The Relation between Dough Rheology and Bread Crumb Properties in Winter Wheat

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Summary

The present paper is focused on rheology dough properties of winter wheat cultivars in relation to bread crumb properties. The rheological characteristics of wheat flour were evaluated by using Farinograph and Extensograph tests. The image analysis for bread crumb grain assessment was applied as alternative technique for more rapid and efficient measurement of bread characteristics. The highest significant positive correlation ($P<0.05$) was found between bread crumb properties and extensographic parameters: dough energy, maximum dough resistance and resistance to extensibility ratio. Cultivars 'Klara', 'Barbara', 'Žitarka' and 'Golubica' have shown finer and uniform bread crumbs with regard to optimal dough physicochemical characteristics.

Key words

bread; dough rheology; bread crumb properties; image analysis

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Introduction

The bread-making quality of wheat is strongly affected by gluten characteristics. Sufficient expansion and good distribution of the gas cells within dough depend on degree of the gluten strength and extensibility (Veraverbeke and Delcour, 2002; Prabhasankar et al., 2002; Lasztity, 2003). Bread crumbs and their properties depend on wheat cultivar, fermentation conditions, baking and storage parameters (Giovanelli et al., 1997; Magdić et al., 2006; Karaoglu, 2006). Different tests as farinograph, extensograph, alveograph and mixograph can be used to provide an assessment of gluten quality through determination of physical dough properties. For the evaluation of wheat end use quality the bread crumb properties are certainly one of the most important. In general, the gluten quality is inherent in a genotype and is not greatly affected by environmental conditions or cultural practices. In assessment of bread crumb the image analysis has been used as an objective and highly confident method (Zayas, 1993; Zghal et al., 1999, 2001; Magdić et al., 2004).

For applying image analysis in bread crumb evaluation, bread loaves should be correctly sliced and slices must be properly illuminated for obtaining objective results of image analysis. Later image processing is optional and depends on a sample area that can be rectangular medium part or total surface of a slice. Finally, main bread crumb attributes can be evaluated by computer programs based on different algorithms (Heijden, 1998; Zghal et al., 1999; Crowley et al., 2002; Gallagher et al., 2003).

Material and methods

Cultivars 'Žitarka', 'Srpanjka', 'Barbara', 'Klara', 'Golubica', 'Kata', 'Monika', 'Ana', 'Demetra', 'Divana' and 'Sana' were grown in the experimental field of the Agricultural Institute Osijek in 2001 and 2002. The experiment was set up as Randomized Complete Block Design (RCBD) with three replications. Cultural practices were as recommended for optimum wheat production in this area. All plots were machine-planted and harvested. Rheological dough properties and bread crumb properties of the eleven cultivars were analyzed on samples pooled over replications.

The water absorption of flours and the mixing behaviour of dough, made from them, were determined by using Brabender Farinograph (Brabender, Duisburg, Germany) in accordance with HRN ISO 5530-1:1999. Farinogram evaluation was performed using software Brabender Farinograph for Windows ver. 2.3.7. The stretching and elasticity characteristics of dough were measured by Brabender Extensograph (Brabender, Duisburg, Germany) according to HRN ISO 5530-2:1999. Extensogram evaluation was automatically performed using software Brabender Extensograph for Windows ver. 2.1.5. All analyses were done in duplicates. Data analysis was performed using SAS Stat Software ver. 8.2. Baking test was done according to ICC No 131. This method is applicable for untreated flour, experimentally or commercially milled from wheat for the production of yeast raised bread.

In preparing for quality assessment by image analysis, bread loaves were sliced in the middle, providing two cross sections. Slices were properly illuminated (700 lux) by low voltage, halogen, and indirect illumination with four lamps.

