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Stability and predictability of baking quality of winter wheat

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Abstract. Baking quality of 11 winter wheat varieties was studied at the Jõgeva Plant Breeding Institute during 5 years (2005–2009). Protein content, farinograph absorption, dough stability time and loaf volume were examined in this study. The varieties were divided into clusters according to the average value of quality characteristics and coefficient of variation. Ada, Tarso, Portal, Ramiro had high protein content. Bjorke, Portal, Tarso belonged to the cluster with the highest farinograph absorption. Ada had the highest value of dough stability every year. Ada, Ebi, Compliment, Gunbo, Ramiro, Širvinta 1 and Tarso had higher loaf volume. For all the wheat quality parameters the variety effect was statistically significant but had very small magnitude compared to year effect. For the milling and baking industry, it is desirable that quality traits should be maintained as stable as possible through all environments. Varieties that had lower Cultivar Superiority value usually had higher coefficient of variation. Protein content is commonly used as predictor of baking quality. The correlation existed between protein content and farinograph absorption. Farinograph absorption correlated also with dough stability. Loaf volume had correlation with protein content only in one year out of five.

Key words: winter wheat, baking quality, stability

INTRODUCTION

Hard red winter and spring wheat quality is defined in terms of specific properties that determine suitability for milling and bread production (Finney et al, 1987). Estonian wheat production has been used for the traditional yeast bread baked by long fermentation process. Evaluation of wheat baking quality involves measurement of a large number of properties. **Protein** is a primary quality component that influences the most of wheat grain baking quality characteristics. In hard wheat, the majority of the variation in loaf volume of bread can be attributed directly to differences in protein concentration (Fowler, 2002). Flour protein percentage is a good predictor of loaf volume, which itself is a function of the environmental conditions under which the crop is grown (Simmonds, 1989). Reese et al (2007) found that determination of grain protein is only one test of flour quality and additional information is needed. The physical properties of wheat-flour dough such as extensibility and resistance to extension influence its mixing behaviour very strongly. These properties, called **rheological properties**, are highly heritable (Simmonds, 1989). Rheological tests (farinorgam and extensiogram) are carried out on unfermented dough and can be subdivided into tests, which give information about water absorption, mixing requirements and dough behaviour. **Water absorption** is an important quality factor to the baker as it is related to the amount of bread what can be produced from a given weight of flour. It also has a profound influence on crumb softness and bread keeping characteristics (Tipples, 1986). The baking test is therefore the most useful test available for determining the practical value of a particular flour sample. Traditionally, **loaf volume** has been considered as the most important criterion for the bread-making quality.

Bread-making quality of a variety usually reacts like other quantitative characteristics to favourable or unfavourable environmental conditions and varies its performance. It is unrealistic to expect the same level of performance in all environments (Grausgruber, 2000). For the milling and baking industry, it is desirable that quality traits should be maintained as stable as possible through all environments. There exit different concepts of stability definition. According to static concept (called also as biological) stable genotypes possess unchanged or constant performances regardless of any variation of environmental conditions. A genotype is considered to be stable if its among-environment variance is small (Lin et al 1986). Parameter used to describe this type of stability is coefficient of variability (CV) used by Francis & Kannenberg (1978). This measure depends on the diversity of the environments in the experiments. In the terms of relative stability we compare genotype quality trait with other genotypes in certain environment for using Pi (cultivar performance) value for example. Lin & Binns (1988a; 1988b) defined Pi of genotype i as the mean square distance between genotype (i) and the genotype with the maximum response. The smaller the estimated value of Pi the less its distance to the genotype with maximum value, and thus the better the genotype. (Flores et al, 1998).

The genotypes response to environment is multivariate, yet the parametric approach tries to transform it to univariate problem via stability characters. There is possible to cluster genotypes according to their response structure. This represents shifts from ranking stability by a quantitative measure to assigning genotypes into qualitatively homogeneous stability subset (Lin et al 1986).

The objectives of this study were as follows: evaluation of overall bread-making quality magnitude and stability; find quality differences between the genotypes and the years; find influence of environment and genotype; grouping of the genotypes by quality and finding out correlations between the quality characteristics.

MATERIALS AND METHODS

Baking quality of 11 winter wheat varieties was studied at the Jõgeva Plant Breeding Institute during 5 years (2005–2009). The field trials were carried out in the Estonian traditional production area of wheat and other cereals. The N fertilizer level used was N 90 kg ha^{-1}. Although the plots of varieties in the field were replicated one farinogram and baking test per genotype was performed each year.

Protein content (PC) was determined by Kjeldahl analyses. Farinogram test was conducted using ICC standard method No 115. By farinogram farinograph absorption (FAB) and dough stability time (DST) were measured. Baking tests were carried out by the method of Finnish State Granary (Suomen Valtion ..., 1996). Bread loaf volume (LV) was analysed by measuring the displacement of canola seeds.

