RELATIONSHIPS BETWEEN THE RYE QUALITY FACTORS

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Abstract: The processing value of the grain can be predicted by combining measurements made from grain, flour, or dough and combining them into prediction models. This study evaluated the correlations between grain rye quality factors: proximate structural and compositional particularities, endosperm matrix protein, and milling performance. Those three factors, derived from the orthogonal transformation of the matrix, were retained to explain 91.8% of the variation according to eigenvalues. Twelve samples of rye have been analysed: four rye varieties (*Orizont*, *Suceveana*, *Gloria* and *Impuls*) from the crop years 2004, 2005, 2006.

Keywords: *rye, quality factors, correlation coefficient, Mixolab*

INTRODUCTION

The processing value of the grain (wheat, rye) can be predicted by combining measurements made from grain, flour, or dough and combining them into prediction models [7].
For prediction of the bread quality of the wheat, grain or flour protein content is the most important, but the model could be improved slightly by adding measures of dough

strength, absorption, protein quality, or viscoelastic properties. Dowell et al. [7] measured the relationship between bread quality and grain, flour, and dough quality characteristics. The estimated bread quality attributes included loaf volume, bake mix time, bake water absorption, and crumb grain score. The best-fit models for loaf volume bake mix time, and water absorption had R^2 values of 0.78 – 0.93 with five to eight variables [7]. The loaf volume could be predicted with accuracies adequate considering the variables that could be rapidly measured (protein content, test weight, single kernel moisture content, single kernel diameter, single kernel hardness, bulk moisture content, and dark hard and vitreous kernels). Tronsmo et al. [12] analysed the relationships between wheat protein quality and baking properties. The strain hardening index obtained from dough inflation measurements, the proportion of unextractable polymeric protein, and mixing properties were among the variables found to be good indicators of protein quality and suitable for predicting potential baking quality of wheat flours. The accuracy of using near-infrared spectroscopy (NIR) for predicting grain, milling, flour, dough, and breadmaking quality parameters of hard red winter and hard red spring wheat was evaluated by Dowell et al. [6]. The results showed that near-infrared spectroscopy can be used to predict many grain quality and functionality traits, but mainly because of the high correlations of these traits to protein content.

The constituents of the rye that has special significance to baking quality are pentosans and enzymes. High pentosans content and high amount of water extractable pentosans are beneficial for rye bread processing, but detrimental for feed purposes [13]. Resistance to pre-harvest sprouting is considered the most important condition for baking quality rye, but important are the proteins and especially the pentosans and their corresponding enzymes [9]. Weipert [13] used, for the rye, a scheme that combining the information of main agricultural (grain yield and resistance to sprouting), the quality characteristics (falling number, amylogram, protein and pentosan contents), the milling performance (1,000 kernel weight, flour yield), and the baking performance (dough yield, loaf volume, crumb elasticity and overall score). These characteristics were scored in 9 classes (very low to very high pronounced). Weipert considered that the relevant quality factors of the rye processing are the pentosan contents, particularly with the amount of water extractable pentosans.

Repeikiene et al. [10] developed a method for characterization of the degree of dispersion and follow the behaviour of a rye meal suspension. The amount of adhesive material present during heating from 45 °C to a maximum of 62.1 – 67.1 °C was measured. The adhered material depended on the rye chemical composition and these changes might not be observed by viscography. The analyzed temperature range is optimal for enzyme pentosanase activity. As described elsewhere, the amylograph is not very sensitive to small changes in relative viscosity. Thus, the methods used by Repeikiene et al. can be considered a new opportunity for the assessment of rye for breadmaking.

For a correct estimation of baking quality of rye, the understanding of the relationships between grain quality factors is necessary. In this paper we evaluated the correlations between grain rye quality factors, proximate chemical composition, physical and technological properties. Factors analysed included test weight, 1,000 kernel weight, density, vitreous kernel, protein content, water absorption index, water extractable pentosans, falling number, specific bread volume, gelatinization, and starch retrogradation.

MATERIALS AND METHODS

Materials

Twelve samples of rye have been analysed: four variety rye (*Orizont*, *Suceveana*, *Gloria* and *Impuls*) from crop years 2004, 2005, 2006.

