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REGULAR ARTICLE

BUCKWHEAT AS A GLUTEN-FREE CEREAL IN COMBINATION WITH MAIZE FLOUR

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ABSTRACT

Celiac disease is an autoimmune disorder of the small intestine that occurs in genetically predisposed people of all ages. Symptoms include chronic diarrhoea, and fatigue. The only treatment is long life diet with absence of gluten. Many researches concerning gluten-free nutrition have been done but it is still a big challenge. The main aim of this work was to observe changes in gluten-free breads quality made from maize-buckwheat mixtures depending on ratio of maize and buckwheat flour. To obtain samples, bread baking test was applied and these were provided to analyses (dough and pastry yield, baking loss, specific volume and texture analysis). The results showed that rising amount of maize flour in mixtures improved texture characteristics such as chewiness and gumminess, concerning specific volume of breads no significant differences were found and it was proved, that all texture parameters deteriorate with staling time.

Keywords: celiac disease, buckwheat, maize, flour, quality

INTRODUCTION

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 monomeric gluten units (gliadin) which cause viscous behaviour while polymeric gluten units (glutenin) are elastic. When kneading and/or mixing wheat flour with water 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 (**Rosell *et al.,* 2007; Veraverbeke and Delcour, 2002; Wang *et al.,* 2007**). Nevertheless, in cases of celiac disease gluten must be absolutely eliminated from nutrition because its ingestion causes serious intestinal damage (**Demirkesen *et al.,* 2010**). Celiac disease is a chronic entheropaty characterised by an inflammation of small intestinal mucosa that results from a genetically based immunological intolerance to gluten (**López *et al.,* 2004; Murray, 1999**). The inadequate immunological response to gluten proteins may lead to nutrient malabsorption. General symptoms include diarrhoea, weight loss and fatigue and the only therapy for celiac patients is based on a lifelong gluten-free diet (**Sciarini *et al.,* 2010a**). Unfortunately 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.,* 2003b; Moroni *et al.,* 2009**). The shelf life is influenced by moisture loss, staling conditions and microbial deterioration and this process involves crumb firming and which is caused by amylopectin crystallization, water redistribution (**Sciarini *et al.,* 2010b**).

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 posseses higher antioxidant activity, mainly due to high rutin content, phenolic acids, flavonoids, phytic acid, vitamin B1, B2 and E, glutathione, carotenoids, phytosterols and as a gluten-free cereal can be widely used for producing gluten-free products (**Sedej *et al.,* 2011; Wronkowska *et al.,* 2010**).

In this study, flour from common buckwheat (*Fagopyrum esculentum* Moench) was used to prepare mixtures with commercially available maize flour to make gluten-free 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. Although many gluten-free breads have been developed, only a few studies concerning products made from maize flour are available, because more usual used component is corn starch.

MATERIAL AND METHODS

Materials

The research was realized on maize and buckwheat flour provided by commercial mills (Mill Herber Ltd and Buckwheat mill Šmajstrla Ltd.). Maize-buckweat mixtures were inscribed "ZF" (*Zea mays* L.; *Fagopyrum esculentum* Moench) and 11 ratios F 100, ZF 1090, ZF 2080, ZF 3070, ZF 4060, ZF 5050, ZF 6040, ZF 7030, ZF 8020, ZF 9010 and Z 100 (for example F 100 means 100% of buckwheat flour; ZF 1090 means 10% (w/w) of maize flour and 90% of buckwheat flour in mixture) were prepared and subjected to analyses.

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 (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 to 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 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) 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 Z 100 and F 100 were selected as the standards and statistically significant differences between them and remaining samples were assessed.

RESULTS AND DISCUSSION

The basic quality characteristics were calculated and evaluated from baking test and comprise dough yield, pastry yield, baking loss. Concerning pastry yield, higher portions of maize flour showed increasing values ranging from 178% (F 100) to 195% (Z 100). The same trend was regarded for pastry yield, which was risen by 9% (from 157 % for F 100 to 171 % for Z 100).

Samples were first provided to analyses on texture analyser 24 hrs after baking then all the obtained parameters were statistically evaluated (Tab 1). Statistically significant differences for hardness [N] were found between F 100 (114.4) as the first standard and samples ZF 1090 (152.6), ZF 2080 (156.9), ZF 4060 (128.1), ZF 7030 (131.2), ZF 8020 (130.2) and Z 100 (130.1), however statistically significant differences stressed to the standard Z 100 were proved only for ZF 2080, ZF 5050 (110.6) and ZF 6040 (109.7). Other significant differences were found between F 100 (3.6) and Z 100 (0.282); Z 100 and ZF 2080 (3.5) for the parameter elasticity. Then cohesiveness and chewiness were observed. For cohesiveness, statistically significant differences were regarded between F 100 (0.772), ZF 3070 (0.625) and Z 100 (0.282), and the second standard Z 100 differs from all remaining samples. Concerning the chewiness, statistical differences were proved between F 100 (314.0) and ZF 1090 (423.7), ZF 2080 (388.7), ZF 6040 (250.3), ZF 8020 (227.8) to Z 100 (151.6), then between Z 100 and ZF 8020. The last parameter that showed statistically significant differences was gumminess where F 100 differs from all other samples, and Z 100 (36.8) differs from F 100 (88.3) to ZF 8020 (57.7). Adhesive power did not show any statistical differences.

