REGULAR ARTICLE

QUALITY OF GLUTEN-FREE BUCKWHEAT-RICE BREAD

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ABSTRACT

In case of celiac disease the products containing gluten must be excluded from the nutrition. The offer of gluten-free products (especially pastry) is low and in addition the gluten-free breads are typical of dry crust and crumb and higher firmness in comparison with wheat bread. This work deals with gluten-free mixtures prepared from buckwheat and rice flour and the effect of rising amount of these flours on bread quality, crumb hardness, elasticity, chewiness and gumminess. With rising portion of buckwheat flour in the mixture the bread volume, dough and bread yield increased. The biggest improvement was found for mean bread volume (30%) between the samples FO 1090 (166.7 cm^3) and FO 9010 (216.7 cm^3). The texture analysis showed positive effect of rice flour on hardness, chewiness and gumminess. Hardness decreased from 114.5 N (F 100) to 91.3 N (FO 1090). Very similar results showed chewiness and gumminess. Chewiness of F 100 (314.0) was reduced by 32.5% to 212.2 at the sample FO 1090. Gumminess was improved almost linearly through the samples, the biggest difference (44.3%) was found between the check sample F 100 (88.3) and FO 1090 (49.7).

Keywords: celiac disease, rice, buckwheat, bread quality

INTRODUCTION

Celiac disease is becoming an increasingly recognized autoimmune enteropathy of approximately 1% of population in regions such as Europe, North and South America, north Africa and the Indian subcontinent, thus is an important public health issue (**Hischenhuber *et al.*, 2006**). The harmful proteins are gliadins (wheat), secalins (rye), hordeins (barley) and avenins (oats). These storage proteins share some repetitive sequences, but the exact peptide sequences involved have not been identified precisely, although peptides rich in glutamines and prolines are potent activators of the immune response in celiac disease (**Murray, 1999; Dewar *et al.*, 2004**). Therefore all foods and medications containing gluten are eliminated as even small quantities of gluten may be harmful and must be excluded from the patient nutrition (**Niewinski, 2008; Konic-Ristic *et al.*, 2009**). On the other hand wheat (*Triticum aestivum* L.) is typical of unique characteristics which can be ascribed to the visco-elastic properties of gluten proteins (80 to 85% of total wheat proteins). Gluten proteins 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, gluten protein functionality is crucial (**Veraverbeke and Delcour, 2002; Rosell *et al.*, 2007; Wang *et al.*, 2007**). But in cases of celiac disease gluten must be eliminated from nutrition because its ingestion causes serious intestinal damage (**Demirkesen *et al.*, 2010**). Unfortunately the gluten-free technology involves many complications. The 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**). 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.*, 2010**).

This work deals with the use of buckwheat and rice flour to produce gluten-free bread mixtures. 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 routine 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 (**Wronkowska *et al*., 2010; Sedej *et al*., 2011**). Rice flour is considered to be a suitable substitute for wheat as it is available worldwide and has several significant properties such as natural, hypoallergenic, colourless and blend taste. It has also low level of protein, sodium, fat, fibre and high amount of easily digested carbohydrates (**Sanchez *et al.*, 2002; Demirkessen *et al*., 2010; Yano, 2010**)

The aim of this study was to prepare gluten-free bread from mixtures of buckwheat flour (*Fagopyrum esculentum* Moench) and rice flour (*Oryza sativa* L.) and to compare textural properties of gluten-free breads. On the basis of our previous studies, it was expected that the final bread quality will be linearly changed (positive effect of buckwheat/rice flour) with the modification of the gluten free mixture (ratio of buckwheat and rice flour).

MATERIAL AND METHODS

Materials

The research was realized on buckwheat flour provided by commercial mill (Buckwheat mill Šmajstrla s.r.o.) and rice flour provided by Natura Hustopeče s.r.o. Czech Republic. Eleven buckwheat-rice mixtures were prepared (Table 1). Samples F 100 and O 100 were selected as the check samples.

