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IMAGE ANALYSIS OF BREAD CRUMB STRUCTURE IN RELATION TO GLUTEN STRENGTH OF WHEAT

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SUMMARY

The objective of this study was to determine bread slice medium part properties in relation to quality parameters with a focus on gluten strength. Since sensory evaluation of bread is time consuming, expensive and subjective in nature, computerized image analysis was applied as objective method of bread crumb quality evaluation. Gluten Index method was applied as fast and reliable tool for defining gluten strength of wheat. Significant (P<0.05) positive correlation was noticed between bread slice medium part properties and Gluten Index and bread appearance (h/d), while wet gluten content have shown negative influence on these properties. The cultivars with over strong gluten (GI>90) Ana, Demetra, Klara, Srpanjka and Divana have shown trend to give unequal and bigger crumb grains while cultivars Golubica, Barbara, Žitarka, Kata and Sana with optimal gluten strength (GI= 60-90) have shown finer and uniform crumb grain.

Key-words: bread, image analysis, crumb structure, gluten strength

INTRODUCTION

The technological properties of wheat flour are strongly dependent on total gluten quantity and quality. Quality gluten, describing by degree of strength and extensibility, allows sufficient expansion and good distribution of the gas cells within dough (Lasztity, R., 2003). For gluten strength evaluation different tests, including Gluten Index and physical dough properties determined by Brabender farinograph and extensograph, have been applied in Croatia (Jurković et al., 1996).
Among bread making parameters accessed by flour and dough analysis and baking test, loaves volume and crumb quality are certainly the two most important for the end use quality. In evaluation of this attributes image analysis is confirmed as objective and high confidence method and has became almost standard crumb evaluation method in last decades **(**Zayas, 1993; Chtioui et al., 1996; Magdić, 1999), since sensory evaluation of bread is time consuming, expensive and subjective in nature. For applying image analysis in crumb quality evaluation bread loaves should be correctly sliced and slices must be properly lightening, captured by camera and digitized. Later image processing is optional and depends on necessity of cropping the rectangular medium part or all internal part of slice. Finally, main crumb texture 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

The Prebasic seeds from ten winter wheat cultivars: Žitarka, Srpanjka, Barbara, Klara, Golubica, Kata, Ana, Demetra, Divana and Sana were analyzed. All cultivars were grown in the experimental field of Agricultural Institute Osijek, Croatia in years 2001 and 2002. The chemical composition and technological properties of flour were evaluated by standard research procedure published by International Association for Cereal Science and Technology (ICC). The crude protein content of sample grains was measured by Infratec 1241 (Foss Tecator) which is calibrated according to ICC

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standard method No 105/2. All samples were milled into flour using a Brabender Quadrumat Jr. Mill, and flour was standardised for ash 0.55%. Wet gluten content and Gluten Index were determined according to ICC standard method No 155. Wet gluten in wheat flour is a plastic-elastic substance consisting of the proteins gliadin and glutenin, obtained after washing out the starch from wheat flour dough. Gluten separated from wheat flour is centrifuged to force wet gluten through a specially constructed sieve under standardized conditions. The percentage of wet gluten remaining on the sieve after centrifugation is defined as the Gluten Index. All analyses were done in duplicates. Baking test of all samples was done according to ICC standard method No 131. Baking test was done in the industry bakery ("Croatia", Osijek). A dough is made of flour (1000 g), water, according to farinographic water absorption, dry yeast (18 g), salt (15 g), sucrose (18.6 g), ascorbic acid (0,05 g). Dough pieces are scaled rounded, rested 30 min, sheeted and moulded, placed in tins, proofed 50 min and baked at 230°C for 30 min. Dough handling properties were noted. The loaves were evaluated the following day for volume, shape and crumb structure. The bread volume was measured by volumeter filled with millet grains. Statistical analysis of data was carried out with Statistica 6.0 (StatSoft software).
In preparation for quality assessment by image analysis, bread loaves were sliced in the middle, providing two cross sections. Slices were properly illuminated (700 lux) by halogen, indirect illumination and images were captured. The acquired images represented surfaces with a 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 half of a loaf were recorded as 8-bit bitmap file with 256 grey levels. The threshold value 128 was chosen and determined by the "trail and error" method in order to gain the best cell resolution. The same image processing operations were applied to all records (Fig. 1). After image pre-processing, evaluation of crumb texture appearance was performed. Slice texture analysis was done, calculated 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 squared) as the main crumb texture attributes. The attributes were evaluated by use of GLI/2 Scientific Imaging Software.