Table 1 Bread characteristics – mean values of mixtures (24 hrs after baking)[a]

Mixtures (ratio)	Hardness [N]	Adhesive power	Elasticity	Cohesiveness	Chewiness	Gumminess
F 100	114.4bc	-0.001a	3.6a	0.772b	314.0c	88.3d
ZF 1090	152.6d	0a	3.7a	0.754b	423.7f	114.8g
ZF 2080	156.9d	0a	3.5a	0.708be	388.7f	111.0g
ZF 3070	122.1abc	0a	3.8ab	0.625a	286.5abc	76.3acd
ZF 4060	128.1a	0a	3.8ab	0.641ae	309.4bc	82.2d
ZF 5050	110.6b	0a	3.8ab	0.617a	261.1abc	68.4ab
ZF 6040	109.7b	0a	3.7ab	0.614ad	250.3ab	67.3ab
ZF 7030	131.2a	0a	3.8ab	0.535d	267.4abc	70.2ac
ZF 8020	130.2a	0a	3.9ab	0.444c	227.8ae	57.7bf
ZF 9010	124.2ac	0a	3.9ab	0.369c	177.8de	45.9ef
Z 100	130.1a	0a	4.1b	0.282f	151.6d	36.8e

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

Tab 2 shows statistically significant differences and mean values of mixtures after 72 hrs of storing. Statistically significant differences were found for hardness [N] between F 100 (242.5) and ZF 5050 (148.7) and ZF 9010 (104.3) while Z 100 did not prove any difference. The same results were found for elasticity. Cohesiveness showed statistical differences between F 100 (0.665) and all other samples; Z 100 (0.255) differs from F 100 and ZF 3070 (0.539). Chewiness was different for F 100 (573.1) and ZF 4060 (290.4) to Z 100 (212.4) and Z 100 differed from F 100 to ZF 3070 (399.1). Regarding gumminess F 100 (161.4) differed from ZF 3070 (107.7) to Z 100 (54.3) and Z 100 differed from F 100 to ZF 3070. No significant differences were observed for adhesive power.

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

Mixtures (ratio)	Hardness [N]	Adhesive power	Elasticity	Cohesiveness	Chewiness	Gumminess
F 100	242.5b	0a	3.6a	0.665e	573.1e	161.4e
ZF 1090	229.4ab	0a	3.7a	0.562be	474.1de	128.8de
ZF 2080	208.5ab	0a	3.9ab	0.528abe	426.1cde	110.8cde
ZF 3070	199.8ab	0a	3.7a	0.539abe	399.1bcde	107.7bcde
ZF 4060	162.5ab	0a	3.8ab	0.464abcd	290.4abcd	75.4abcd
ZF 5050	148.7ab	0a	3.9ab	0.516abd	303.5abcd	76.8abcd
ZF 6040	167.3ab	0a	3.9ab	0.410acd	260.3abcd	66.9abc
ZF 7030	177.2ab	0a	4.0ab	0.386cd	277.4abcd	69.9abcd
ZF 8020	154.5ab	0a	3.9ab	0.355cg	216.1abc	55.3abc
ZF 9010	104.3a	0a	4.4b	0.204f	93.2a	21.3a
Z 100	201.8ab	0a	4.0ab	0.255fg	212.4ab	54.3ab

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

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 did not (data not shown).

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)**. Crumb of gluten-free products is wet after baking and sticks together, after 72 hours of staling becomes dry and crumbly (**Torbica *et al.,* 2010; Alvarez-Jubete *et al.,* 2010**). This phenomenon is caused by partial crystallization of gelatinized starch named retrogradation while cooling down the brad to ambient temperatures and absence of gluten network which slows the movement of water by forming an extensible protein network (**Gallagher *et al.,* 2003a; Guarda *et al.,* 2004; Pruska-Kędzior *et al.,* 2008; Sciarini *et al.,* 2010b**).

