Effects of Location and Year on Technological Quality and Pentosan Content in Rye

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Abstract

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Four year trials were undertaken to study the milling and baking rye quality, the hybrid variety Picasso and population varieties Dankowskie nowe and Selgo having been examined coming from three different locations of the Czech Republic. The variety significantly ($P < 0.01$) influenced the specific weight, grain size, amylograph maximum, and grain yield. The year of harvest significantly ($P < 0.01$) influenced the thousand grain weight, maltose content, protein content, amylograph maximum, and grain yield. The location significantly ($P < 0.01$) influenced the thousand grain weight, protein content, amylograph maximum, and grain yield. The highest pentosan content (average of the four years and three locations) was achieved by the hybrid variety Picasso (8.04%), which had the highest Falling number (232 s) as well as amylograph maximum (597 AU). The location Hradec nad Svitavou proved to be the best (8.02% pentosans) while the year 2005 (8.34% pentosans) was the most positive. A positive correlation ($P < 0.05$) was found between the pentosan content and the Falling number.

Keywords: rye; technological quality; pentosans; variety; year; location

More than 90% of the total world rye production comes from Europe where the production and breeding centres are situated in eastern, central, and northern regions of Europe.

Rye is adapted to less fertile and climatically less favourable conditions. It also sustains sandy soils, is winter and frost resistant and tolerant to worse preceding crops. Therefore, its yields are higher than those of wheat under such conditions (Pelikán *et al.* 1998; Petr *et al.* 1999). Rye exhibits a higher resistance to fungal diseases and lower production of *Fusarium* mycotoxins. The most important qualitative disadvantage is enzymatic degradation of starch caused by sprouting, which negatively affects bread making (Münzig 2007). Such starch is not able to absorb the water released in dough which results in sticky crumb, often with cracks, and frequently with streaks in the lower crust (Pelikán 2007).

In the Czech Republic, rye is grown as a winter form mostly for the use as food, which accounts for 90%. At present, nine rye cultivars are registered in the CR, five of which are population and four hybrid cultivars (Horáková *et al.* 2007).

Technological quality and, to a certain extent, nutritional quality of rye are, similarly to other cereals, affected by growing, climatic and soil conditions, and actual weather course, whereas rye cultivars differ less from one another than those of wheat. The milling and baking quality of rye is different from that of wheat.

The milling quality is determined by the specific weight, thousand grain weight (TGW), percentage of 2.2-mm sieving grain fraction (grain size), appropriate endosperm texture properties (grain hardness), ash content, and ease of flour extraction. The rye grain is smaller and more resistant to milling (rye is milled with stronger press) because of a tougher connection of the coat layers with endosperm. Due to the lower proportion of endosperm, the flour yield from rye is decreased. Rye flour is darker, with a higher ash content (Příhoda *et al.* 2003).

For the baking quality of rye, which is different from that of wheat, the saccharide amylase complex is of crucial importance. It is composed of starch, sugars, and related enzymes, and the effects of non-starch polysaccharides – pentosans and a certain effect of protein-protease complex are also involved. Pentosans, rather arabinoxylans, are the major non-starch polysaccharides and can be divided into water extractable pentosans (WEP) and water unextractable solids (WUS), which are comprised in the 25:75 ratio. Some of the arabinose side-chains are esterified with phenolic acids, mostly ferulic acid (Izydorczyk & Biliaderis 1995), which is involved in the oxidative cross-linking form as published by Izydorczyk *et al.* (1990). It is reported that WEP decrease the dough extensibility and in wheat also the gluten extensibility, which is ascribed to ferulic acid (Wang *et al.* 2002).

Even though rye flour has a lower protein content than wheat flour, rye proteins are characterised by a higher biological value due to a higher percentage of soluble fractions (35–45%) as published by Kučerová (2001).

Rye bread in our food contributes to increased percentage of pentosanes, which exert a protective effect on mucous membrane of intestines and contribute to blood cholesterol regulation (Příhoda 2005). With regard to healthy human nutrition, supplements of rye and rye milling products to yeast-leavened bakery products are important (Brümmer 2005b), moreover, they also improve their sensoric value. Other improving traits are a longer durability (shelf live), compact crumb, and excellent taste (Zentgraf *et al.* 2005; Zentgraf 2008).