Table 1 Proportions of wheat and rye flours in the investigated wheat-rye mixtures

Sample	% (w/w)	
	Proportion of buckwheat flour	**Proportion of rice flour**
O 100 (pure rice flour)	0	100
FO 1090	10	90
FO 2080	20	80
FO 3070	30	70
FO 4060	40	60
FO 5050	50	50
FO 6040	60	40
FO 7030	70	30
FO 8020	80	20
FO 9010	90	10
F 100 (pure buckwheat flour)	100	0

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, resp. related to flour weight, addition of water to optimum consistency.

Texture analysis

Texture analysis of bread crumb was performed according to breadcrumbs measurement set by the producer of Texture Analyser (Stable Micro Systems, Surrey, UK). The measurement was done on a 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 with four repetitions 24 hours after baking.

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); 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); chewiness (product of hardness times cohesiveness times elasticity; unitless) and gumminess (product of hardness times cohesiveness; unitless) were observed. All these parameters are helpful in comparing which of the measured samples are more/less acceptable for the consumers.

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 0.05. These tests were realized in

Statistica 10 software (StatSoft, Inc.). Statistically significant differences between check samples (O 100; F 100) and remaining samples were assessed.

RESULTS AND DISCUSSION

The mean volume and specific volume of the bread samples decreased with higher portion of rice flour (Table 2). Rice proteins are mostly hydrophobic and resist swelling in water (**Kadan *et al.*, 2001**) that may be the reason of the bread quality deterioration connected with increasing amount rice flour in the mixture and worse results of the check sample O 100. The comparison of the samples with the check sample O 100 showed that decreasing amount of rice flour increased mean volume, specific volume, dough and bread yield but decreased baking loss, contrariwise the check sample F 100. The biggest differences can be observed between the samples FO 1090 and FO 9010; the mean bread volume increased by 30% (from 166.7 to 216.7 cm^3) and the specific volume enhanced by 27% (0.3 cm^3/g). These low values of specific volume are typical of gluten free breads, which is in agreement with **Brites *et al.* (2010)**. The dough yield in most cases increased between the two nearby samples in average about 2%. The bread yield showed enhancement from the sample FO 5050 further. The biggest decrease of baking loss (26.5%) was calculated between the check sample O 100 (14.3%) and FO 2080 (10.5%), but with increasing amount of buckwheat flour in the mixture, this value decreased that denoted the enhancing trend. Lowering amount of buckwheat flour in the mixture decreased mean volume, specific volume of bread, dough and bread yield.

Table 2 Values of bread qualitative parameters

Sample	**Mean volume [cm^3]**	**Specific volume [cm^3/g]**	**%**		
			Dough yield	**Bread yield**	**Baking loss**
O 100	166.7	1.1	169.9	145.6	14.3
FO 1090	166.7	1.1	171.3	152.1	11.2
FO 2080	175.0	1.1	170.7	152.7	10.5
FO 3070	191.7	1.3	170.4	152.3	10.6
FO 4060	200.0	1.3	171.1	151.5	11.5
FO 5050	208.3	1.4	173.3	150.5	13.2
FO 6040	208.3	1.4	175.1	153.2	12.5
FO 7030	208.3	1.4	175.2	152.0	13.2
FO 8020	208.3	1.4	176.5	154.1	12.7
FO 9010	216.7	1.4	175.1	155.2	11.3
F 100	216.7	1.4	178.6	157.9	11.6

It is known that crumb of gluten-free products is wet after baking and stuck together, but after cooling it becomes dry (**Alvarez-Jubete *et al.*, 2010; Torbica *et al.*, 2010**). This phenomenon is caused by the starch retrogradation while cooling down the bread to ambient temperatures and absence of gluten network which slows the movement of water by forming an extensible protein network (**Guarda *et al.*, 2004; Pruska-Kędzior *et al.*, 2008; Sciarini *et al.*, 2010**). Lower hardness reached the check sample O 100 (93.4 N) in comparison with F 100, but the increasing trend of hardness was observed with higher portion of buckwheat flour in the mixture. The highest value of crumb hardness reached the sample containing 90% of buckwheat and 10% of rice flour (Figure 1). The increasing amount of buckwheat flour in the mixture had deteriorating effect on the crumb hardness starting from the sample FO 2080 which had higher hardness compared with the check sample O 100. On the other hand the check sample F 100 proved lower hardness characteristics than the samples FO 7030, FO 8020 and FO 9010, resp.