The last statistically evaluated parameter was volume of bread, which revealed that both standards had identical specific volume of bread (1.2), values among remaining samples did not change markedly and fluctuated between 1.1 to 1.4 (as can be seen in Fig 1), nevertheless, no statistical significant difference was found. This is in agreement with **Brites *et al.* (2010)** who confirm that compact crumb texture and low specific volume is typical for gluten-free breads.

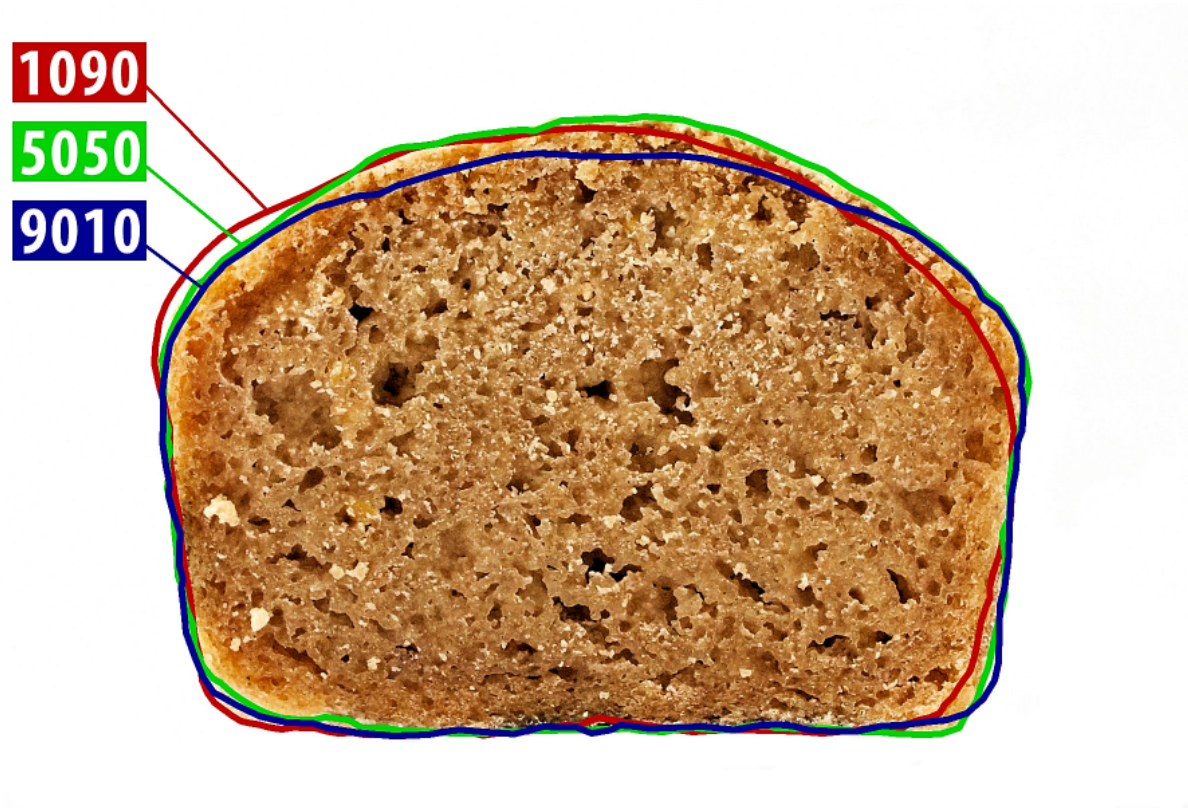

Figure 1 Volume of selected mixtures

These results showed that maize flour can be used an improver of buckwheat bread quality, because higher portions of maize in the mixtures proved positive effect on bread yield and texture parameters as chewiness and gumminess, that can be seen in Fig 2, 3. However, with increasing amounts of maize dough became crumbly and incoherent, hence these mixtures (ZF 8020, ZF 9010) and Z 100 was worse machine workable.