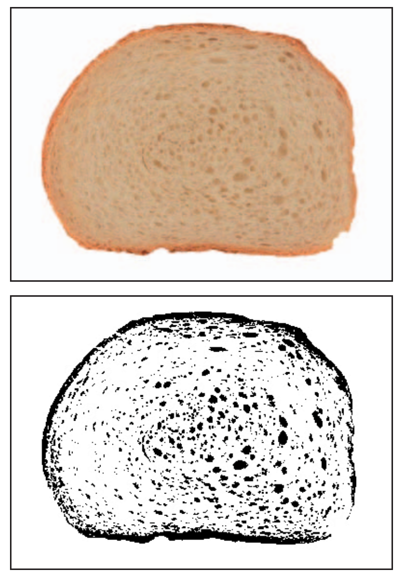

Figure 1. Original image before and after applying the threshold operation

Images were captured and presented with a surfaces size of 10 x 8 cm (960 pixels per cm^2). Three loaves were produced from each of ten wheat cultivars and images of each loaf cross-section were recorded as 8-bit bitmap file with 256 grey levels. The threshold value 128 was chosen as appropriate for all samples. The same image processing operations were applied to all records (Fig. 1).

After image pre-processing, evaluation of bread crumb appearance was performed. The slice crumb analysis was done by calculating the total area of cells (sum of all spots where more than 5 pixels were connected), number of cells bigger than 5 pixels, average cell area, average radius, perimeter, minimum and maximum radius and roundness of crumbs/cells (measure of roundness is in the range between 0 - not round and 1 - perfectly circular). The value was calculated as roundness = 4 π total area / perimeter

Table 1. Mean values of rheological dough properties of analyzed wheat cultivars

Cultivars	WA[a]	DDT	STA	R	DS	E	EXT	R_{MAX}	R/EXT
Žitarka	66.2	3.3	0.7	4.0	87	58	203	206	0.8
Srpanjka	60.8	1.9	2.3	4.2	82	107	176	466	1.8
Barbara	66.5	3.8	1.4	5.2	77	69	193	267	1.0
Klara	64.9	3.1	0.8	3.8	79	76	183	311	1.2
Golubica	66.7	5.4	1.1	6.4	53	79	232	252	0.7
Kata	64.7	3.1	0.2	3.3	102	41	207	146	0.6
Monika	62.7	3.8	0.5	4.2	104	41	156	202	1.0
Ana	60.0	3.4	0.9	4.3	49	114	205	414	1.3
Demetra	60.9	4.2	1.3	5.5	66	129	218	462	1.3
Divana	65.8	12.0	1.7	13.7	7	139	254	422	0.9
Sana	61.7	2.8	0.5	3.3	110	45	192	171	0,7
$\bar{X}$	63.7	4.3	1.0	5.5	75	82	202	303	1.0
SD	2.53	2.84	1.03	3.82	30.70	37.27	28.97	123.87	0.38

[a]WA=Water absorption (%); DDT=Dough development time (min); STA=Stability (min); R=Resistance (min); DS=Degree of softening (FU); E=Dough energy (cm^2); EXT=Extensibility (mm); R_{MAX}=Maximum resistance (EU); R/EXT=Resistance to Extensibility ratio

squared. The bread crumb attributes were evaluated by use of Global LabImage Software ver. 2.6.

Results and discussion

Prominent differences among cultivars were found for dough rheological properties as well as for bread crumb characteristics (Table 1 and Figure 2). Farinograph water absorption of the analyzed cultivars varied between 60.0 % for cultivar Ana and 66.7 % for cultivar Golubica. Flour water absorption is favourable genotype characteristic from miller's and baker's point of view because the increase of water absorption for 1 or 2 % causes 1 or 2 % higher profit. Concerning the mixing behaviour of dough, cultivars 'Divana' and 'Golubica' have shown properties of strong flour with the longest dough development time (12 min and 5 min, respectively) as well as the lowest degree of softening (7 FU and 53 FU, respectively) The lowest mixing tolerance index has been shown for the cultivars 'Kata', 'Monika' and 'Sana' with degree of softening over 100 FU (Table 1).

Regarding the resistance to stretching and elasticity of dough, the maximum height (over 400 EU) and area under the extensogram curve (over 100 cm^2) have been shown for the cultivars 'Srpanjka', 'Demetra', 'Divana' and 'Ana'.

