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TEXTURAL PROPERTIES OF BREAD FORMULATIONS BASED ON BUCKWHEAT AND RYE FLOUR

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Abstract

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Modern nutrition and nutritionists worldwide more and more require high nutritional quality foods including breads. Products based on rye (*Secale cereale* L.) and other cereals such as buckwheat (*Fagopyrum esculentum* Moench) provide nutritional benefits such as higher intake of fibre which has a positive effect on digestion and decreases a risk of obesity and heart disease, therefore current trend is to replace part of gluten breads with other cereal products. The main aim of this work was to observe changes in breads based on buckwheat and rye mixtures influenced by ratio of buckwheat and rye flour. Eleven ratios of buckwheat-rye flours were prepared. Dough and bread quality were tested in terms of dough machine workability, dough and pastry yield, baking loss, specific volume and texture analyses 24 and 72 hours after baking. The results were statistically evaluated and showed that rising amount of rye flour in mixtures did not affect dough machine workability but improved all of the investigated texture characteristics such as chewiness and gumminess, concerning specific volume of breads, no significant differences were found. All texture parameters deteriorated with staling time.

buckwheat, rye, flour, mixture, texture

Wheat (*Triticum aestivum* L.) flour is functional in many applications. Its 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 monomer gluten units (gliadin) which cause viscous behavior 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; Rosell *et al.*, 2007; Wang *et al.*, 2007; Demirkesen *et al.*, 2010). Unfortunately, other cereal flours do not contain these key gluten proteins thus they are worse treatable in comparison with wheat flour. Different studies claim that the baking quality of rye flour is much lower, which is related with lower gas holding capacity of rye dough and these products with lack of gluten matrix are typical of worse technological quality, low specific volume, high crumb hardness and short staling time (Gallagher *et al.*, 2003a; Moroni *et al.*, 2009; Sciarini *et al.*, 2010a). Their shelf life is influenced by moisture loss, staling conditions and microbial deterioration and this process involves crumb firming which is caused by amylopectin crystallization and water redistribution (Sciarini *et al.*, 2010b). But nowadays consumers are paying more attention on the quality and nutritional aspects of foods. Nutritional specialists propose consumption of non-gluten cereal products for the nutritional benefits as improvement in blood glucose level regulation, preventing obesity, reducing the risk of cardiovascular diseases (Hansen *et al.*, 2004; Dewettinck *et al.*, 2008; Horszwald *et al.*, 2009).

Baking performance of rye (*Secale cereale* L.) has been ascribed to the pentosans (arabinoxylans and arabinogalactans). These polysaccharides are thought to stabilize 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 fiber and antioxidants which is far below the recommendations (Wannerberger *et al*., 1997).

Buckwheat (*Fagopyrum esculentum* Moench) is highly nutritious pseudocereal known as a dietary source of protein with favourable amino acid composition and vitamins, starch and dietary fibre, essential minerals and trace elements. In comparison to most frequently used cereals, buckwheat possesses higher antioxidant activity, mainly due to high rutin content, phenolic acids, flavonoids, phytic acid, vitamin B_1, B_2 and E, glutathione, carotenoids, phytosterols and as a gluten-free cereal can be widely used for producing gluten-free products (Wronkowska *et al*., 2010; Sedej *et al*., 2011).

In this study, flour from common buckwheat (*Fagopyrum esculentum* Moench) was used to prepare mixtures with commercially available rye flour to make breads. The main goal of this study was to observe and compare bread characteristics and textural properties of these mixtures and prove a machine workability of all samples.

