Fermentation times (43 – 50 min) and fermentation gas volumes (110–129 fermentograph units, FeU) were statistically insignificant from ones of the standard M (52 min and 124 FeU, respectively). Moreover, they could be considered as comparable also with results recorded for both wheat varieties and commercial wheat samples (Švec, Hrušková, 2003; Švec et al., 2004). Although the final dough volume values do not exceed ranges found during several-years research of the wheat cultivars quality, in the case of the tritordeum lines and composite flours this parameter testified its worth as distinguishing factor. The lowest three-crop average was calculated for T2 line – within the tritordeum set, it also rather failed in the Zeleny's test of the protein quality. Furthermore, the highest mean of the final dough volume (72 FeU) was established for T3 sample. That fact could be more or less an exception owing to its alveograph test results, where the line belonged to bakery weaker ones.

At the maturograph trial, pure dough prepared from the M standard reached averagely 36 min in the proofing time, 562 maturograph units (MU) in the dough resistance and 202 MU in the dough elasticity. Deviations caused by 50% tritordeum flour substitution rarely exceeded 10% for all mentioned maturograph traits, thus ANOVA results did not show any noticeable differences. In the second stage of the fermentation process, the highest values were measured for the T3 composite, which ended as the best at the fermentograph test. The flour mixture with T3 levelled the standard in the proofing time, and overcome it in values of the dough resistance and the dough elasticity (35 min, 645 and 223 MU, respectively). Summarised, the detected differences at the proofing were lower compared to the fermentograph test. For the bakery usage, dough quality from the six tritordeum lines was comparable to standard and, generally, it quite represented an average technological behaviour. Also during the first stage of baking in oil bath, fermented dough samples manner was not significantly diverse together. Observed oscillations against the standard were in order of 10–15%. Due to mutual approach of the dough volumes at the beginning and at the end of the OTG proof, the volume increase of the T6 composite was lower than 200 units. In that case, likewise lower specific bread volume could be predicted.

Table 2. Tritordeum line effect on rheological traits of pure flour (harvest year 2006–2008 average)

Sample	Elasticity P (mm H_20)	Extensibility L (mm)	Ratio P/L (–)	Energy W (10–4 J)
T1	59 a	120 b	0.49 a	155 a
T2	42 a	89 ab	0.49 a	111 a
T3	56 a	73 ab	0.77 a	94 a
T4	54 a	103 ab	0.53 a	136 a
T5	41 a	68 a	0.61 a	98 a
T6	54 a	68 a	0.85 a	96 a
M	*123*	*95*	*1.33*	*292*

a, b – means in columns followed by the same letter are not significantly different ($P < 0.05$)

Table 3. Tritordeum line effect on amylograph parameters of composite flour (harvest year 2006–2008 average)

Sample	Amylograph curve maximum (AU)	Temperature of gelatinisation beginning (°C)	Temperature of gelatinisation maximum (°C)
T1	367 a	62.0 a	79.5 a
T2	408 a	60.5 a	78.3 a
T3	275 a	62.5 a	76.8 a
T4	803 a	60.5 a	92.8 a
T5	367 a	61.5 a	79.5 a
T6	240 a	60.0 a	75.8 a
M	*785 a*	*60 a*	*89 a*

Abbreviations: AU – amylograph unit
a, b – means in columns followed by the same letter are not significantly different ($P < 0.05$)

Table 4. Tritordeum line effect on bakery test results of composite flour (harvest year 2006–2008 average)

Sample	Water absorption (%)	Specific bread volume (ml/100 g)	Shape ratio (1)	Crumb penetration (mm)	Sensory profile (points)
T1	55.0 a	345 a	0.61 a	15.9 a	12 a
T2	54.2 a	367 a	0.61 a	16.3 a	13 a
T3	55.3 a	349 a	0.65 a	14.6 a	12 a
T4	55.0 a	343 a	0.57 a	11.9 a	14 a
T5	54.3 a	345 a	0.60 a	16.5 a	12 a
T6	54.6 a	378 a	0.54 a	14.2 a	13 a
M	*55.2 a*	*301 a*	*0.68 a*	*15.4 a*	*10 a*

a, b – means in columns followed by the same letter are not significantly different ($P < 0.05$)