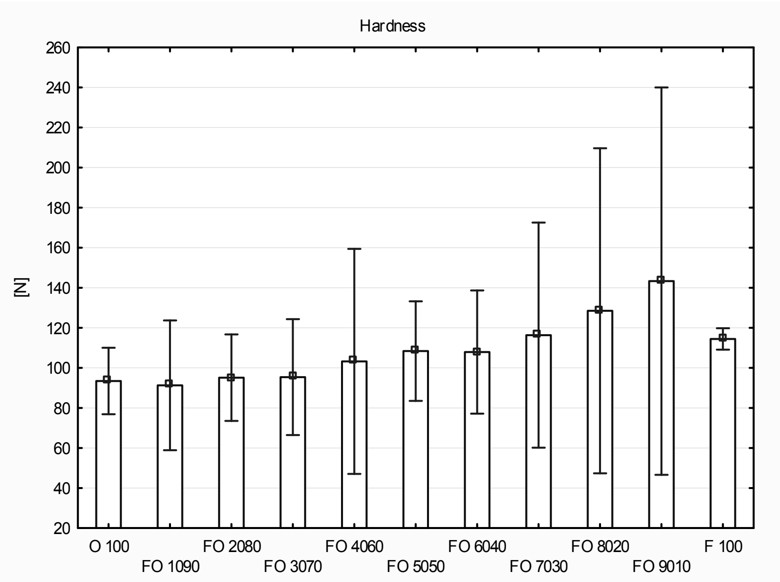

Figure 1 Hardness of tested samples

Elasticity is the ability of a material to return to its original shape after a stress. All of the measured mixtures showed very similar elasticity of the bread crumb (Figure 2). When comparing with the check sample prepared from the 100% rice flour (4.3), all of the remaining samples proved lower values of elasticity while comparing with the check sample F 100 (3.6) that means the addition of buckwheat flour decreased the elasticity of the samples. No similar results in the literature are available to compare with. These values and not very changed trend of elasticity may be ascribed to proteins and polysaccharides naturally present in both raw materials and that are the key factors affecting the final gluten-free bread quality. It could be concluded that in this case the components of both rice and buckwheat flour did not negatively affect each other thus did not significantly influence the crumb elasticity.

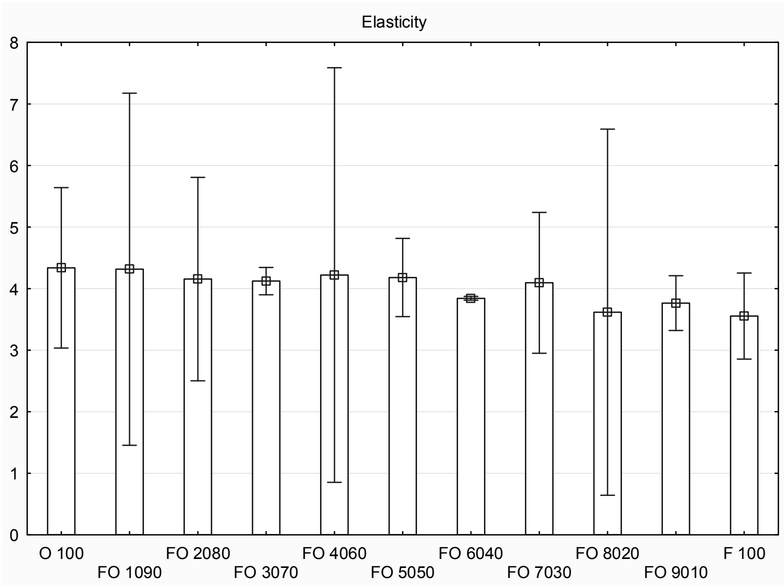

Figure 2 Elasticity of tested samples

The comparison of the samples with the check samples O 100 (186.7) revealed increasing tendency of chewiness with addition of buckwheat flour in the mixture as the remaining mixtures (FO 1090 to FO 9010) had higher chewiness, contrariwise the comparison with the check sample F 100 (314.0) (Figure 3). Very similar trend and results were observed for the parameter gumminess (Figure 4). Higher gumminess showed again the check sample F 100 (88.3); the check sample O 100 reached 43.0. It was proved that higher portions of buckwheat flour increased the gumminess of the tested sample which was caused faster retrogradation of buckwheat starch (**Gallagher *et al.*, 2003b**). When regarding the check sample O 100 (43.0) the biggest deterioration was observed for the sample FO 9010 (81.2); the value increased more almost twice. The comparison with the check sample F 100 affirmed the positive effect of the addition of rice flour to the mixture. The results showed that buckwheat flour and the absence of wheat flour in these mixtures negatively affected the texture parameters (**López *et al.*, 2004; Moore *et al.*, 2004**).