Methods

The methods used were:
- test weight through the SR ISO 7971-2 : 1995 method [17];
- 1,000 kernel weight was determined for each sample by weighing 100 randomly selected, unbroken kernels to within 0.01 g and multiplying the result by 10;
- density through the pycnometer method [8];
- vitreous kernel according Godon and Willm [8];
- protein content through the NIR technique according ICC 195-1995 method [18];
- water absorption index according Buffo et al. [1];
- water extractable pentosans according Hashimoto method modify by Delcour [4];
- falling number through the AACC 56-81B method [14];
- specific bread volume, cm^3/100 g bread through the SR 91-2007 method [17];
- gelatinization, and starch retrogradation through the Mixolab Chopin method [15, 16]. Mixolab analysis was carried out at the water absorption level determined by the Alveograph using the AACC 54-30 method [14]. For the analysis of the mixing and pasting behaviour, the standard Chopin+ protocol was followed: initial equilibrium at 30 ºC for 8 min, heating to 90 ºC over 15 min (at a rate of 4 ºC/min), holding at 90 ºC for 7 min, cooling to 50 ºC over 5 min (at a rate of 4 ºC/min) and holding at 50 ºC for 5 min. The mixing speed was kept constant at 80 rpm C3, C4, C5 representing the end points of the corresponding mixing stages: C3 (N.m) – peak torque, expresses the starch gelatinization; C4 (N.m) – indicates the stability of the starch gel formed; C5 (N.m) – measures the starch retrogradation during the cooling stage.

Statistical analysis

Descriptive statistics (mean, standard deviations, range and coefficients of variation), correlation coefficients and principal component factor analyses with varimax rotation [11] were performed by using the package Statistica for Windows 4.3.

RESULTS AND DISCUSSION

Statistical parameters for the quality factors are presented in Table 1. The correlation coefficients between the quality factors are shown in Table 2. Table 3 shows the results of principal components analyses through the correlation matrix. Three factors, derived from the orthogonal transformation of the matrix, were retained to explain 91.8% of the variation according to eigenvalues: Factor 1 – 52.4%; Factor 2 – 22.9% and Factor 3 – 16.3%.

***Table 1.** Descriptive statistics for rye quality factors*

Factors	Mean ± SD*	Range	CV** (%)
Test weight (TW) [$kg.hL^{-1}$]	75.15 ± 0.700	74.20 – 76.10	0.93
1,000 kernel weight (TKW) [g]	28.63 ± 0.940	27.50 – 30.00	3.28
Density (D) [$g.cm^{-1}$]	1.151 ± 0.033	1.11 – 1.21	2.86
Vitreous kernel (VK) [%]	34.3 ± 11.430	20.00 – 56.00	33.32
Rotein (P) [%]	10.39 ± 1.013	9.00 – 11.70	9.74
Water absorption index (WAI) [%]	1.248 ± 0.077	1.15 – 1.38	6.16
Water extractabele pentosans (WSP) [%]	1.862 ± 0.104	1.72 – 2.04	5.58
Falling number (FN) [s]	223 ± 11.700	200.00 – 238.00	5.24
Bread specific volume (VSP) [$g.cm^{-1}$]	1.83 ± 0.126	1.64 – 2.00	6.88
Peak torque (C3) [N.m]	2.28 ± 0.043	2.22 – 2.35	1.88
Starch retrogradation (C5-C4) [N.m]	0.63 ± 0.018	0.60 – 0.66	2.85

