BAKING QUALITY OF WHEAT-RYE MIXTURES

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ABSTRACT

The most important chemical compounds for wheat dough are gluten proteins – gliadins and glutenins which have the distinctive rheological ability to form a dough matrix that determines bread quality. Other cereal flours as rye flour do not have these unique properties, but they can improve nutritional aspects of daily consumed breads such as higher intake of fibre which has a positive effect on digestion and decreases risk of hypercholesterolemia, obesity and heart disease, and current trend in bakery is to replace part of wheat flour with rye flour. In this work 11 ratios of wheat-rye mixtures were prepared; flour quality (Zeleny sedimentation volume, Hagberg falling number, water absorption), machine workability of dough and consequently bread quality characteristics (bread shape, mean bread volume, dough yield, pastry yield, baking loss, texture parameters, image analysis) were investigated. The results showed that parameters of final product are significantly affected by wheat-rye ratio and flour quality. Moreover the addition of rye flour does not influence machine workability of the mixtures.

Key words: wheat, rye, flour, bread, quality, texture

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INTRODUCTION

Wheat (*Triticum aestivum* L.) flour is functional in many applications and these unique characteristics absolutely differ from other cereals and can be ascribed to the visco-elastic properties of gluten proteins. Gluten proteins represent about 80 to 85% of total wheat proteins and consist of monomeric gluten units (gliadin) which cause viscous behaviour while polymeric gluten units (glutenin) are elastic. When kneading and/or mixing wheat flour with water, gluten proteins, facilitate a formation of cohesive visco-elastic dough able to retain gas produced during fermentation. That results in typical foam structure of bread. Although the role of other flour components is important too, it is evident that gluten protein functionality is crucial (Veraverbeke and Delcour, 2002; Wang et al., 2006). Other cereal flours are then worse treatable in comparison with wheat flour. Wannerberger et al. (1997) claims that the baking quality of rye flour is much lower, which is related to the lower gas holding capacity of rye dough. Rye flour is often used in sour doughs because the low pH resulting from acetic and lactic acid originating from fermentation is believed to improve the baking performance. Baking performance of rye has been ascribed to the pentosans (arabinoxylans and arabinogalactans). These polysaccharides are thought to stabilise foams by decreasing the gas diffusion, nevertheless rye pastry will never give such volume and shape typical for wheat bread, but can improve an intake of dietary fibre and antioxidants which is far below the recommendations. Nowadays consumers are paying more attention on the quality and nutritional aspects of foods. Nutritional specialists propose consumption of cereal-based products for the nutritional benefits as improvement in blood glucose level regulation, preventing obesity, reducing the risk of cardiovasculat diseases (Horszwald et al., 2009; Hansen et al., 2004, Dewettinck et al., 2008). Ragaee and Abdel-Aal (2005) discovered that in case of cookies and cakes, replacement of wheat flour up to 30% of rye had no significant effects on the quality and sensory properties and developed healthier products with higher portion of fibre.

The aim of this work was to investigate the effect of the wheat/rye ratio in wheat-rye mixtures on machine workability and properties of baked bread.

MATERIALS AND METHODS

The research was realized on wheat and rye flour provided by commercial mill Penam, a.s. Wheat-rye mixtures were inscribed “TS” (*Triticum aestivum* L.; *Secale cereale* L.) and 11 ratios T 100, TS 1090, TS 2080, TS 3070, TS 4060, TS 5050, TS 6040, TS 7030, TS 8020, TS 9010 and S 100 (for example T 100 means 100% of wheat flour; TS 1090 means 10% (w/w) of wheat flour and 90% of rye flour in mixture) were prepared and subjected to analyses.