MATERIAL AND METHODS

We obtained samples of hybrid variety Picasso and population varieties Dankowskie nowe and Selgo between 2002 and 2005. The selected set of rye varieties came from different locations in the Czech Republic. Rye grain samples used for laboratory evaluation were obtained from the variety test stations of the Central Institute for Supervising and Testing (ÚKZÚZ): Hradec nad Svitavou (HRA), Krásné Údolí (KUD), and Staňkov (STA) (in the year 2002 only from two locations, Hradec nad Svitavou and Krásné Údolí). This guaranted that the field testing would be done using consistent methodology. The samples of rye grain were analysed at the Department of Food Technology, Mendel University of Agriculture and Forestry in Brno, pentosans in the Research Institute of Brewing and Malting in Brno.

The location Hradec is situated in a potato producting region 450 m above sea level, the average annual air temperature is 7.4°C, annual sum of precipitation 616 mm. The type of soil is orthic luvisol and this soil is clayey-loam (heavy). The location Krásné Údolí is situated in a forage producting region 647 m above sea level, with the average annual air temperature 6.3°C and annual sum of precipitation 602 mm. The type of soil is eutric cambisol and this soil is loamy-sand (light). The location Staňkov is situated in a cereals producting region 370 m above sea level, the average annual air temperature being 8.1°C and annual sum of precipitation 537 mm (according to the long term average). The type of soil is orthic luvisol and this soil is loamy (medium).

Picasso was registered in the Czech Republic in the year 2001. It is a semi-late hybrid variety suitable for all regions, less resistant to lodging and rye rust. Dankowskie nowe is the oldest certified population variety which was registered in 1977. It is medium-early, winter resistant variety, resistant to lodging, suitable for more intensive conditions. Selgo is a later population variety of 1997 suitable for all regions of the Czech Republic.

We evaluated 8 characteristics, which determine the technological quality (milling and baking) of rye. The analyses were carried out using Czech Standards (ČSN) identical with those of the European Union and methodological procedures ICC. Conprised were the grain analyses (thousand grain weight in g, specific weight in kg/hl, grain size, i.e. percentage of grain size 2.2 mm in %), protein content (after Kjeldahl) in % according to the Czech Standard ČSN 46 1011, analyses according to the Czech Standard ČSN 560512 (maltose content in %), Falling number in s after the Czech Standard ISO 3093, amylograph analysis in AU after ICC 148.

Table 1. Significance (ANOVA) (2002–2005)

Source of variability	TGW	Specific weight	Grain size	Falling number	Maltose	Protein content	Amylograph max.	Pentosans	Grain yield
Variety	*	**	**	NS	NS	NS	**	NS	**
Year	**	*	*	NS	**	**	**	NS	**
Location	**	NS	NS	NS	*	**	**	NS	**

NS – not significant; *,**significant at the 0.05 or 0.01 probability levels

Determination of pentosan content. The content of pentosans was assessed by spectrophotometry method according to Cracknell and Moye (1970) in the modification by Douglas (1981). Orange-red colour intesity was measured at A_{510} and A_{552} (Havlová *et al.* 2001).

Statistic evaluation. Analysis of variance of multiple classifications was used for the results evaluation and the LSD method at 95% for more detailed evaluation. The results were processed in the programme Unistat, version 4.53 (Unistat Ltd., London, England). The numerical results obtained were processed by the correlation analysis to find out the correlations between the traits of the grain quality.

RESULTS AND DISCUSSION

Analysis of variance (Table 1) confirmed highly significant effects of varieties on the specific weight, grain size, amylograph maximum, and grain yield, and significant effects on TGW. No effects of varieties on other technological characteristics examined were found. The year of harvest influenced highly significantly ($P < 0.01$) the TGW, maltose content, protein content, amylograph maximum, and grain yield, significantly ($P < 0.05$) the specific weight and grain size. It did not affect the Falling number and pentosan content. In the overall evaluation, the year 2004 was the best in five characteristics and the year 2003 in three characteristics.

Location influenced highly significantly ($P < 0.01$) the TGW, protein content, amylograph maximum, and grain yield, significantly ($P < 0.05$) the maltose content. No effect of the location on other technological characteristics examined was found.