The cultivars 'Klara', 'Barbara', 'Žitarka' and 'Golubica' with medium gluten characteristics, according to both, the farinographic and extensographic properties, had smaller crumbs on slices (12.60-15.32 pixels in total per crumb), while the cultivars 'Srpanjka', 'Ana', 'Demetra' and 'Divana' with very strong gluten characteristics had bigger crumbs (17.16-21.07 pixels per crumb) (Table 1 and Figure 2). In our previous dough rheological studies (Jurković et al., 2000; Horvat et al., 2006), the cultivars 'Srpanjka', 'Ana', 'Demetra' and 'Divana' have also shown very strong gluten characteristics regarding gluten index value, farinographic and extensographic properties.

The highest positive correlation ($P<0.05$) was found between all bread crumb attributes, except roundness, and gluten strength expressed as dough energy ($r=0.59-0.84$), dough resistance expressed as maximum resistance to ex-

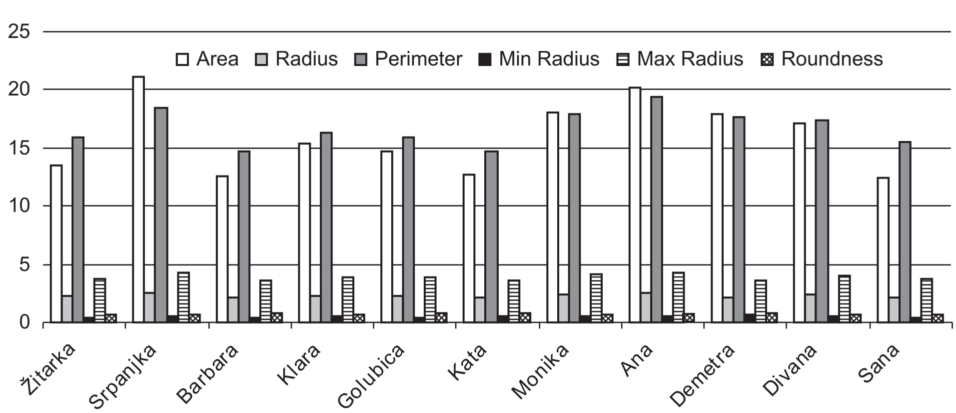

Figure 2.
Bread slice image analysis results (all in pixels except Roundness (dimensionless)) for eleven wheat cultivars

Table 2. Correlation between bread crumb properties and rheological dough properties

Parameters	WA[a]	DDT	STA	R	DS	E	EXT	R_{MAX}	R/EXT
Area	−0.57	0.03	0.59*	0.18	−0.42	0.64*	−0.22	0.78*	0.84*
Radius	−0.57	−0.01	0.64*	0.14	−0.47	0.70*	−0.20	0.83*	0.86*
Perimeter	−0.60*	0.05	0.48	0.17	−0.42	0.62*	−0.23	0.73*	0.78*
Min radius	−0.33	0.28	0.65*	0.44	−0.62*	0.84*	0.12	0.89*	0.73*
Max radius	−0.64*	−0.06	0.57	0.07	−0.37	0.59*	−0.30	0.74*	0.83*
Roundness	0.53	0.10	0.08	0.09	−0.01	−0.11	0.30	−0.16	−0.26

[a]Rheological dough properties: WA=Water absorption (%); DDT=Dough development time (min); STA=Stability (min); R=Resistance (min); DS=Degree of softening (FU); E=Dough energy (cm^2); EXT=Extensibility (mm); R_{MAX}=Maximum resistance (EU); R/EXT=Resistance to Extensibility ratio

tension (r=0.73-0.89) and dough elasticity expressed as resistance to extensibility ratio (r=0.73-0.86) (Table 2), which is in agreement with results of other authors (Scanlon et al., 2000; Zghal et al., 2001).

Among farinographic dough properties, the highest positive correlations ($P<0.05$) were noticed between stability and area (r=0.59), radius (r=0.64) and minimum radius (r=0.65). Significant negative correlations ($P<0.05$) were found between water absorption and perimeter (r=-0.60) and maximum radius (r=-0.64), as well as between minimum radius and degree of softening (r=-0.62) (Table 2).