Flour technological quality

Hagberg falling number was assessed according to ISO 3093 (ISO, 2004). Obtained values depend on α-amylase activity through changes in starch viscosity. Excessive activity has a deleterious effect on the bread-making quality. Sedimentation volume according to Zeleny was measured by ISO 5529 (ISO, 1992). The method is based on suspension of test flour in a lactic acid solution in the presence of bromophenol blue. After specified shaking and rest times the volume of the deposit was determined. Flours and mixtures water absorption was obtained by Egger promylograph in accordance with ICC standard no. 115 (ICC, 1992). Each laboratory test was carried out on two test portions simultaneously or rapidly one after the other. The arithmetic mean of the two determinations was taken as a result if the conditions of repeatability set by standards were satisfied. If the absolute difference between two independent single test results was outside standard limits the two determinations were performed again.

Baking test

Baking test was conducted on 300 g flour samples using a straight-dough baking formula and short fermentation time (ICC, 1980). High speed dough mixing and a short fermentation time are typical of this method. Bread loaves were evaluated in relation to yield (dough and bread), baking loss, volume, shape (loaf height/width ratio) and crumb characteristics. Dough was prepared from flour (100%), 1.8% dry yeast, 1.5% salt, 1.86%, 0.005% ascorbic acid related to flour weight, water according to pharinographic parameters.

Image analysis

Crumb of bread loaves was submitted to pore size estimation. The principle of this method is scanning a plane surface of a cellular material and consequent digital image analysis of the scan (Matoušek et al., 2011).

Texture analysis

Texture analysis of bread crumb was performed on cylinder of 2.5 cm diameter and 2 cm thickness using Texture Analyser TA.XT Plus (Stable Micro Systems, Surrey, UK) which was equipped with a compression cell of 30 kg and a matrix of 500 mm in diameter. The speed of matrix was set at 1 mm s^{-1}. This analysis was performed twice, 24 hours after baking and 72 hours after storage at 27±1 °C and relative humidity of 50±1% according to Xie at al. (2003).

The texture analyses were carried out by two sequential penetration events (penetration depth 10 mm, probe speed 2 mm s^{-1}, trigger force 5 g). The test was performed using a 50 mm stainless steel cylinder and the force-deformation curve was recorded. Hardness (force needed to attain a given deformation – maximum force during the first penetration cycle; N); adhesive power (relative strength of adhesive power between the bread crumb and the probe surface – ratio of the absolute value of the negative force area to the positive force area of the first peak; unitless); elasticity (length to which the sample recovers in height during the time that elapses between the end of the first compression cycle and the start of the second compression cycle; unitless); cohesiveness (strength of the internal bonds of bread crumb – ratio of the positive force area of the second peak to that of the first peak; unitless); chewiness (product of hardness times cohesiveness times elasticity; unitless) and gumminess (product of hardness times cohesiveness; unitless) (Mochizuki, 2001) were observed.

Statistical analysis

Results were analysed using one way analysis of variance (ANOVA) and the test of Fisher's least significant difference at a significance level of 0.01. These tests were realized in Statistica 9 software (StatSoft, Inc.). Samples S 100 and T 100 were selected as the standards and statistically significant differences between them and remaining samples were assessed.

RESULTS AND DISCUSSION

Flour technological quality

Zeleny sedimentation test, Hagberg falling number, bread shape and mean bread volume showed rising tendency with increasing amount of wheat in the mixture. Contrariwise water absorption (the highest water absorption achieved S 100 – 70.3%, the lowest value T 100 – 62.0%) and dough yield exposed decreasing trend (from 173% for S 100 to 166% for T 100). Concerning the pastry yield and baking loss, both indicated not regular but apparent downtrend/upward trend resp., with higher portion of wheat in the mixture. These results indicate that different chemical composition of wheat and rye flour notably affects basic characteristics applied on rye flour, especially pentosans and different amylase activity. It is well known that rye flour has lower amylase activity thus cannot reach the values of Hagberg falling number as wheat flour (307 s) whereas rye flour 183 s which is in agreement with Burešová and Palík (2010). Wannerberger et al. (1995) in his work proved that proteins present in rye grain have similar properties as gliadin, but these are not expressed in flour which explains these results obtained by Zeleny sedimentation test where the highest value was detected for T 100 (36 ml) and the smallest for S 100 (<10 ml). All these factors affect remaining parameters too – mean volume of 100% wheat bread attained 1.13 (height/width quotient) while 100% rye bread only 0.68 as can be seen in Table 1 (see appendix).

