Evaluation of methods for wheat grain hardness determination

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ABSTRACT

Grain hardness of winter wheat cultivars was evaluated during 1997–2001 using several methods: wheat hardness index WHI (DO-Corder Brabender), 0.140 mm sieve threw ratio PPS (DO-Corder Brabender), grain hardness by NIR (Inframatic 8611 Perten), particle size index PSI (LM 3303 Perten). All tested methods showed varietal (genetic) origin of grain hardness trait and it is possible to use these methods for grain hardness determination. NIR method have had the lowest coefficient of variation (12.6%), WHI and PSI coefficient of variation was 32.8 and 30.6%, respectively. A significant influence of year-class was found only for PPS method. A high value of correlation coefficient was found between methods: WHI × NIR (r = 0.84), WHI × PPS (r = –0.79), and NIR × PPS (r = 0.74). During 2000–2001 was correlation coefficient r = –0.93 for PSI × NIR. The coefficient of variation for PSI method was 28.5%.

Keywords: wheat; grain hardness; methods

Endosperm structure is one of the most important criteria for wheat classification and it influences significantly the milling process, particle size of flour and milling yield. Wheat hardness is influenced especially by genetic factors, but can be influenced also by environment and factors like moisture, lipids, pentosans and protein content (Turnbull and Rahman 2002). Starch granules of different sizes are coated by a protein matrix created predominantly by gluten proteins (Morris et al. 1999). Differences in wheat hardness result probably from adhesion between starch granules and storage proteins. Low molecular proteins of starch granules are present in a larger amount in soft wheat compared to hard cultivars. Gaines et al. (2000) found out that softer wheat had a higher content of amylose bound with lipids and had a lower content of total starch. Cultivars with softer endosperm texture had bigger starch granules and harder wheat had smaller starch granules. Smaller granules have a larger surface available for non-covalent bonds with endosperm proteins and can be cramped up more effectively which ensures harder endosperm.

Soft varieties of wheat had a large ratio of 25 μm particles after milling. It corresponds with isolated starch granules. In hard cultivars this particle size was rare or missing. A 25 μm particle ratio could be used to monitor the milling and breaking process (Devaux 1998). Hardness correlates well with semolina and wheat flour yield. Correlation hardness × wheat vitreousness has been found out (Koeksel et al. 1993). A close relationship between hardness and energy consumption during milling has been described on collections of hard and soft wheat (Glenn et al. 1991).

Low protein content and soft grain are required for cake and biscuit flours. Such flours have low starch damage during milling. High protein content and hard grain are traits required for bakery flour. Pasta wheat should have characteristics between the two above-mentioned types. Flours for starch and gluten production should be relatively soft to exclude damaged starch production during milling. At the same time they should provide high gluten content (Brown et al. 1993).

MATERIAL AND METHODS

Winter wheat samples from cultivar trials at Selgen Inc. in Stupice during 1997–2001 have been used to determine grain hardness. Wheat cultivars used in the evaluation were: Alka, Brea, Ebi, Estica, Samanta, Samara, Saskia, Siria, Šárka, and Versailles (1997–2000). 25 winter wheat cultivars have been tested in 2001. The aim of our study was to compare the methods for grain hardness determination in selected cultivars of winter wheat.

Wheat hardness index (WHI) was determined by DO-Corder with an accessory for hardness measurement (Brabender). The methodology of the former Milling and Baking Research Institute in Prague was used. 50 g of cleaned wheat grain is ground

(200 rounds per minute). A recorder registers the torque value during grinding (Brabender units). In order to extend the measurement scale a special load is used for the power transmission on register paper. Acquired meal is sieved for 3 minutes using 0.140 mm sieve. Sieve threw are weighed. Grain moisture should be 11–13%.

WHI = [peak height on hardness tester (B.u.) + load value (g)]/[0.140 mm sieve threw weight (g) × 2]

Ground stock threw ratio (on 0.140 mm sieve) determination by WHI method was evaluated separately. The measurement principle corresponds with the PSI method.

Grain hardness determination in the near infrared area (NIR) was performed using Inframatic 8611 equipped with hardness calibration. Grain was milled using Perten LM 3100 mill.

PSI method was performed according to AACC 55-30 methodology. Cleaned wheat with moisture 11–13% is used for determination. The meal is prepared by laboratory mill Perten LM 3303 equipped with head No. 2. 22–23 g of wheat grain is ground. Made up meal weighs 10 g. Meal is sieved on 0.075 mm sieve for 10 minutes using sieve cleaner. The sieve threw are weighed. PSI value are calculated as follows:

PSI % = [0.075 mm sieve threw weight (g)/sample weight (g)] × 100

RESULTS AND DISCUSSION

Different methods for grain hardness determination, which could be used in the Czech Republic during 1997–2001, are published in this study. Ten evaluated cultivars have been selected out of all cultivars that were measured during 1997–2000. Ten selected cultivars represent all quality ranges: E (Brea, Ebi), A (Alka, Samanta, Saskia), B (Siria, Šárka), and C (Estica, Samara, Versailles).