MATERIALS AND METHODS

Materials

The research was realized on buckwheat and rye flour provided by commercial mills (Penam corp. and Buckwheat mill Šmajstrla Ltd.). Buckwheat-rye mixtures were inscribed "FS" according to their Latin equivalents (*Fagopyrum esculentum* Moench; *Secale cereale* L.) and 11 ratios S 100, FS 1090, FS 2080, FS 3070, FS 4060, FS 5050, FS 6040, FS 7030, FS 8020, FS 9010 and F 100 (for example F 100 means 100% of buckwheat flour; FS 1090 means 10% (w/w) of buckwheat flour and 90% of rye flour in mixture) were prepared and subjected to analyses. Samples S 100 and F 100 were selected as control samples.

Baking test

Baking test was conducted on 300 g flour samples using a straight-dough baking formula and short fermentation time in accordance with ICC standard No. 131 (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 sugar, 0.005 ascorbic acid related in % on flour weight, addition of water to optimum consistency.

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 50 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 23 ±1 °C and relative humidity of 50 ±1% according to Xie *et al.* (2003).

The texture analyses were carried out by the original software provided by Stable Micro System automatically and performed by two sequential compression events (compression depth 40%, probe speed 2 mm s^{-1}, trigger force 5 g) 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) were calculated automatically by integrated macro functions.

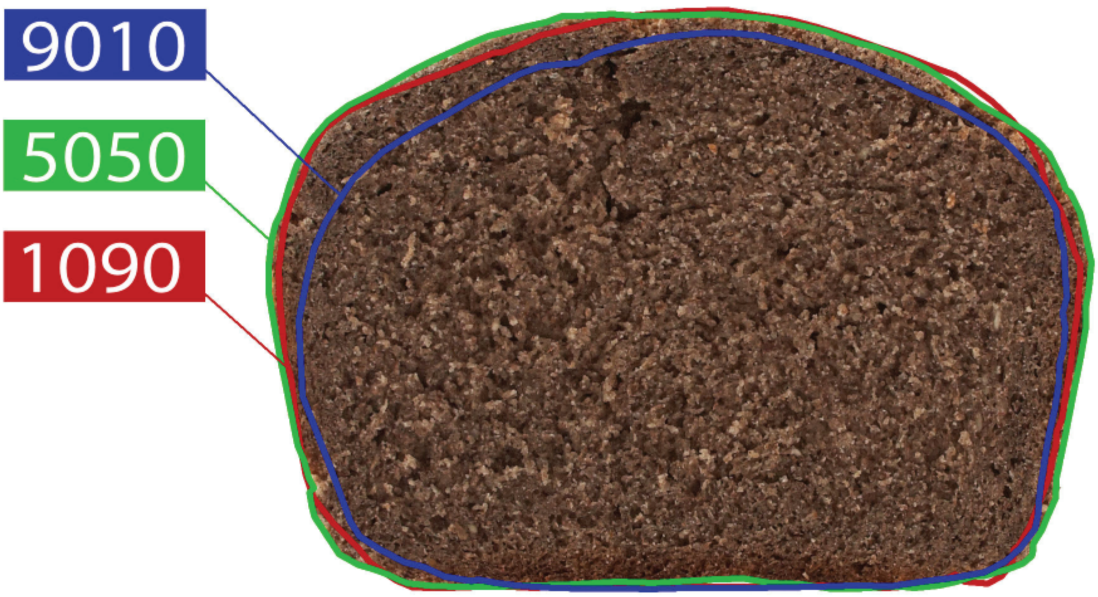
Statistical analysis

Results were analyzed using one way analysis of variance (ANOVA) and consequent test of Fisher's least significant difference at a significance level of 0.01. These tests were realized using Statistica 9 software (StatSoft, Inc.). Samples F 100 and S 100 were selected as the control samples and statistically significant differences among them and remaining samples were assessed.

RESULTS AND DISCUSSION

Baking test

The basic quality characteristics were calculated and evaluated from baking test and comprise dough yield, pastry yield, baking loss. Concerning dough yield, higher portions of buckwheat flour showed increasing values ranging from 173% (S 100) to 179% (F 100). The same trend was regarded for pastry yield, which was risen by 6% (from 149% for S 100 to 158% for F 100). On the other hand, baking loss and specific volume of samples did not prove any significant differences. The shape and volume of breads can be seen in Fig. 1.