Bread quality

Samples were first provided to analyses on texture analyser 24 hrs after baking then all the obtained parameters were statistically evaluated (Table 2, appendix). Statistically significant differences for hardness [N] were found between S100 (61.7 N) and all other samples including the second standard T100 (12.4 N), however statistically significant differences stressed to the standard T 100 were proved only for TS 1090 (40.2 N), TS 2080 (30.3 N), TS 3070 (28.1 N), TS 4060 (21.3 N), and between S 100 and TS 5050 (19.8 N). Other significant differences were found between S100 (0.539) and TS 2080 (0.669), TS 5050 (0.654), TS 6040 (0.679), TS 7030 (0.702), TS 8020 (0.704), TS 9010 (0.676) and T100 (0.684), and between T100 and TS 1090 (0.546), S100 for cohesiveness. Next, chewiness and gumminess were discovered. For chewiness statistically significant differences were found between standard S100 (116.1) and all of the remaining samples, while for the standard T100 (28.1) only samples TS 1090 (78.2) to TS 4060 (47.0) were found as statistically different. Concerning the gumminess all the samples were statistically significantly different from the standard S100 (33.2), but only TS 1090 (21.9) to TS 5050 (12.9) were significantly different from the second standard T100 (8.4). Regarding adhesive power and elasticity, no statistical differences were found between the standards and remaining samples.

Table 3 (appendix) shows statistical significant differences and mean values of mixtures after 72 hrs of storing. Statistically significant differences were found for hardness [N] between S100 (81.1 N) and all other samples except from TS 2080 (75.1 N) furthermore for the standard T100 (25.1 N) samples TS 1090 (61.6 N) to TS 4060 (47.3 N) and TS 6040 (37.9 N) to TS 9010 (28.0 N). For adhesive power the only difference was found between both standards S 100 (-0.0001), T 100 (0) and TS 1090 (-0.011289). Cohesiveness showed statistical differences between S 100 (0.514) and TS 7030 (0.582), and T100 (0.551) and TS 1090 (0.491), TS 2080 (0.503). Chewiness was different for S 100 (162.6) and all of the remaining samples except from TS 2080 (135.9) and T 100 (49.6) differed from TS 1090 (110.5) and TS 2080. Regarding gumminess S 100 (41.6) differed from all other samples except from TS 2080 (37.8), and standard T 100 (13.9) differed from S 100 and TS 1090 (30.2) to TS 4060 (24.9) and TS 6040 (20.5). No significant differences were observed for elasticity.

Other statistical analysis calculated significant differences between all texture bread characteristics measured after 24 and 72 hours and showed that parameters hardness, cohesiveness, chewiness and gumminess change during storing and their values proved statistical differences while adhesive power and elasticity do not (see Table 4, appendix).

Generally, all of the observed parameters deteriorated during stalling at defined conditions, which is in agreement with Xie et al. (2003), Moore et al. (2004). This phenomenon is caused by partial crystallization of gelatinized starch named retrogradation while cooling down the brad to ambient temperatures. These changes along with moisture migration through the crust imply hardening of starch gel hence causes the increasing firmness of bread crumb Fessas (1998). According to Vinkx and Delcour (1995) rye arabinoxylans (pentosans) increase starch retrogradation which is in agreement with these results that showed increasing hardness, chewiness and gumminess with raising amount of rye flour in mixtures.

The last statistically evaluated parameter was mean volume of bread, which revealed that with the addition of rye bread volume decreased nevertheless no statistical significant difference was found.