All statistical analyses were performed using the Agrobase 4 package and Statistica. Components of variance of ANOVA for each quality characteristic were expressed as percentage (determination index or coefficient of determination R^2) to illustrate the relative contribution of each source to the total variance. Stability analyses of genotypes were based on their coefficient of variation CV and Cultivar Superiority Measure Pi. Cluster analyse (k-means clustering) was used for grouping genotypes according to values of quality traits. Spearman Rank correlation *r* was calculated between quality characteristics.

RESULTS AND DISCUSSION

The **protein content** depended mostly on year, determination index was R^2 = 90,8%, P < 0,001 (Table 1). Similar results concluded Konvalina et al (2009).

Table 1. Determination indexes.

Source of variation	PC	FAB	DST	LV
Year	90.8***	63.6***	49.1***	51.7***
Variety	1.7ns	24.3***	23.3**	17.4*
Residual	7.5	12.1	27.5	31.0

PC = protein content; FAB = farinograph absorption; DST = dough stability time; LV = bread loaf volume. ***,**,* significant at P < 0,001; 0,01 and 0,05 respectively, ns = not significant

Influence of the year was most remarkable also in the investigation with 15 winter and 14 spring wheat varieties in the years 2004–2007 in Estonia (Koppel & Ingver, 2008). The average PC value was 8,7–13,8 % (Table 2) in the different years, which was quite variable result. It is known that wheats of less than about 11% PC are less suitable for breadmaking. The requirements for PC in grain stocking may be even more srtict. The protein content requirements of the Tartu Grain Mill Ltd for the first category wheat is 15% and for the third 12%. The average value was much lower than required for flour in 2005. The higher average PC had the varieties Ada, Lars, Portal and Tarso (Table 3). High protein content had also Ramiro – maximum value 15,0% (data not shown here).

Table 2. Average values of quality traits.

	PC %	FAB %	DST min	LV cm^3
2005	8.7	51.3	1.4	1130
2006	13.8	54.9	9.6	1391
2007	10.9	56.8	4.8	1251
2008	13.1	58.2	4.2	1225
2009	13.2	57.8	5.9	1269
LSD_{05}	0.36	0.72	1.30	42.3

PC = protein content; FAB = farinograph absorption; DST = dough stability time; LV = bread loaf volume

Table 3. Clusters of genotypes according to data 2005–2009.

	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Average PC, %	11.7	11.8	12.2	12.0
CV, %	17.8	14.1	19.8	24.7
Members of cluster	Compliment, Olivin, Širvinta 1	Bjorke, Ebi, Gunbo	Ada, Lars, Portal, Tarso	Ramiro
Average FAB, %	53.9	55.7	57.9	
CV, %	6.7	4.7	5.4	
Members of cluster	Compliment, Gunbo,, Olivin	Ada, Ebi, Lars, Ramiro, Gunbo, Širvinta 1	Bjorke, Portal, Tarso	
Average DST, min	9.5	6.1	3.8	
CV, %	66.4	77.7	46.4	
Members of cluster	Ada	Lars, Portal, Ramiro, Tarso	Bjorke, Ebi, Compliment, Gunbo, Olivin, Širvinta 1	
Average LV, cm^3	1285	1198		
CV, %	9.2	9.2		
Members of cluster	Ada, Ebi, Compliment, Gunbo, Ramiro, Širvinta 1, Tarso	Bjorke, Lars, Olivin, Portal		

PC = protein content; FAB = farinograph absorption; DST = dough stability time; LV = bread loaf volume; CV = coefficient of variation

Ramiro differed from other genotypes by higher than others CV value (Fig. 1). The cluster, where Compliment, Olivin, Širvinta 1 and the cluster with the varieties Bjorke, Ebi and Gunbo had similar PC value but the second group had lower variation according to CV.

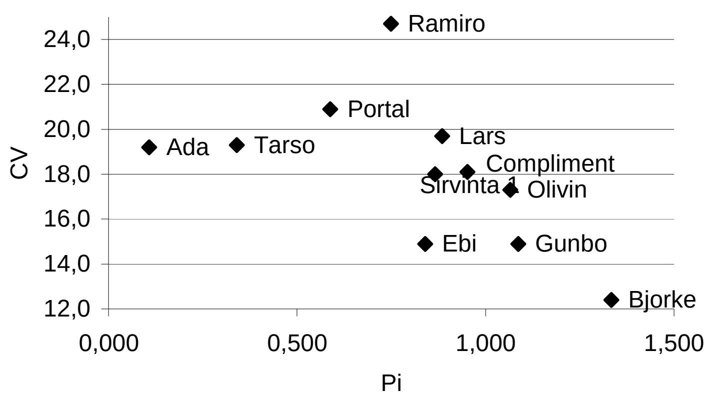

Figure 1. Stability parameters of protein content of the genotypes.