1: *Volume and shape of samples*

Bread quality

Samples were first provided to analyses on texture analyzer 24 h after baking then all the obtained parameters were statistically evaluated (Tab. I). Statistically significant differences for hardness [N] were found between rye control sample S 100 (61.7) and samples FS 6040 (103.6) to FS 9010 (171.9), however statistically significant differences stressed to the control sample F 100 were proved for samples FS 1090 (45.7) to FS 3070 (64.8) and FS 9010 (171.9). Significant differences for adhesive power were found between S 100 (–0.004) and FS 1090 (–0.031) with FS 2080 (–0.052). For cohesiveness, statistically significant differences were regarded between S 100 (0.539) and FS 6040 (0.581) to FS 9010 (0.704), which was the same for the parameter gumminess, and the buckwheat control sample F 100 differed from all remaining samples, contrariwise gumminess showed differences among F 100 and all other samples excluding FS 7030 (70.9) and FS 8020 (89.4). The last value which showed statistically significant differences was chewiness – S 100 (116.1) differed from FS 6040 (224.0) to FS 9010 (447.4), then F 100 differed from all other tested samples except from FS 8020 (321.3). Elasticity did not show any statistical differences.

Tab. II shows statistically significant differences and mean values of mixtures 72 h after baking and storing at specified conditions. Statistically significant differences for hardness [N] were found between S 100 (81.1) and samples from FS 6040 (146.3) to FS 9010 (238.9) while the control sample F 100 differed from all remaining samples except from FS 1090 (238.9). Elasticity proved statistical differences only between F 100 (3.6) FS 2080 (4.2) and FS 3070 (4.1). Cohesiveness showed statistical differences between F 100 (0.665) and all other

I: *Bread characteristics – mean values of mixtures (24 h after baking)*[1]

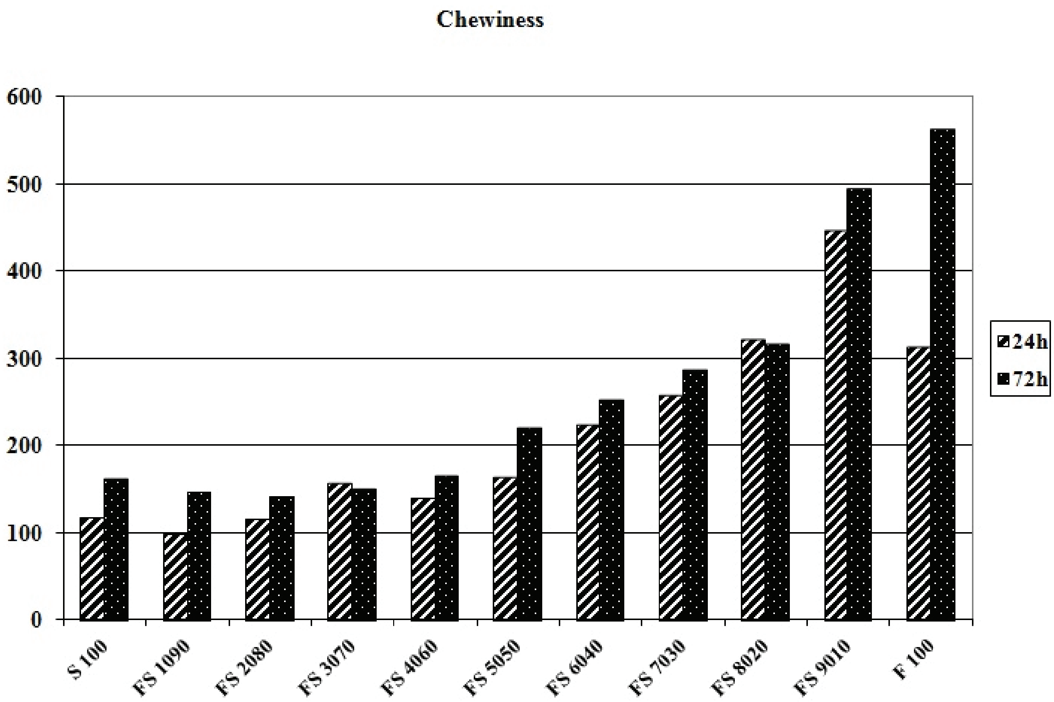
Mixtures (ratio)	Hardness [N]	Adhesive power	Elasticity	Cohesiveness	Chewiness	Gumminess
S 100	61.7ab	–0.004a	3.5a	0.539a	116.1ab	33.2a
FS 1090	47.5a	–0.031bc	3.8a	0.553ab	98.9b	26.2a
FS 2080	57.0ab	–0.052c	3.8a	0.541a	116.9ab	30.9a
FS 3070	64.8ab	–0.019ab	4.6a	0.534a	158.1a	34.6a
FS 4060	69.8abe	–0.008ab	3.6a	0.557ab	140.9ab	38.8a
FS 5050	82.8bce	ND[2]	3.7a	0.543a	164.4a	44.9ac
FS 6040	103.6cde	–0.001a	3.7a	0.581ab	224.0c	60.2cd
FS 7030	117.9cd	ND	3.7a	0.602b	259.3c	70.9bd
FS 8020	135.2d	ND	3.6a	0.662c	321.3d	89.4b
FS 9010	171.9f	ND	3.7a	0.704c	447.4e	120.9e
F 100	114.4cd	ND	3.6a	0.772d	314.0d	88.3b