Image analysis

Table 5 (appendix) describes bread image analysis. The studied set of wheat-rye mixtures showed that increasing amount of wheat flour caused decreasing density of the sample (T 100 – 0.38 g/cm^3; S 100 – 0.79 g/cm^3) that can be caused by chemical composition of rye flour and especially pentosans which are responsible for condensation of the pores Fessas (1998). Concerning the mean pore size the samples TS 3070, TS 4060, TS 5050, TS 6040 and TS 7030 exposed similar mean pore size (~ 0.13 mm³) while remaining samples with higher portion of rye/wheat flour were different (from 0.011 to 5.260 mm³). And finally the pore size distribution was very concentrated except from samples TS 9010 (3.471 mm²) and T 100 (5.752 mm²) thanks to the protein-polysaccharide complex and its interactions which ensure gas retention, better maturing thus regular distribution of number of pores. Other observed parameters – pore wall thickness, total pore wall area and total count of pores – did not show regular tendency, but concerning the total count of pores, absolutely highest amount of pores confirmed the samples S 100 (18 982) and TS 1090 (28 474), contrariwise T 100 – 117 and TS 9010 – 265.

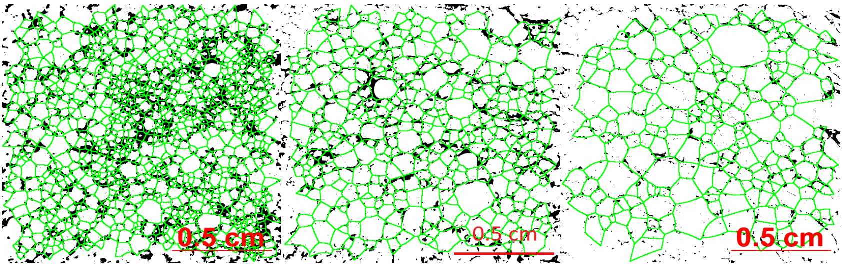

Fig. 1 Image analysis of pore size estimation; from the right: S 100, TS 5050, T 100

CONCLUSIONS

The data demonstrated that flour quality changed with varying ratio of wheat-rye mixtures. Consequent analyses proved that this fact significantly affected final quality of baked bread samples. Changes of texture parameters were caused by chemical composition of rye flour, especially pentosans which evoked deterioration of all observed parameters. Moreover these changes were also caused by natural processes during bread storing such as water loss and starch retrogadation. Shape and distribution of the pores throughout the crumb were connected with protein-polysaccharide complex and dough gas retention during proofing.

All these findings proved that with varying amount of wheat/rye in the mixture quality of bread changed, but all the samples reached satisfactory values, furthermore test machine workability of all tested mixtures was confirmed.

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APPENDIX

Tab. 1 Selected parameters of basic analyses and rapid mix test

Mixtures (ratio)	Moisture [%]	SEDI [ml]	FN [s]	Water absorption [%]	Bread shape (height/width)	Mean bread volume [ml]	Dough yield [%]	Pastry yield [%]	Baking loss [%]
S 100	11.49	<10	183	70.3	0.68	200	173	149	13.86
TS 1090	11.62	12	211	70.2	0.74	225	174	151	13.47
TS 2080	11.92	15	215	70.1	0.79	238	173	150	13.35
TS 3070	11.98	25	226	70.0	0.84	250	172	147	14.71
TS 4060	12.11	25	222	68.0	0.98	275	171	146	14.89
TS 5050	12.38	27	235	67.9	0.92	313	172	149	13.18
TS 6040	12.60	29	243	68.1	0.96	363	171	149	13.10
TS 7030	12.81	31	243	66.5	0.97	375	170	148	12.70
TS 8020	12.91	33	259	64.5	1.08	400	168	141	16.35
TS 9010	13.21	34	301	63.6	1.12	425	167	142	15.12
T 100	13.52	36	307	62.0	1.13	433	166	141	15.12

SEDI Zeleny sedimentation volume, *FN* Hagberg falling number

Tab. 2 Bread characteristics – mean values of mixtures (24 hrs after baking)[a]