*SD = standard deviation; **CV = coefficient of variation

***Table 2.** Correlation coefficients between rye quality factors*

Factors	TW	TKW	D	VK	P	WAI	WSP	FN	VSP	C3	C5-C4
TW	1.00										
TKW	**0.92***	1.00									
D	0.03	0.22	1.00								
VK	-0.23	0.03	**0.81**	1.00							
P	0.17	0.29	0.56	**0.75**	1.00						
WAI	0.14	0.12	-0.19	0.22	0.47	1.00					
WSP	-0.42	-0.24	-0.14	0.39	0.36	**0.69**	1.00				
FN	-0.31	-0.12	-0.07	0.48	0.56	0.61	**0.89**	1.00			
VSP	-0.46	-0.29	-0.25	0.28	0.21	**0.65**	**0.98**	**0.84**	1.00		
C3	0.32	0.13	0.11	-0.44	0.50	**0.68**	**0.95**	**0.97**	**0.91**	1.00	
C5-C4	-0.33	-0.15	-0.19	0.32	0.47	0.55	**0.89**	**0.95**	**0.84**	**-0.93**	1.00

*bold marked correlations are significant at $p < 0.05$ level

***Table 3.** Loadings for rotated factors of the correlation matrix for rye factors*

Factors	Factor 1	Factor 2	Factor 3
Eigenvalue	5.77	2.52	1.79
Proportion	52.49	22.97	16.33
Cumulative proportion	52.49	75.46	91.80
TW	-0.22	-0.06	**-0.97**
TKW	-0.09	0.14	**-0.93**
D	-0.24	**0.95**	-0.03
VK	0.30	**0.92**	0.10
P	0.44	**0.74**	-0.33
WAI	**0.78**	-0.01	-0.33
WSP	**0.95**	0.06	0.20
FN	**0.94**	0.20	0.09
VSP	**0.92**	-0.05	0.26
C3	**0.97**	-0.14	-0.09
C5-C4	**0.92**	0.06	0.11

It was confirmed the significant direct correlation between some analysed quality factors well-known for wheat [8]. So, between test weight and 1,000 kernel weight, and between density and vitreous kernel were obtained the significant direct correlations (Table 2). The vitreous kernel was highly direct correlated with protein content. High variation in vitreous kernel and protein content may be partly explained by climate, soil composition, fertilizer application, and agronomic practices. The same explanation can be considered for the variation of the water extractable pentosans, the falling number value.

The content of water extractable pentosans was direct correlated with water absorption index, owing-to the high water holding capacity. For the water extractable pentosans the retention of 3.5-6.3 times their weight in water has been reported [3].

The bread specific volume was highly direct correlated with the water extractable pentosans. This correlation is explained through the capacity of the water extractable pentosans to the increase the stability of the films that surround the carbon dioxide gas bubbles, and the stability and the resistance to the pressure in the oven, preventing their coalescence [3]. In this stabilisation important is the coupling of two ferulic acid residues, or ferulic acid and protein, through a covalent bond.

The correlation between peak torque (C3) and falling number was good (0.97, $p < 0.05$). Repeckiene et al. [10] found that high falling number values corresponded to high viscosity values obtained from the viscograms, the correlation being 0.87.

The bread specific volume correlated well with the peak viscosity and the starch retrogradation.

The peak torque is direct correlated with water extractable pentosans (0.95, $p < 0.05$). The presence of water extractable pentosans influenced the viscosity because they are able to form gels by covalent cross-linking of arabinoxylans chains through coupling of two adjacent ferulic acid residues [5].

Three factors, derived from the orthogonal transformation of the matrix explain 91.8% of the variation according to eigenvalues.

Factor 1, which was called the structural and compositional particularities of the rye kernel, was influenced positively by water extractable pentosans contents, high hygroscopicity of the kernel, falling number value, and the behaviour of the flour constituents at different temperatures. It can be considered that the chemical composition of rye may be a good indicator of its baking quality [2].

Factor 2, which was called endosperm matrix protein, was influenced positively by protein, vitreous kernel and density.

Factor 3, which defined the milling performance, was negative correlated with test weight and 1,000 kernel weight; by rye milling the extraction of the white flour is lower than wheat. According to Bushuk [2] the high TKW do not always indicate a high flour extraction for rye; he is considering that there is no relation between TKW and baking quality.

Principal component factor analyses reinforced the relationships among quality factors derived from the correlation matrix, since the components with the highest eigenvalues closely followed the trends initially derived using simple correlation coefficients [1]. Primary among the relationships were the increase of the bread specific volume with increasing water extractable pentosans content, falling number value, and peak viscosity of the flour-water slurry.

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