[1]Different letters in the same column indicate a significant difference between means at 1% level according to Fisher LSD test. [2]ND not detected.

II: *Bread characteristics – mean values of mixtures (72 h after baking)*[1]

Mixtures (ratio)	Hardness [N]	Adhesive power	Elasticity	Cohesiveness	Chewiness	Gumminess
S 100	81.1ab	ND[2]	3.9ab	0.514a	162.6a	41.6ab
FS 1090	66.3a	ND	4.0ab	0.492a	130.9a	32.7a
FS 2080	70.3a	ND	4.2a	0.501a	147.0a	35.2ab
FS 3070	75.4ab	ND	4.1a	0.456a	138.4a	34.4ab
FS 4060	89.4ab	ND	4.0ab	0.445a	158.1a	39.8ab
FS 5050	128.7bc	ND	3.9ab	0.457a	228.6a	58.8ab
FS 6040	146.3c	ND	3.9ab	0.478a	283.2a	72.3ab
FS 7030	162.6c	ND	3.8ab	0.443a	277.2a	72.2ab
FS 8020	181.8c	ND	3.8ab	0.443a	305.7a	80.6b
FS 9010	238.9d	ND	3.8ab	0.554b	507.1b	132.7c
F 100	242.5d	ND	3.6b	0.665b	573.2b	161.4c

[1]Different letters in the same column indicate a significant difference between means at 1% level according to Fisher LSD test. [2]ND not detected



2: *Chewiness of the tested samples (unitless)*

samples excluding FS 1090 (0.554). Chewiness was statistically different for S 100 (162.6) and FS 9010 (507.1) then F 100 differed from all other samples excluding FS 9010 (507.1). Regarding gumminess S 100 (41.6) differed from FS 9010 (132.7) and F 100 differed from all remaining samples excluding FS 9010. No statistical differences stressed on the two control samples S 100 and F 100 were found for adhesive power.

Regarding values as hardness, chewiness and gumminess, the results showed very similar interesting decreasing trends. Increasing portion of rye flour in the mixture caused improvement in value mentioned above. On the other hand higher portion of buckwheat flour in the mixtures showed enhancement of the samples' cohesiveness.