The results of LSD method with mean values are presented in Table 2. In further tests, significant differences were found in TGW between the years 2003 and 2004, 2004 and 2005, between the population variety Selgo and hybrid Picasso, and between Krásné Údolí and Staňkov locations. In specific weight, a significant difference was found between the years 2003 and 2005, and between the population varieties and the hybrid Picasso. The percentage of grain size 2.2 mm significantly differed between the years 2003 and 2005, 2004 and 2005, and between the population variety Selgo and hybrid Picasso. In the Falling number, a significant difference was confirmed only between the location of Hradec nad Svitavou and Krásné Údolí. The differences were not substantial between either the individual varieties or the years which means they were insignificant. The maltose content was significantly affected by the year, which was documented by the differences between 2002 and 2004, 2003 and 2004, 2003 and 2005, 2004 and 2005, and between the locations of Hradec nad Svitavou and Krásné Údolí. In the protein content, significant differences were found between the years 2002 and 2003, 2004, 2005, and 2003 and 2004. The location of Staňkov significantly differed from the other two locations, Hradec nad Svitavou and Krásné Údolí. Amylograph maximum significantly differed between the years 2002 and 2003, and between the population varieties and the hybrid variety Picasso. The pentosan content significantly differed only between the years 2002 and 2005. In the grain yield, significant differences were found between the years 2002 and 2004, 2003 and 2004, 2004 and 2005, and between the population varieties and the hybrid variety Picasso. The results indicated particularly the effect of the weather conditions in individual experimental years on most quality characteristics of rye, which is also in correspondence with a number of other authors' findings (Hýža 1990; Münzig 2007; Kučerová 2008).

Both population varieties had higher TGW (Dankowskie Nowe 30.8 g, Selgo 32.6 g), specific weight

Table 2. Significance of the effect of year, variety, and location in all quality parameters in 2002–2005

Parameter	TGW (g)	Specific weight (kg/hl)	Grain size (%)	Falling number (s)	Maltose (%)	Protein content (%)	Amylograph. max. (AU)	Pentosans (%)	Grain yield (t/ha)
Year									
2002	30.6^{ab}	73.6^{ac}	92.3^{ab}	190^{a}	2.01^{ac}	7.57^{a}	310^{a}	7.41^{a}	6.67^{a}
2003	30.0^{b}	74.7^{ac}	92.4^{a}	189^{a}	1.80^{a}	10.39^{c}	550^{b}	7.76^{ab}	5.96^{a}
2004	33.7^{a}	76.2^{ab}	93.1^{a}	221^{a}	1.46^{b}	9.13^{b}	344^{ab}	8.04^{ab}	8.71^{b}
2005	29.7^{b}	73.6^{c}	90.2^{b}	208^{a}	2.13^{c}	9.23^{b}	346^{ab}	8.34^{b}	6.84^{a}
Variety									
Dank. nowe	30.8^{ab}	75.6^{a}	92.2^{ab}	192^{a}	1.81^{a}	9.39^{a}	315^{a}	7.87^{a}	6.69^{a}
Selgo	32.6^{a}	75.4^{a}	93.2^{a}	183^{a}	1.92^{a}	9.44^{a}	272^{a}	7.88^{a}	6.85^{a}
Picasso	29.7^{b}	72.8^{b}	90.5^{b}	232^{a}	1.78^{a}	8.82^{a}	597^{b}	8.04^{a}	8.09^{b}
Location									
HRA	30.9^{ab}	75.6^{a}	92.4^{a}	235^{a}	1.73^{a}	8.52^{a}	478^{a}	8.02^{a}	7.7^{a}
KUD	32.7^{a}	74.4^{a}	92.5^{a}	171^{b}	2.02^{b}	8.54^{a}	314^{a}	7.85^{a}	6.8^{a}
STA	28.9^{b}	73.5^{a}	90.8^{a}	201^{ab}	1.73^{ab}	11.04^{b}	390^{a}	7.91^{a}	6.6^{a}

Means within the groups (year, variety, location) followed by the same letter are not significantly different ($P \le 0.05$, LSD test)

Table 3. Pearson correlation (r) beetwen quality parameters of rye and grain yield

Parameter	TGW	Specific weight	Falling number	Maltose	Protein content	Amylograph maximum	Pentosans	Grain yield
TGW	1.000							
Specific weight	0.469**	1.000						
FN	0.153	–0.051	1.000					
Maltose	–0.233	–0.280	–0.392*	1.000				
Protein content	–0.285	–0.040	0.051	–0.142	1.000			
AM	–0.178	0.128	0.572**	–0.411**	0.047	1.000		
Pentosans	0.056	–0.271	0.362*	0.137	0.134	–0.024	1.000	
Grain yield	0.280	0.130	–0.465**	–0.449**	–0.340*	0.238	0.251	1.000

