Effect of Buckwheat Flour on Microelements and Proteins Contents in Gluten-Free Bread

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Abstract

Krupa-Kozak U., Wronkowska M., Soral-Śmietana M. (2011): **Effect of buckwheat flour on microelements and proteins contents in gluten-free bread**. Czech J. Food Sci., **29**: 103–108.

Coeliac disease is an autoimmune gluten-sensitive entheropathy. The only available treatment for it is the life-long adherence to a gluten-free diet although these products are often poor in proteins, minerals, and vitamins. The current study was designed to investigate the effect of buckwheat flour incorporation to a gluten-free experimental formulation on the size-related parameters, and microelements and proteins contents. Buckwheat flour affected positively the technological quality of bread, like bread specific volume index and loaf size. Increasing concentration of buckwheat flour (10–40%) in bread affected the proportional enrichment in proteins and microelements, especially in copper and manganese.

Keywords: microelements; proteins; buckwheat flour; gluten-free bread; coeliac desease

Coeliac disease (CD), originally thought to occur only rarely in childhood, is now recognised as a common condition that may be diagnosed at any age. Serologic screening studies have shown the worldwide prevalence to be 0.3–1.2% in unselected European, North American, South American, and Indian populations (Fasano *et al.* 2003; Tommasini *et al.* 2004; Sampson *et al.* 2005). The factors responsible for that primary life-long intolerance in genetically predisposed individuals are wheat gliadins and other prolamins, like secalin of rye, hordein of barley, and possibly avenein of oat (Vader *et al.* 2003). The clinical classification of coeliac disease can be based on the presence of gastrointestinal symptoms. Recently, to categorise the possible forms of clinical presentation, terms such as classic, atypical and typical should be discouraged, whereas the terms silent, minor, and major can characterise the clinical presentation simply and clearly (Di Sabatino & Corazza 2009). The list of clinical features that can be encountered in silent CD includes an irritable bowel syndrome, anemia, decreased bone density, neurologic diseases, and malignancy (Green 2005). It has been also suggested that the reproductive disorders in CD patients are a consequence of nutritional deficiencies caused by malabsorption (Rostami *et al.* 2001). Abnormal ovarian development, obstatical disorders such as spontaneous abortion and still birth (Bougle & Proust 1999), male subfertility (Wong *et al.* 2000) have been associated with zinc, selenium, iron, and folate deficiencies, often diagnosed in CD patients. The only proven treatment for coeliac disease is strict and life-long adherence to a gluten-free diet. However, it is difficult to avoid gluten completely. The results of a double-blind placebo control trial established that 10 mg gluten per day is tolerated whereas 50 mg is harmful (Catassi *et al.* 2007), although patients vary in their sensitivity to gluten concentration.

Partly supported by the Ministry of Science and Higher Education, Poland, Grant No. NN312 3450 33.

Gluten is a structure-forming protein responsible for the elastic characteristics of dough, and it contributes to the crumb appearance and structure of many baked products. Therefore, due to the absence of gluten, the quality of baked gluten-free products is low; they exhibit crumbling texture and poor colour, mouthfeel, and flavour (Arendt *et al*. 2002). Diet based on gluten-free products is often characterised by low contents of some nutritional components such as proteins and mineral components, as well as non-nutritional but physiologically important components, like dietary fibre. Therefore, efforts are made to enrich gluten-free products especially in proteins, micro- and macroelements (Krupa-Kozak *et al*. 2011), and vitamins. Dairy ingredients were used in the production of gluten-free bread resulting in nutritional benefits and improved volume, appearance, and sensory aspects of the loaves (Gallagher *et al.* 2003). The application of bean starch in the gluten-free formulation increases the protein content and the overall quality of bread (Krupa *et al.* 2010). Pseudocereals, quinoa (Taylor & Parker 2002) and amaranth (Tosi *et al*. 1996), which have a high nutritional value, were applied in the production of enriched gluten-free bakery products. The effects were studied of different starches (rice, corn, soya, millet, buckwheat, and potato), in combination with different fat sources on the formulation of gluten-free biscuits (Arendt *et al.* 2002).

The incorporation of buckwheat flour to gluten-free bread is promissing as buckwheat is rich in polysaccharides, proteins, dietary fibre, lipids, and vitamins of the B group (Christa & Soral-Śmietana 2008; Wronkowska *et al.* in press). Proteins content in buckwheat flour was reported to range from 8.5 to 18.9%, depending on the variety (Krkošková & Mrázová 2005; Christa & Soral-Śmietana 2008). Buckwheat grains are also a source of microelements, such as: Zn, Cu, Mn, Se (Stibilj *et al.* 2004), and macroelements: K, Na, Ca, Mg (Wei *et al.* 2003).

The aim of the current study was to investigate the effects of buckwheat flour incorporation in the gluten-free formulation on the protein and microelements contents in gluten-free bread.

MATERIAL AND METHODS

Materials. The raw materials used for the gluten-free batter were: corn (AgroTrade, Warsaw, Poland) and potato starches (Przedsiębiorstwo Przemysłu Ziemniaczanego S.A., Niechlów, Poland). Sunflower oil (ZPT, Warsaw, Poland) and fresh yeast were used. The premix ingredients: salt, sugar, and pectin (E 440(i), ZPOW Pektowin, Jasło, Poland) were commercially available. Commercial dehusked buckwheat was purchased from a local shop and milled in order to obtain flour.