According to the stability analyses Ada, Tarso and Portal had good (low) relative stability value but high static stability value. Usually these varieties had high protein content. But in unfavorable conditions (2005), PC of the high quality varieties remained lower than required by industry.

Farinograph absorption. High absorption values are desirable in bread baking as added moisture slows staling. Higher water absorption also means that less flour is needed to make a loaf of bread. The average FAB was higher in 2008 (58.2%) and lower in 2005 (51.3%). According to Kulhomäki & Salovaara (1985) for yeast bread 55–65% absorption is appropriate. FAB depended on year (R^2 = 63.6%, $P < 0.001$) but the influence of variety was also remarkable (R^2 = 24.3%, $P < 0.001$). Lukow & McVetty (1991) obtained the similar results for spring wheat.

The varieties Bjorke, Portal and Tarso belonged to the cluster with the highest FAB. These varieties together with Ada had also low Pi value (Fig. 2) but thereat Portal and Ada had higher than average CV. It means that these varieties had good FAB but it varied in different years. Olivin, Compliment and Gunbo had lower FAB value than other genotypes and according to the CV value were more variable in different years. PC is often used as indirect indicator of baking quality – higher PC means better baking quality. But no correlation between PC and FAB was determined in this study (correlations are not shown).

Dough stability indicates the time when the dough maintains maximum consistency and is a good indication of dough strength. DST is measure that is expected by baking industry for producing yeast bread. Good quality dough has stability of 4–12 min (Kulhomäki & Salovaara, 1985). Satisfactory DST is about 6 min by Tartu Grain Mill Ltd (personal conversation). For the industrial dough mixing equipment too short or too long mixing time is not desirable. Flours having short mixing time are problematic in baking technology that involves long fermentation, as they are less tolerant to over-mixing and over fermentation. The average DST varied between 1.4 min (2005) and 9.6 min (2006).

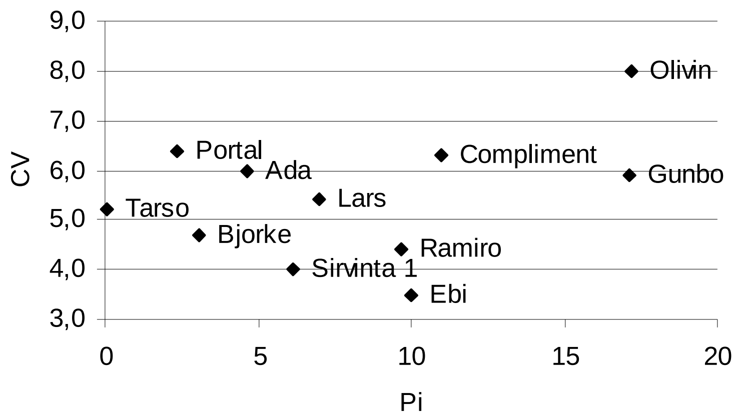

Figure 2. Stability parameters of farinograph absorption of the genotypes.

Variation between the varieties was more remarkable in the years when the average DST was higher – in 2006 and 2009 (data not shown here). Ada had the highest value of DST every year and therefore also low Pi value (Fig. 3). Lars, Portal, Ramiro and Tarso belonged to the cluster with average DST value whereby Lars, Portal and Ramiro had the highest CV value. According to this study Ada and Tarso seems to be varieties, which have good balance between stability and DST.

As it was with other quality traits, DST depended more on year (R^2 = 49.1%, P < 0.001 but influence of a genotype was also reliable (R^2 = 23.3%, P < 0.01). Genotype effect by Ji-Chun et al (2007) was the most noticeable followed by the interaction of the genotype and the environment and the environmental effect was the least significant. Reese et al (2007) investigated the correlation between flour quality, dough stability and protein content. There aim was to assess the possibility to predict flour quality by protein content. In our experiment there was strong correlation between PC and DST (r = 0.90, P < 0.001). Good correlation means that DST is predictable if we know the PC of the variety. Relation was found also between DST and FAB (r = 0.69, P < 0,05 (data not shown here).