*$P < 0.05$ (significant), **$P < 0.01$ (highly significant)

(Dankowskie Nowe 75.6 kg/hl, Selgo 75.4 kg/hl), percentage of grain size 2.2 mm (Dankowskie Nowe 92.2%, Selgo 93.2%) ($P \leq 0.05$), and protein content (9.39%, 9.44%), even though statistically insignificant, and lower though statistically insignificant Falling number (192 s, 183 s), pentosan content (7.87%, 7.88%), and amylograph maximum (315 AU, 272 AU) ($P \leq 0.05$). They were also characterised by lower yields (6.69 t/ha, 6.85 t/ha) ($P \leq 0.05$) and higher maltose contents (1.81%, 1.92%) though statistically insignificant.

The hybrid variety Picasso had the lowest TGW (29.7 g), specific weight (72.8 t/ha), and percentage of grain size 2.2 mm (90.5%). The maltose content of 1.78% corresponded with the Falling number of 232 s, characterised by a higher resistance to enzymatic activity, which was confirmed by the amylographic value of 597 AU documenting better baking characteristics.

Pearson's correlation coefficients were calculated between the examined technological characteristics, including pentosans and the grain yield (significance at α = 0.05 and α = 0.01) (Table 3). Highly significant positive correlations were confirmed between the specific weight and TGW, Falling number and amylograph maximum, and highly significant negative correlations between the yield and Falling number and maltose content, and a negative significant correlation with protein content, i.e. the higher grain yield, the worse technological characteristics.

Regression analysis demonstrated a relationship of the pentosan content with the Falling number. The correlation coefficient ($r = 0.3623$) and regression line (Figure 1) show an apparent significant positive relationship. This result is in agreement with the findings of Weipert *et al.* (1995) who found that the Falling number increased with the

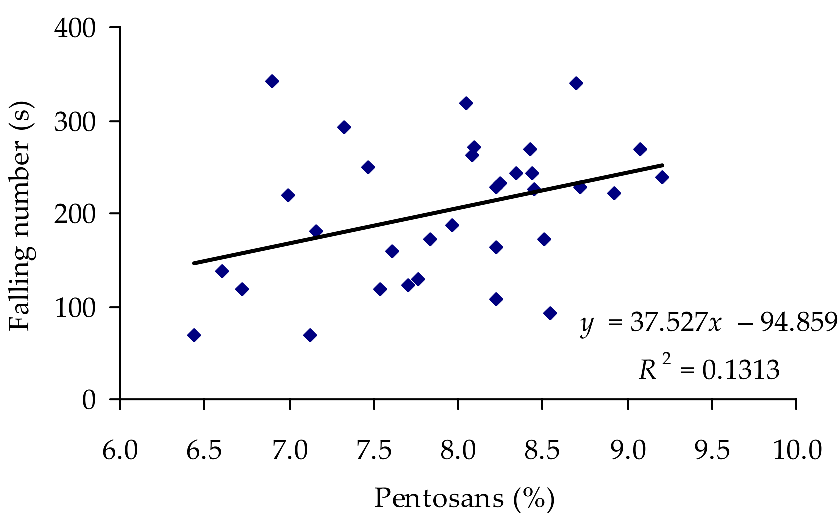

Figure 1. Dependence between pentosans content and Falling number

pentosan content. The negative correlation of this parameter with the Falling number reported by Saastamoinen *et al.* (1989) was probably related to the population varieties that have usually lower values of the Falling number, which is also documented by our results.

The ratio between the soluble and insoluble pentosans is also important (Brümmer 2005a). A higher percentage of water unextractable pentosans leads to increased values of the Falling number of rye flour, whereas higher percentages of extractable pentosans do not affect the Falling number directly but rather the values of amylograph maximum.

The results of evaluation and statistical analysis suggest that the rye variety does not apparently influence the grain quality because the differences between varieties, and particularly of the same type, are small. The differences in quality characteristics of both population and hybrid varieties are caused by the weather conditions, particularly during the kernel development and maturation, and by the location as reported also by Beneš (2005), Petr and Mikšík (2006), and others.

Our results show that most quality characteristics examined are affected particularly by the year. The most suitable conditions for growing rye with the best milling-baking quality are in the potato producting region. This result is in agreement with the findings of Hýža (1990) and Petr *et al.* (1999).

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