Mixtures (ratio)	Hardness	Adhesive power	Elasticity	Cohesiveness	Chewiness	Gumminess
S 100	61.7f	-0.004a	3.50ab	0.539b	116.1ff	33.2g
TS 1090	40.2e	-0.005a	3.56ab	0.546b	78.2de	21.9f
TS 2080	30.3d	-0.016a	4.23b	0.669a	83.8e	19.8ef
TS 3070	28.1cd	-0.008a	3.44ab	0.621abc	59.8cd	17.4de
TS 4060	21.3bcd	-0.003a	3.49ab	0.631abc	47.0bc	13.5cd
TS 5050	19.8abc	-0.009a	3.32a	0.654ac	42.9abc	12.9bc
TS 6040	15.3ab	-0.004a	3.36a	0.679a	34.8ab	10.4abc
TS 7030	14.4ab	-0.001a	3.33a	0.702a	33.6ab	10.1abc
TS 8020	12.5ab	0a	3.30a	0.704a	29.1ab	8.8ab
TS 9010	11.6a	0a	3.36a	0.676a	26.3a	7.8a
T 100	12.4ab	0a	3.33a	0.684a	28.1a	8.4a

[a]Different letters in the same column indicate a significant difference between means at 1% level according to Fisher LSD test.

Tab. 3 Bread characteristics – mean values of mixtures (72 hrs after baking)[a]

Mixtures (ratio)	Hardness	Adhesive power	Elasticity	Cohesiveness	Chewiness	Gumminess
S 100	81.1f	0a	3.89b	0.514a	162.6e	41.6e
TS 1090	61.6de	-0.011b	3.66ab	0.491a	110.5cd	30.2cd
TS 2080	75.1ef	0a	3.59ab	0.503a	135.9d	37.8de
TS 3070	45.8c	0a	3.69ab	0.523ab	88.6bc	23.9bc
TS 4060	47.3cd	0a	3.59ab	0.528ab	89.5bc	24.9bc
TS 5050	36.0abc	0a	3.47ab	0.533ab	66.6ab	19.2ab
TS 6040	37.9bc	0a	3.59ab	0.538ab	73.9ab	20.5ab
TS 7030	24.8ab	0a	3.39a	0.582b	49.1a	14.5a
TS 8020	23.9a	0a	3.27a	0.547ab	43.1a	13.1a
TS 9010	28.0ab	0a	3.52ab	0.545ab	53.4a	15.3a
T 100	25.1a	0a	3.54ab	0.551ab	49.6a	13.9a

[a]Different letters in the same column indicate a significant difference between means at 1% level according to Fisher LSD test.

Tab .4 Bread characteristics[a]

Time (after baking)	Hardness	Adhesive power	Elasticity	Cohesiveness	Chewiness	Gumminess
24 hrs	24.58a	-0.004912a	3.45a	0.534a	52.89a	15.08a
72 hrs	48.53b	-0.000944a	3.56a	0.643b	80.89b	22.38b

[a]Different letters in the same column indicate a significant difference between means at 1% level according to Fisher LSD test.

Tab. 5 Bread image analysis

Mixtures (ratio)	Density [g/cm³]	**E***V* [mm³]	σ_V	**E***S* [mm²]	σ_S	Pore wall thickness [mm]	In 1cm³ of sample: Total pore wall area [mm²]	In 1cm³ of sample: Total count of pores
S 100	0.79	0.011	0.001	0.120	0.005	0.347	2277	18982
TS 1090	0.71	0.010	0.006	0.110	0.042	0.227	3124	28474
TS 2080	0.72	0.051	0.011	0.330	0.047	0.396	1819	5521
TS 3070	0.61	0.110	0.014	0.554	0.047	0.311	1964	3543
TS 4060	0.56	0.198	0.083	0.804	0.228	0.313	1791	2226
TS 5050	0.53	0.101	0.003	0.526	0.011	0.218	2436	4632
TS 6040	0.52	0.074	0.007	0.424	0.027	0.188	2767	6527
TS 7030	0.50	0.157	0.106	0.671	0.306	0.235	2131	3175
TS 8020	0.41	0.817	0.178	2.102	0.306	0.270	1518	722
TS 9010	0.35	2.444	4.111	3.471	3.943	0.379	922	265
T 100	0.38	5.260	9.038	5.752	6.651	0.561	677	117

Density density of dried bread, *EV* mean volume of pores, σV standard deviation of pores volumes, *ES* mean pores surface area, σV standard deviation of pore surface.