Results of the encompassed baking test indicated, that the basic wheat supplement by tritordeum flour at level of 50% did not seriously change an overall quality of the final product. Composite flours rendered soft up to middle increase of the specific bread volume (14–26%) and bread was defined by a weak vaulting lowering (about 10% in average) (Table 4). Sensory profile was not in principle changed, because used point scale begins at 9 points (the best profile) and ends at 27 points (unacceptable bread). Concluded, found changes were not statistically important ($P = 95\%$). Similarly, remarkable changes in bread cut areas did not occur (34.2 cm^2 for M, 34.0–36.2 cm^2 for T1–T6 composites bread); gained values correspond to the specific bread volumes measured. Deviations in a crumb porosity (mean cell area 1.310 ± 0,111 mm^2, 21 ± 3 cells/cm^2) were insignificant with respect to accuracy of measurement; therefore Tukey's test tagged all samples as non-distinguishable.

Table 5. ANOVA of tritordeum line and harvest year influence for PC1 and PC2

Line	PC1	1		
T1	–0.150	****		
T2	0.016	****		
T3	–0.275	****		
T4	0.396	****		
T5	–0.214	****		
T6	–0.065	****		
M	*0.292*	****		
Line	PC2	1	2	
T1	0.014	****		
T2	–0.480	****		
T3	–0.320	****		
T4	–0.032	****		
T5	0.083	****		
T6	–1.175	****		
M	*1.909*		****	
Harvest year	PC1	1	2	3
2006	–0.380	****		
2007	–0.089		****	
2008	0.469			****
Harvest year	PC2	1		
2006	–0.164	****		
2007	0.050	****		
2008	0.114			****

Statistical evaluation of line and harvest year influences

For both factor (line and harvest year) influence assessment, cluster analysis in the Euclidean space with clustering algorithm „Furthest" and principal component analysis were used. For the mentioned statistics, both data groups were used − the first encompassed the analytical characteristics of the pure tritordeum flour (Table 1), the second covered the parameters of the composite flours (Tables 3–5) (in total, 26 variables). The former multidimensional method revealed differences in the harvest year 2006 and 2008 impact, for both year samples separate location in a dengrogram (with exception of T4'06 a T6'08) (Fig. 1). Between harvest years 2006 and 2007, a higher quality closeness could be found − as for tritordeum, so for wheat samples. In detail, T1 and T5 lines were similar in the technological quality from over 75% connected to harvest years 2006 and 2007. On the other hand, lines T3 and T5 associated together at the similar rate of likeliness in the harvest years 2006 a 2008; samples were conjoined in the tertiary and the secondary clustering step, respectively.

Sixty-seven percent of the variation in the bread loaf characteristics was explained by the first three principal components (PCs), 40% by PC1, 15% by PC2, and 12% by PC3, respectively (data not shown). Principal components (PC's) divided tested samples in agreement of the harvest year (Fig. 2) – PC1 explained six quality traits at least from 70% (Falling Number, maturograph dough elasticity, OTG sample volume, specific bread volume, crumb penetration a cut area) (Fig. 3). Further five variables (amylograph maximum, temperature of gelatinisation maximum, proofing time, dough resistance and OTG bread volume) were explained by PC1 at least from 60% (Fig. 3). In summary, PC1 could be interpreted as a representative of the fermented dough behaviour and bread properties. PC2 separated wheat flour samples, rich in protein quality as the Zeleny's test (69% of variability) and better in the bread sensory profile (59% of variability) (Fig. 3). From further technological parameters, only the shape ratio could be taken under PC2 (43% of explained variability).