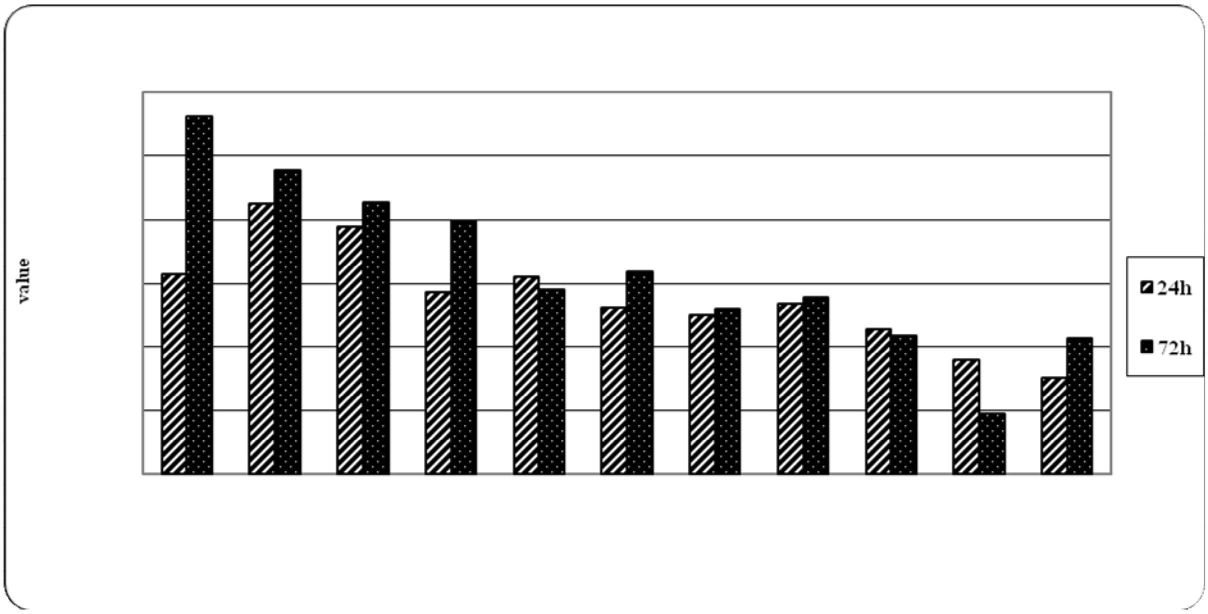

Figure 2 Chewiness after 24 and 72 hours after baking

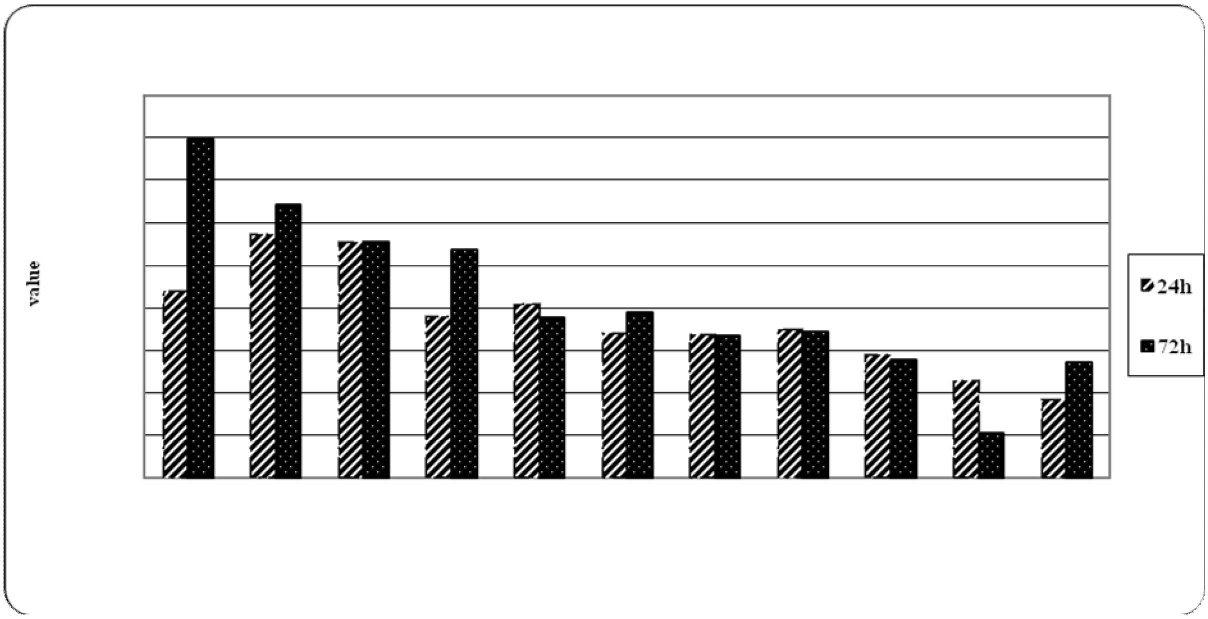

Figure 3 Gumminess 24 and 72 hours after baking

CONCLUSION

The data demonstrated that final product change witch changing ratios of flours in maize-buckwheat mixtures. Furthermore, this can influence machine workability. Our results proved that maize flour positively influences bread crumb characteristics, but negatively affects machine workability of prepared mixtures. Changes of texture parameters were caused by chemical composition of both maize and buckwheat flours. 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 gluten-free breads in almost all ratios that can help to improve food possibilities and nutrition for patients suffering from celiac disease. Further research needs to be done to examine consumer acceptance of these products.

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