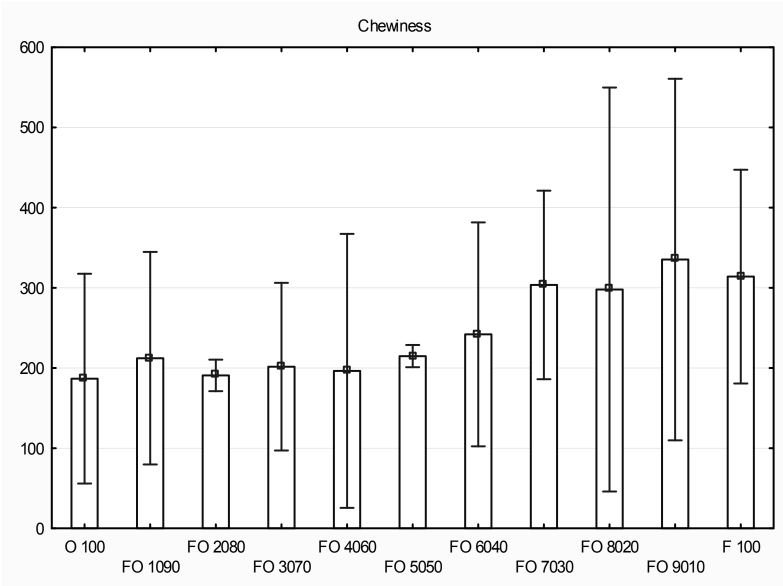

Figure 3 Chewiness of tested samples

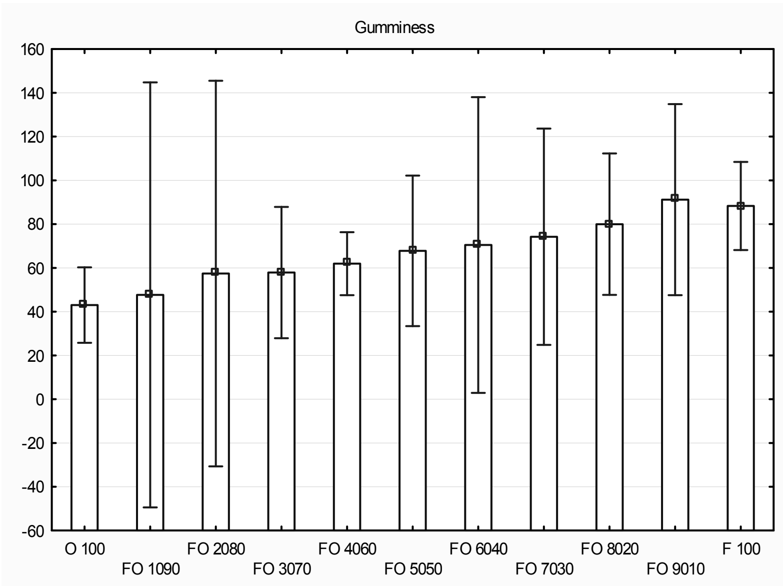

Figure 4 Gumminess of tested samples

CONCLUSION

It was found that mixing buckwheat and rice flour in specific ratios significantly affected the final bread quality. It was determined that higher amounts of buckwheat flour enhanced the parameters of baking test – mean bread volume, specific volume of bread, dough and bread yield. For example the specific volume increased by 1.2 times comparing the check samples O 100 (1.1) and FO 9010 (1.4). Crumb texture analysis proved the deteriorating effect of buckwheat flour on the samples' hardness. Newly the elasticity, chewiness and gumminess of the samples were determined. These parameters showed improving effect of rice addition; the higher portion of rice flour, the better results. The comparison of the samples with the check sample F 100 showed that in almost all cases the values were lower than these of check sample.

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