Conclusions

The cultivars 'Klara', 'Barbara', 'Žitarka' and 'Golubica' have shown the best loaf medium part porosity with optimal gluten quality regarding analyzed dough and bread crumb parameters. The highest positive correlation was found between bread crumbs attributes and gluten strength properties evaluated by extensographic analysis. In accordance with the obtained results of dough rheological and bread crumb properties it would be possible to evaluate the cultivars suitability for bread making industry.

References

Crowley P., Schober T. J., Clarke, C. I. Arendt, E. K. (2002). The effect of storage time on textural and crumb grain characteristics of sourdough wheat bread. Eur Food Res Tech 214:489-496

Gallagher E., Gormley T. R., Arendt E. K. (2003). Crust and crumb characteristics of gluten free breads. J Food Eng 56:153-161

Giovanelli G., Peri C., Borri V. (1997). Effects of baking temperature on crumb-staling kinetics. Cereal Chem 74:710-714

Global Lab Image/2 ver. 2.6, Data Translation Inc., Marlboro, USA

Heijden F. (1998). Image Operations. In: Image Based Measurement Systems (John Wiley & Sons, eds), University of Twente, The Netherlands, 69-129

Horvat D., Drezner G., Jurković Z., Šimić G., Magdić D., Dvojković K. (2006). The importance of high-molecular-weight glutenin subunits for wheat quality evaluation. Poljoprivreda 12:53-57

HRN ISO 5530-1:1999 Fizikalna svojstva 1: Određivanje apsorpcie vode i reoloških svojstava farinografom.

HRN ISO 5530-2: 1999 Fizikalna svojstva 2: Određivanje reoloških svojstava ekstenzografom.

ICC No. 131: Baking Test for Wheat Flour

Jurkovic Z., Sudar R., Drezner G., Horvat D. (2000). The HMW glutenin subunit composition of OS wheat cultivars and their relationship with bread-making quality. Cereal Res Comm 28:271-277

Karaoglu M. M. (2006). Effect of baking procedure and storage on the pasting properties and staling of part-baked and rebaked white pan bread crumb. Int. J Food Prop 9:609-622

Lasztity R. (2003). Prediction of Wheat Quality-Succes and Doubts. Periodica politechnica Ser Chem Eng 46:39-49

Magdić D., Horvat D., Drezner G., Jurković Z., Šimić G. (2006). Image analysis of bread crumb structure in relation to gluten strength of wheat. Poljoprivreda 12:58-62

Magdić D., Horvat D., Baranyai L. (2004). Examination of slice rotation and zoom influence on results of bread slice image analysis. In: Ž Ugarčić-Hardi (eds) Proc of International Congress "Flour-Bread'03", 4th Croatian Congress of Cereal Technologists, Osijek, Croatia, pp 45-249

Prabhasankar P., Manohar R. S., Gowda L. R. (2002). Physicochemical and biochemical characterisation of selected wheat cultivars and their correlation to chapati making quality. Eur Food Res Tech 214:131-137

SAS System 8.2 Software (SAS Institute Inc. Cary, NC. USA, SAS/STAT User's Guide 1989)

Scanlon M. G., Sapirstein H. D., Fahloul D. (2000). Mechanical properties of bread crumb prepared from flours of different dough strength. J Cereal Sci 32:235-243

Zayas IY. (1993). Digital image texture analysis for bread crumb grain evaluation. Cer Foods World 38:760-766

Veraverbeke W. S., Delcour J. A. (2002). Wheat protein composition and properties of wheat glutenin in relation to breadmaking functionality. Crit Rev Food Sci Nutr 42:179-208

Zghal M. C., Scanlon M. G. Sapirstein H. D. (1999). Prediction of bread crumb density by digital image analysis. Cereal Chem 76:734-742

Zghal M. C., Scanlon M. G., Sapirstein H. D. (2001). Effects of flour strength, baking absorption, and processing conditions on the structure and mechanical properties of bread crumb. Cereal Chem. 78:1-7.

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