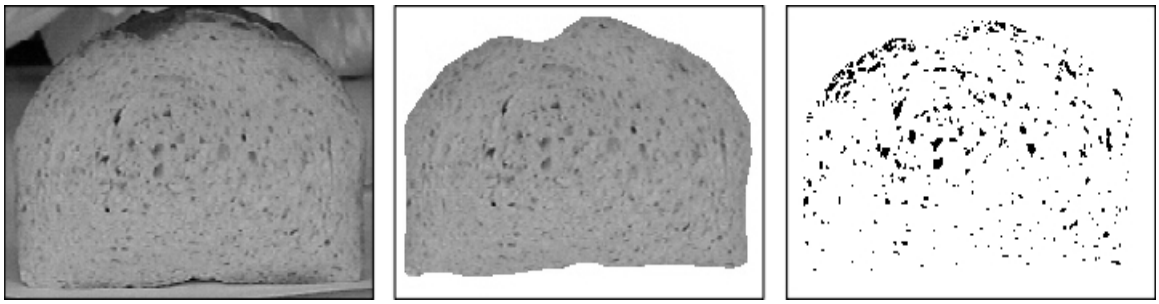

Figure 1. Original image and applied transformations
Slika 1. Izvorna slika i primijenjene transformacije

RESULTS AND DISCUSSION

Textural appearance of bread crumbs depends on flour protein quality and quantity (Magdić et al., 2002; Prabhasankar et al., 2002; Lasztity, R., 2003). The grain samples taken from two years were different in breadmaking quality and on average their crude protein content varied between 12.9% (Srpanjka and Ana) and 14.7% (Golubica).
Quantity of gluten expressed as wet gluten varied between 29.8% (Srpanjka) and 43.4% (Golubica) (Table 1). It must be mentioned that protein and wet gluten content is not a measure of gluten quality. Gluten quality is defined by the degree of elasticity and extensibility. In accordance with our previous investigation strong correlation between the extensographic parameters and Gluten Index indicates that the Gluten Index can be accepted as fast and reliable tool for describing gluten strength of Croatian wheat flour (Jurkovic et al., 2000; Curic et al., 2001; Horvat et al., 2002). In the investigated cultivars Gluten Index values were ranged from 62 (Kata) to 99 (Srpanjka). According to the results of

the baking test, the best loaf volume had cultivars Divana (573 cm^3/100 g flour) and Klara (514 cm^3/100 g flour).

Table 1. The mean values of quality parameters of tested winter wheat cultivars
Tablica 1. Srednje vrijednosti parametara kakvoće analiziranih kultivara pšenice

Cultivar *Kultivari*	P[a]	WG	GI	V	h/d
GI >90					
Srpanjka	12.9[b]	29.8	99	473	0.70
Ana	12.9	30.7	98	455	0.80
Demetra	13.2	32.3	97	466	0.77
Klara	13.2	35.0	93	514	0.76
Divana	16.5	42.2	93	573	0.88
Mean *Prosjek*	13,5[c]	33.8	95	505	0,74
GI <90					
Barbara	13.3[b]	39.5	84	490	0.70
Žitarka	13.4	41.4	76	486	0.66
Golubica	14.7	43.4	75	462	0.68
Sana	12.6	34.2	71	499	0.70
Kata	13.2	39.7	62	467	0.69
Mean *Prosjek*	13.0[c]	37.1	72	486	0,68

[a]P=crude protein content of grains (%); WG=wet gluten (%); GI=Gluten Index;
V=loaf volume (cm^3/100 g flour); h/d = ratio of loaf height and diameter measured on a half of loaf length;
[b]Mean value (n=2 years); [c]Mean value (n=10)

[a]P=udio ukupnih bjelančevina u zrnu (%); WG=vlažni gluten (%); GI=gluten indeks;
V=volumen vekne (cm^3/100 g brašna); h/d=omjer visine i širine vekne mjeren na polovici dužine;
[b]Prosjek (n=2 godine); [c]Prosjek (n=10)

The results obtained by digital image analysis demonstrated cultivars' specific differences (Table 2).

Table 2. Bread slice image analysis results (pixels)
Tablica 2. Rezultati analize slike kriške kruha (pikseli)

Cultivar *Kultivari*	Area *Površina*	Radius *Polumjer*	Perimeter *Opseg*	Min radius *Min. polumjer*	Max radius *Maks. polumjer*	Roundness [a] *Okruglost*
GI >90						
Srpanjka	21.07[b]	2.55	18.50	0.60	4.26	0.73
Ana	20.19	2.54	19.44	0.57	4.29	0.68
Demetra	17.87	2.13	17.67	0.64	3.67	0.77
Klara	15.32	2.33	16.24	0.52	3.89	0.72
Divana	17.16	2.37	17.43	0.59	3.97	0.71
Mean *Prosjek*	18,17[c]	2,36	17,74	0,59	3,98	0,73
GI < 90						
Barbara	12.60[b]	2.16	14.77	0.47	3.63	0.74
Žitarka	13.54	2.25	15.96	0.46	3.79	0.73
Golubica	14.71	2.29	15.88	0.46	3.88	0.75
Sana	12.40	2.17	15.44	0.42	3.75	0.69
Kata	12.70	2.18	14.77	0.47	3.66	0.76
Mean *Prosjek*	13.19[c]	2,21	15,37	0,46	3,74	0,73