The WHI method has had higher grain hardness values in relation to scale span (Brabender units). The added load for the power transmission (the extend of measure scale) was necessary for the hardness measurement. Load value has been considered in WHI calculation and it resulted in an increase of WHI absolute values especially in

Table 1. Variability markers for wheat grain hardness measurements using various methods (Stupice, 1997–2000)

Method/variability marker	1997	1998	1999	2000
WHI				
Average	162.4	172.2	199.3	193.9
Variance range	160	121	216	191
Coefficient of variation (%)	31.4	24.6	34.6	33.5
NIR				
Average (%)	51.1	50.4	52.1	52.6
Variance range (%)	18.5	17.0	18.5	19.0
Coefficient of variation (%)	14.0	12.1	12.3	11.3
0.140 mm sieve threw ratio WHI				
Average (%)	13.2	10.9	10.3	15.3
Variance range (%)	9.7	6.9	10.1	11.2
Coefficient of variation (%)	25.2	23.1	31.4	24.6

Table 2. Variability markers for wheat grain hardness measurements using various methods (Stupice, 1997–2000 average)

Variability marker	WHI	NIR (%)	0.140 mm sieve threw ratio WHI (%)
Average	182.0	51.5	12.4
Variance range	228.0	21.5	15.6
Coefficient of variation (%)	32.86	12.58	30.56

Table 3. Correlation coefficients between methods for wheat grain hardness determination (Stupice, 1997–2000)

Methods	Correlation coefficient
WHI × NIR	0.84
WHI × 0.140 mm sieve threw ratio WHI	–0.79
NIR × 0.140 mm sieve threw ratio WHI	–0.74

cultivars with harder grain for which it has been necessary to adjust the load. Consequently WHI values belong to a wide range from 94 to 322. The lower values have cultivars with softer endosperm; higher values have harder grain cultivars. A wider range of WHI values for individual varieties have manifested itself also between the years. Even though WHI absolute values have varied yearly (Table 1) differences between years have not been statistically important. Cultivar sequence according to WHI has been similar in individual years. The average value of the coefficient of variation has been 32.9% (Table 2). The four-year grain hardness evaluation using WHI method has showed that this method can characterize endosperm hardness of wheat cultivars in the existing year and can be used to classify wheat cultivars into groups according to grain hardness.

0.140 mm sieve threw weight (part of WHI method) is evaluated separately. The reason for the evaluation was a principal identity with the PSI method – standardized crushing of grain, ground stock sieving and sieve threw ratio evaluation.

Until the year 2000 an instrument for PSI determination has not been available in the Czech Republic and a stopgap solution for similar grain hardness evaluation had been tested. Harder endosperm crumbles during milling into larger sharp-edged particles which remain on the sieve and so harder wheat cultivars have a lower threw ratio compared to softer varieties. According to Morris et al. (1999) during soft wheat crushing the starch-protein matrix surface is more uncovered and a higher quantity of starch granules are disengaged. On an average they are smaller compared to hard wheat.

0.140 mm sieve threw percentage ratio of monitored cultivars collected has ranged from 6.0 to 21.6%. Coefficient of variation for 0.140 mm sieve threw percentage ratio has had more favourable value (30.6%) compared with WHI (32.9%) (Table 2) in four-year average and also in separate years (Table 1). A statistically significant difference has been found between years.

Measurement in the near infrared area was performed on an Inframatic spectrometer. Results are expressed in 0–100% scale. Higher values correspond with higher grain hardness. Results obtained by NIR method have had a narrow range of values for individual cultivars and also between year-classes. Tested cultivars values have ranged from 40 to 60% analogous to German wheat cultivars (Meyer et al. 1997). Based on the results cultivars have been classified only into two significantly different groups according to grain hardness – harder varieties (50–60%) and softer varieties (40–45%). The majority of cultivars have shown values from 52 to 57%.

Slight differences in absolute values of hardness have manifested themselves by the lowest variability of results compared with 0.140 mm sieve threw ratio and WHI. Coefficient of variation was 12.6% (Table 2). Year-class differences have not been statistically significant. Also the NIR method has confirmed that grain hardness is significant for cultivar characteristic and cultivar sequence has not changed very much in individual years.

Correlation coefficient of the grain hardness values determined by three methods has been high. The correlation coefficient between WHI and NIR values is $r = 0.84$ but in 1998 has been higher ($r = 0.93$) (Table 3). Both methods have had in relation to 0.140 mm sieve threw ratio determination high negative correlation coefficient $r = –0.79$ (WHI) and $r = –0.74$ (NIR), critical value $r_\alpha = 0.403$ ($\alpha = 0.01$). All tested methods could be used for endosperm characteristics expressed as grain hardness.