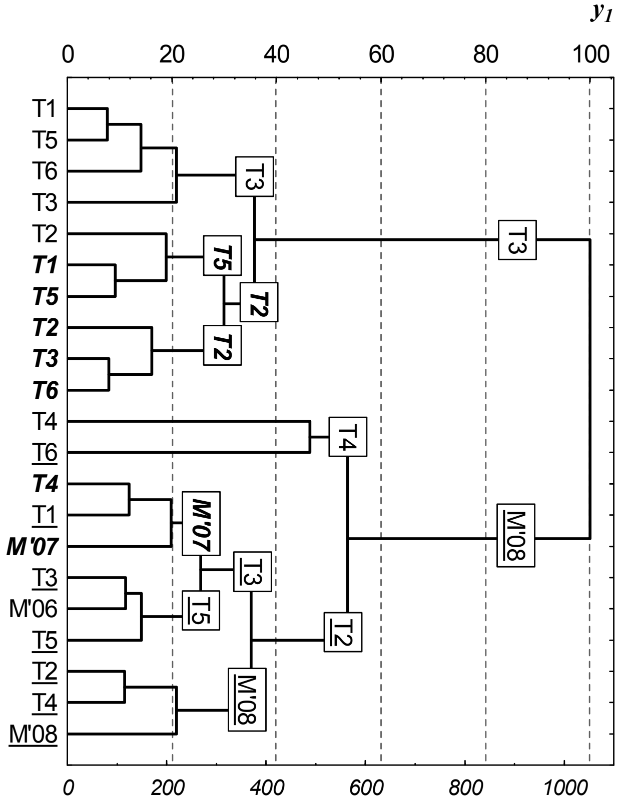

Fig. 1. Cluster analysis of the harvest year effect on quality of the six tritordeum lines; y_1 – statistical dissimilarity, y_2 – Euclidean distance; T1–6 – trirodeum lines; M'06–08 – commercial wheat flour; 2006, 2007, 2008 – harvest years

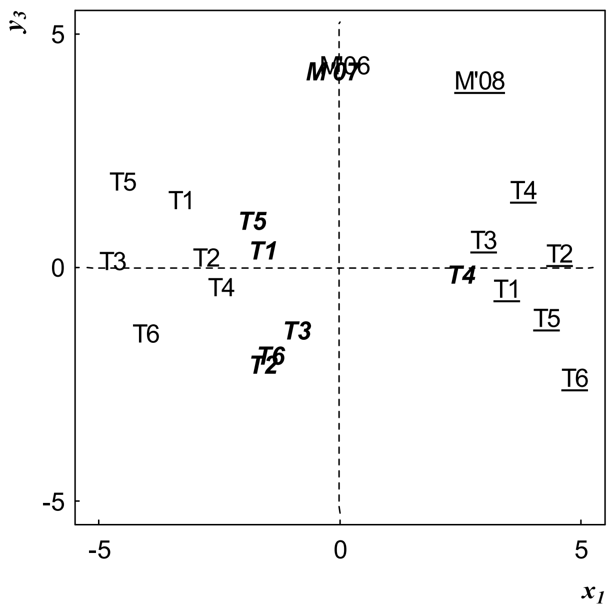

Fig. 2. Component score plot for six tritordeum lines; x_1 – PC1 (40%), y_3 – PC2 (15%); T1–6 – trirodeum lines; M'06–08 – commercial wheat flour; 2006, 2007, 2008 – harvest years

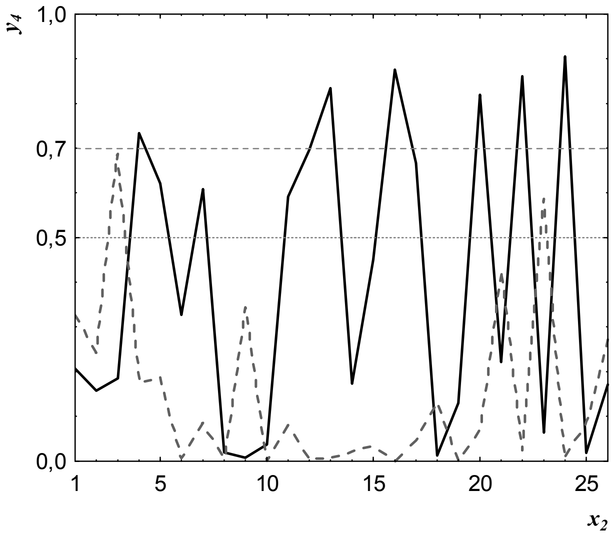

Fig. 3. Component weight plot; x_2 – sequence variable number, y_4 – component weight; —— PC1, - - - PC2

Generally, PC2 could be interpreted as the representative of cereals type, i.e. as a descriptor of differences between two botanical species. PC1 and PC2 together, sufficient explanation of half quality and technology traits of the dataset was reached. Beside that, PC3 involved just one technology feature (fermentation time), which were clarified adequately (73%, data not shown).