[a] Ratio of height and width of cell; [b]Mean values (n=2 years), [c]Mean values (n=10)
[a] Omjer visine i širine šupljine; [b]Prosjek (n=2 godine), [c]Prosjek (n=10)

The cultivars Barbara, Žitarka, Golubica, Sana and Kata with Gluten Index value from 62 to 84 have given smaller crumbs on slice's area (12.4-14.71 pixels per crumb), while cultivars Srpanjka, Ana, Demetra, Klara and Divana with over strong gluten (GI>90) have given bigger crumbs (15.32-21.07 pixels per crumb), even when differences in loaf volumes among cultivars were not noted. The most significant positive impact ($P<0.05$) on increasing of crumb texture attributes had Gluten Index. In accordance with other researchers (Scanlon et al., 2000; Zghal et al. 2001), we have found that the highest impact of Gluten Index was on total crumb area (r=0.84), crumb perimeter (r=0.82) and min radius (r=0.84) (Table 3).

Table 3. Correlation between bread crumb texture properties and wheat quality
Tablica 3. Korelacije između parametara sredine kriške kruha i kakvoće pšenice

Parameters *Parametri*	P[a]	WG	GI	V	h/d
Area *Površina*	-0.04	-0.63*	0.84*	-0.11	0.49
Radius *Polumjer*	0.09	-0.41	0.56	0.00	0.34
Perimeter *Opseg*	-0.04	-0.63*	0.82*	-0.09	0.56
Min radius *Min. polumjer*	0.18	-0.51	0.84*	0.08	0.66*
Max radius *Maks. polumjer*	-0.11	-0.48	0.60	-0.06	0.34
Roundness *Okruglost*	0.04	0.29	-0.18	-0.29	-0.34

[a]P= crude protein content of grains (%); WG=wet gluten (%); GI=Gluten Index; V=loaf volume (cm^3/100 g flour), h/d=ratio of loaf height and diameter measured on a half of loaf length;
* P< 0.05
[a]P=udioukupnih bjelančevina (%); WG=vlažni gluten (%); GI=gluten indeks; V= volumen vekne (cm^3/100 g brašna), h/d= omjer visine i širine vekne mjeren na polovici dužine;

The most significant (P<0.05) negative impact on crumb area and perimeter had wet gluten (r=-0.63). On the other side, loaf appearance (h/d ratio) have shown positive correlation with crumb area (r=0.49), perimeter (r=0.56) and significant (P<0.05) positive impact on minimum radius (r=0.66) (Table 3).

CONCLUSION

The best loaf medium part porosity was found in bread loaves made of Žitarka, Kata, Golubica, Barbara and Sana. At the same time, these cultivars had optimal gluten strength. In this research the most significant positive impact on textural appearance of bread crumbs had Gluten Index, while the most significant negative influence had wet gluten content. Analyzing obtained results it could be concluded that the bread coarse area does not depend on a loaf volume. Crumb texture is a typical property of cultivar and according to crumb texture properties the cultivars can be recommended as a good choice for specific bakery products.

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POVEZANOST RAČUNALNE ANALIZE SLIKE S JAČINOM GLUTENA PŠENICE

SAŽETAK

Cilj istraživanja bio je utvrditi povezanost parametara izgleda sredine kruha i kakvoće pšenice, s naglaskom na jačinu glutena. Budući da je senzorska procjena kruha vremenski zahtjevna, skupa i relativno subjektivna, u procjeni izgleda sredine kruha korištena je računalna analiza slike kao objektivna metoda. Jačina glutena pšenice određena je brzom i pouzdanom gluten indeks metodom. Statistički značajna ($p<0,05$) pozitivna korelacija utvrđena je između svojstava sredine kriške kruha i gluten indeksa te s oblikom vekne kruha (h/d), dok je udio vlažnoga glutena imao negativan utjecaj na ta svojstva. Kultivare s vrlo jakim glutenom (GI>90), Anu, Demetru, Klaru, Srpanjku i Divanu, karakterizira neujednačena poroznost sredine kruha s velikim šupljinama, za razliku od kultivara Golubice, Barbare, Žitarke, Kate i Sane s optimalnom vrijednošću gluten indeksa (GI= 60-90), čija je poroznost, s obzirom na manje šupljine, bila ujednačenija.

Ključne riječi: kruh, računalna analiza slike, struktura sredine kruha, jačina glutena

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