In the year 2001 machine for grain hardness determination according to AACC 55-30 (PSI method) has been put into operation. Thirteen varieties of winter wheat from 2000 harvest and 25 varieties of winter wheat from 2001 harvest have been evaluated. Until 2000 evaluated cultivars had been mostly

Table 4. Variability markers for wheat grain hardness measurements using various methods (Stupice, 2000–2001)

Variability marker	WHI	NIR (%)	0.140 mm sieve threw ratio WHI (%)	PSI (PSI %)
Average	237.0	51.7	15.9	16.2
Variance range	339.0	20.0	26.0	15.0
Coefficient of variation (%)	38.11	11.64	40.94	28.46

Table 5. Correlation coefficients between methods for wheat grain hardness determination (Stupice, 2000–2001)

Methods	Correlation coefficient
PSI × NIR	–0.93
NIR × 0.140 mm sieve threw ratio WHI	–0.82
PSI × 0.140 mm sieve threw ratio WHI	0.81
WHI × 0.140 mm sieve threw ratio WHI	–0.80
PSI × WHI	–0.75
WHI × NIR	0.74

of Czech origin. In year 2001 Czech cultivars have represented only 44% out of evaluated sample collection. The PSI method is very simple and in contrast to similar determination by crushing on a DO-Corder and a meal sieving variable adjustment of the recorder was not necessary.

The measurement range has varied from 10.9 PSI % (hard grain) to 25.9 PSI % (soft grain). Cultivar characteristics of endosperm have been obviously analogous to other methods. A majority of cultivars have had values from 10 to 15 PSI % (harder grain area).

A smaller group of cultivars has become significantly separated with medium soft grain (21 PSI % and more). The results variability has been higher for PSI method (coefficient of variation 28.5%, Table 4) compared with the NIR method (11.64%) evaluating the same collection of cultivars. Two other methods based on crushing using DO-Corder accessory have showed a higher variability described by the coefficient of variation: WHI 38.1% and 0.140 mm sieve threw 40.9% (Table 4). Also in this set of wheat grain hardness measurements (2000–2001) using four methods a relationship has been found between methods similar to the relationship found during 1997–2000. The highest value of correlation coefficient has been found between PSI and NIR methods: $r = –0.93$ (Table 5). The high correlation has resulted from using the PSI method as a reference method for NIR calibration. The hardness calibration was created by an Inframatic producer using a different collection of wheat cultivars and was not adjusted for measurements in this study. Correlation coefficient between 0.140 mm sieve threw ratio and other methods (r = 0.8 for PSI, r = –0.8 for WHI and NIR, Table 5) has been higher compared to WHI and PSI method (r = –0.75) or WHI and NIR method (r = 0.74, Table 5). Nevertheless these other correlation coefficients have had high values. A high connection of measuring using individual methods is documented by the coefficients of correlation $r > 0.74$ or $r > –0.75$, respectively, compare with critical value $r_{\alpha} = 0.413$ on the level of significance $\alpha = 0.01$.

The evaluation of four methods for winter wheat grain hardness determination has showed that all tested methods demonstrated cultivar nature of grain hardness and could be used for the determination of this trait. Measurements by NIR method (Inframatic 8611) and by PSI method have had lower variability of results.

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ABSTRAKT

Hodnocení metod stanovení tvrdosti zrna pšenice

V letech 1997–2001 byla hodnocena tvrdost zrna odrůd ozimé pšenice vybranými metodami: wheat hardness index WHI (DO-Corder Brabender), podíl propadu sítem 0,140 mm PPS (DO-Corder Brabender), tvrdost NIR (Inframatic 8611 Perten), particle size index PSI (LM 3303 Perten). Všechny sledované metody prokázaly genetické (odrůdové) založení znaku tvrdosti zrna a je možné je použít pro stanovení tohoto ukazatele mlynářské jakosti. Variační koeficient byl nejnižší u NIR (12,6 %), u WHI a PPS byl podobný (32,8%, resp. 30,6 %). Významný vliv ročníku byl zjištěn jen u PPS. Mezi ověřovanými metodami byla zjištěna vysoká těsnost vztahů vyjádřená korelačním koeficientem: WHI × NIR (r = 0,84), WHI × PPS (r = –0,79) a NIR × PPS (r = 0,74). V souboru odrůd 2000–2001 byl zjištěn záporný korelační koeficient mezi PSI a NIR (r = –0,93). Variační koeficient u PSI byl 28,5 %.

Klíčová slova: pšenice; tvrdost zrna; metody

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