Differences among all texture bread characteristics measured after 24 and 72 hours were significant. Hardness, cohesiveness, chewiness and gumminess changed during storing and their values proved statistical differences while adhesive power and elasticity did not (data not shown).

All of the observed texture parameters deteriorated during staling at defined conditions that can be seen on an example of chewiness in the Fig. 2, that shows – the higher value, the bigger force needed for chewing (Xie *et al.*, 2003; Moore *et al.*, 2004). Crumb of less gluten products is wet after baking and sticks together, after 72 hours of staling becomes dry and crumbly (Alvarez-Jubete *et al.*, 2010; Torbica *et al.*, 2010). This phenomenon is caused by partial crystallization of gelatinized starch named retrogradation while cooling down the bread to ambient temperatures. These changes along with moisture migration and absence of gluten network which shows the movement of water by forming an extensible protein network (Gallagher *et al.*, 2003b; Guarda *et al.*, 2004; Pruska-Kędzior *et al.*, 2008; Sciarini *et al.*, 2010b) through the crust imply hardening of starch gel hence causes the increasing firmness of bread crumb (Fessas and Schiraldi, 1998).

Both control samples had identical specific volume of bread (1.4), values among remaining samples did not change markedly and fluctuated between 1.3 and 1.6, nevertheless, no statistical significant difference was found. This is in agreement with Brites *et al.* (2010) who confirmed that compact crumb texture and low specific volume is typical for these breads.

CONCLUSIONS

The data demonstrate that final product changed with different ratios of flours in buckwheat-rye mixtures which can also influence machine workability. Our results proved that:

- rye flour positively influenced bread crumb characteristics,
- machine workability of prepared mixtures was maintained thus these breads may be produced worldwide in bakeries,
- changes of texture parameters were caused by chemical composition of both buckwheat and rye flour.

Moreover these changes were also caused by natural processes during bread staling which is a complex process including water loss and starch retrogadation. Nevertheless, these mixtures can be used for producing higher nutritional breads in all ratios that can help to extend the bread choice in the market. Further research needs to be done to examine consumer acceptance of these products.

SUMMARY

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 obesity and heart disease, therefore current trend is to replace part of wheat flour with rye flour or strengthen and improve position of non-gluten breads in the market thus this work stressed on breads based on rye (*Secale cereal* L.) and buckwheat (*Fagopyrum esculentum* Moench) which both offer nutritional benefits (dietary source of protein with favourable amino acid composition, vitamins, starch and dietary fibre, essential minerals and trace elements, higher antioxidant activity, mainly due to high rutin content, phenolic acids, flavonoids, phytic acid, vitamin B_1, B_2 and E, glutathione, etc). In this work 11 ratios of buckwheat-rye mixtures were prepared; flour quality, machine workability of dough and bread quality characteristics were investigated. Samples were baked according to ICC 131 and then evaluated (dough and pastry yield, baking loss, shape and specific volume of breads) next 24 and 72 hours after baking, the samples were provided to texture analysis using Texture Analyser TA.XT Plus (Stable Micro Systems, Surrey, UK) with double compression. All of the obtained values were statistically evaluated using Statistica 9 (StatSoft, Inc.) The results showed that parameters of dough and final product are significantly affected by buckwheat-rye ratio. The texture parameters showed deteriorating trend with higher portion of buckwheat flour in mixtures. For example hardness of buckwheat flour reached 185% of rye flour hardness, then gumminess showed even higher difference, rye sample reached value of 33.2, while buckwheat showed 88.3, which presents 265% of rye hardness. Moreover the ratio of buckwheat and rye flour did not influence machine workability of the mixtures thus all of them may be processed in bakeries. With regards to increasingly discussed use of non-wheat cereal in a healthy diet and taking into account chemical composition of buckwheat and rye flour and effect in preventing obesity, reducing the risk of cardiovascular diseases and improving the blood glucose level regulation, these results can be of interest not only to experts but an international readership.

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