Sample factor scores for PC1 and PC2 were tested by ANOVA, when Tukey's test results (P = 95%) confirmed dissimilarities illustrated on Fig. 2. Harvest year as a dominant factor affected both tritordeum and commercial wheat flour quality, for PC1 values did not distinguished tested lines quality from the standard (Table 5). However, otherness between wheat and tritordeum lines was provable based on PC2's ANOVA results. Prevailing effect of the harvest year is demonstrated by specific quality in the sub-sets − a main impact is summarised by PC1. In spite of that, in the monitored harvest years mean Zeleny's test and sensory profile values (both covered by PC2) were not statistically significant (data not shown).

CONCLUSION

Technological quality of fine flour from the six selected lines of tritordeum from three-crop research was described by the complex procedure, including analytical and rheological methods together with baking tests evaluation. Commercial wheat flour as a standard was examined in the same extent simultaneously. Moreover, also composite flours mixed 50:50 from the tritordeum flours and standard were used.

The highest differences between standard and pure tritordeum flours were observed in protein quality tested by the Zeleny's sedimentation and the alveograph tests. Compared to standard, tritordeum samples baking quality predicted from the both proofs was approximately half, and differences between observed tritordeum lines were statistically insignificant. Fermentation times got softly shorter by tritordeum addition, but the dough volume showed its worth as the lines discriminant factor. Bakery test results of composite flours dough reveal 14–26% rise of the specific bread volumes. The increase was provable from technological viewpoint, but harvest year variation caused its statistical insignificance both between lines and to standard. Regardless to moderately lower bread vaulting, overall sensory profile of the all 6 fortified bread was acceptable including satisfactory crumb softness and structure.

Based on the cluster analysis and the principal component statistics, the main variability portion of measured quality traits of both tritordeum and composite flours was caused by the harvest year factor. Clustering of the tested lines in the single harvest years was always diverse due to their quality oscillation. As the closest together could be tagged T1 and T5 lines, which created primary cluster in harvests 2006 and 2007 with mutual dissimilarity on 10% level. Generally, the harvest year impact on majority of the measured characteristics was different in harvests 2006 and 2008, because these two sub-groups had not any intersection in the principal components plot.

Finally, a prediction of the tritordeum bakery usage brought knowledge about its acceptable technological quality. Regardless to lower protein quality, baking test results and complex sensory profile of bread fortified by 50% of tritordeum flour were at least the same compared to values measured for the wheat standard. Moreover, dough manufacturing together with fermentation times and dough volumes of these 50:50 flour composites alike to wheat one give a chance to extend bakery raw material alternatives.

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Hodnocení jakosti vybraných linií tritordea.

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Pro hodnocení vlastností mouky a směsí s pšeničnou moukou světlou bylo v letech 2006–2008 získáno ze ZVÚ Kroměříž šest linií trirodea, jejichž jakost byla hodnocena komplexně podle interní metodiky cereální laboratoře VŠCHT Praha.

Testované linie tritordea se průkazně vzájemně nelišily obsahem minerálních látek a bílkovin, ale ve srovnání s pšeničnou moukou byl obsah bílkovin vyšší o 39–46 %. Kvalita bílkovin podle Zelenyho testu byla nižší (22–33 ml). Čísla poklesu byla průkazně nižší pro vzorky T6 a T3, které se při zpracování těsta projevily zvýšenou lepivostí.

Přídavek tritordea na úrovni 50 % výrazně nezměnil jakost finálního výrobku. Měrné objemy pečiva z kompozitních mouk byly o 14–26 % s mírně nižším klenutím a srovnatelným senzorickým profilem. Výkyvy v pórovitosti střídy byly minimální – diference se pohybovaly na hranici přesnosti měření.

Shluková analýza určila různý vliv ročníků 2006 a 2008, neboť se tyto vzorky v dendrogramu umístily odděleně. Mezi liniemi T1 a T5 byla zjištěna vysoká podobnost kvality v ročnících 2006 a 2007, podobně mezi vzorky T3 a T5 v letech 2006 a 2008. První tři hlavní komponenty vysvětlily celkem 67 % proměnlivosti vstupního souboru dat. PC1 reprezentovala vlastnosti fermentovaného těsta a pečiva, zatímco PC2 vzájemně odlišila tritordeum a pšenici jako dva botanické druhy.

tritordeum; znaky kvality; reologické charakteristiky; pečivo

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