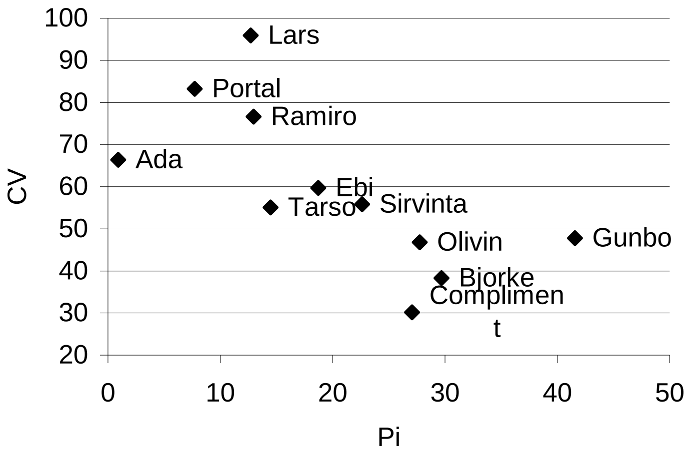

Figure 3. Stability parameters of dough stability time of the genotypes.

Baking test is the final criterion of quality. **Volume of the loaf** is generally taken as the best single factor on which judgement is based. Flour with good baking quality has to give 500–600 cm³ loaf volumes per 100 g flour (Lepajõe, 1984). It means 1250–1500 cm³ per 250 g as it was in our study. LV, as other characteristics, was mostly depending on the year (R^2 = 51.7% P < 0.001), influence of the variety was only R^2 = 17.4%, P < 0.05. The average LV was higher in 2006 (1391 cm³). In two years out of five the average LV was lower than 1250 cm³, it was extremely low in 2005 (1130 cm³). Only Compliment and Ebi had loaf more than 1200 cm³ in this year (data not shown here). By stability analyses was proved that Širvinta 1, Ramiro, Ebi and Gunbo had good balance between static and relative stability – CV and Pi, both were lower than average (Fig. 4). Compliment, Tarso and especially Ada had good relative stability Pi but high static stability CV. Interesting result is that the variety Gunbo was exceptional, belonging to the group of high quality varieties according to the PC, FAB and DST, but anyway had good LV.

Cluster analyse showed that there are two distinctly differentiated variety groups according LV data. Every year bigger loaf had Ada, Compliment, Ebi, Gunbo, Širvinta 1 and Tarso. According to Fowler (2002) in hard wheat, the majority of the variation in

LV of bread can be attributed directly to differences in PC. Johansson & Svensson (1998) found that the correlation between PC and bread volume is not significant in wheat genotypes with large differences in protein quality. LV in our investigation correlated with PC only in 2007 (r = 0.65, P < 0.05). There was no association between LV and quality traits in other years and also between five-year average data.

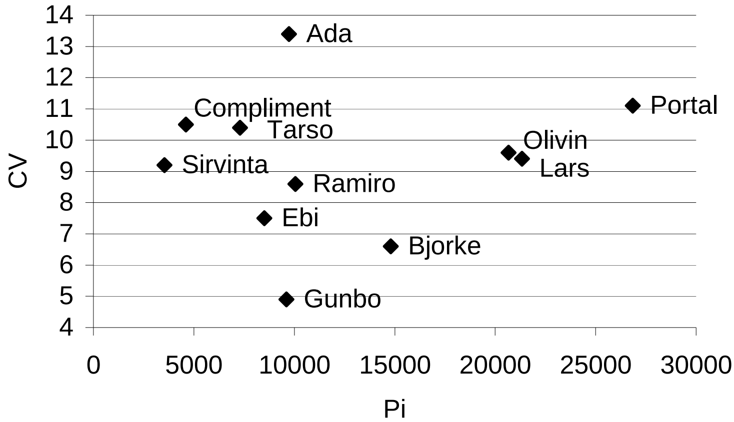

Figure 4. Stability parameters of loaf volume of the genotypes.

It seems that the results of this study carried out in Estonian conditions were not in accordance with the statement about positive correlation between PC and LV. According to Peterson et al. (1998) for many baking parameters, variation attributed to environmental effects had greater magnitude than for genotype of winter wheat and correlations of protein components with baking parameters were generally low. According to Wieser & Kieffer (1999) bread volume was influenced more by the amount of gluten proteins than by the total amount of protein.

CONCLUSIONS

For all the wheat quality parameters examined in this study, the influence of year was confirmed on higher level for all the evaluated baking quality characteristics compared with the variety effect. The most important was influence of year to protein content. In one year out of five baking quality of winter wheat was much lower than minimum level needed for making yeast bread.

For estimating stability of quality traits Cultivar Superiority Measure and coefficient of variation were used. There was tendency that varieties that had low Cultivar Superiority Measure had high coefficient of variation. If the climate change means also more unstable and unpredictable weather in growing period of wheat, varieties with more stable quality traits are recommended. Good balance between static and relative stability is important.

There was strong correlation between dough stability time and protein content. Dough stability correlated also with farinograph absorption. Loaf volume had correlation with protein content only in one year out of five. Predictability of loaf volume by other quality characteristics was low in this study.

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