Breadmaking process. The gluten-free formula was prepared according to the procedure described in Polish patent specification (Wronkowska *et al*. 2008a). A KitchenAid Professional K45SS (Kitchen-Aid Europa, Inc, Brussels, Belgium) mixer with a stainless steel bowl and flat beater was used. In the experiment, buckwheat flour substitute was 10%, 20%, 30%, 40% w/w of gluten-free formulas basis, buckwheat flour was substituted for corn starch. Solid components (Table 1) were mixed. The amount of added water was 80 g for 100 g of the gluten-free formula. A sample of the resulting batter was placed in a greased bread pan and proofed at 35–40°C and 70% humidity for 40 minutes. Then, bread was baked at 210°C for 25–35 min in the laboratory oven with electric heating and temperature control. The baking

Table 1. Composition of batters (in g)

Sample	Corn starch (1)	Potato starch (2)	Buckwheat flour (3)	Premix (4)	Weight of all solid components*
Control	80	20	—	12.5	125.5
B10%	67	20	13	12.5	125.5
B20%	55	20	25	12.5	125.5
B30%	42	20	38	12.5	125.5
B40%	30	20	50	12.5	125.5

*Components in column (1) + (2) + (3) + (4) +10 g yeast + 3 g sunflower oil

tests were carried out in an electric oven with an incorporated proofing chamber (ZBPP, Bydgoszcz, Poland). Bread samples were freeze-dried, ground, and sieved through a 60-mesh screen to obtain powdered bread. The following sample abbreviations were used:
Control (100% formula);
B10% (10% buckwheat flour and 90% formula);
B20% (20% buckwheat flour and 80% formula);
B30% (30% buckwheat flour and 70% formula);
B40% (40% buckwheat flour and 60% formula).

Technological evaluation of bread. After cooling at room temperature, the size-related parameters of gluten-free bread were assessed including weight, volume (rapeseeds displacement), specific volume index (specific volume of the control was taken as 100, and the specific volume of the sample was related to the control), and width/height ratio of the central slice. Proteins content (N × 6.25) was determined by the Kjeldahl method (AOAC 1990). Ash content (AOAC 1990) was estimated in dried crumb of gluten-free breads.

Measurement of microelements contents. The measurement of microelements contents in the crumb was carried out using the atomic absorption spectroscopy (AAS) method using a Unicam 939 spectrometer equipped with data basis ADAX, background correction, and cathode lamps. Before the elements determination, all samples were wet mineralised with a mixture of nitric and perchloric acids (3:1). The details were described in a previous article (Soral-Śmietana *et al.* 2001).

Statistic analysis. The results were analysed using the statistical program Statgraphics Centurion XV (StatPoint Inc., Virginia, USA). Fisher's least-significant differences test was used to define differences between the means at the 5% significance level ($P < 0.05$).

RESULTS AND DISCUSSION

The effect of buckwheat flour on the same quality parameters as those of gluten-free bread is shown in Table 2 and Figure 1. The specific volume index of bread significantly improved with the addition of buckwheat flour. The greatest effect was observed with bread B30% as a result of the replacement of 30% solid components basis with buckwheat, however, 20% replacement gave a similar result. It is worth noting that the effects were evident even with the lowest buckwheat concentration (10%), while no further improvement was observed with the highest buckwheat flour concentration (40%). The results obtained are in contradiction to the findings by Wronkowska *et al.* (2008b) according to which the incorporation of buckwheat flour in the commercial gluten-free formula "Niskobiałkowa" caused the reduction of the bread loaf volume. The differences in the composition between the perimental and commercial formulas, especially in hydrocolloids contents, could explain such a situation. Lazaridou *et al.* (2007) reported a reduction of volume depending on the variety of hydrocolloids and their levels. Generally, the literature data show the improving effect of several hydrocolloids on the volumes of gluten-free breads (Gallager *et al.* 2004), as well as on wheat flour bread (Rosell *et al.* 2001; Barcenas & Rosell 2005).

Table 2. Effect of buckwheat flour addition on quality parameters of fresh gluten-free bread

	Buckwheat flour (%)	Specific volume index	Width/height ratio
Control	–	100^{C}	1.06
B10%	10	123^{B}	1.03
B20%	20	138^{AB}	0.97
B30%	30	141^{A}	0.78
B40%	40	137^{AB}	0.73

$^{A–C}$values followed by the same letter in the same column are not significantly different ($P < 0.05$)

The shape of the loaf slices depended on the buckwheat amount (Table 2). The low buckwheat concentrations in breads B10% and B20% barely modified the slice shape in comparison to the control bread. In the case of both breads with higher amounts of buckwheat, the reduction of the width/height ratio was observed, indicative of the bread shape improvement.

Coeliac disease is often associated with maldigestion resulting in malabsorption of the nutrients, vitamins, and mineral compounds in the gastrointestinal tract. Common ingredients of gluten-free breads and baking mixes are corn starch, potato flour/starch, tapioca flour/starch, and brown/white rice flour (Niewiński 2008). Corn and potato starches, as well as the other components of experimental gluten-free formulas, were poor in proteins, therefore the control bread was characterised by a very low content of proteins (Table 3). Also the amount of total mineral compounds, expressed as

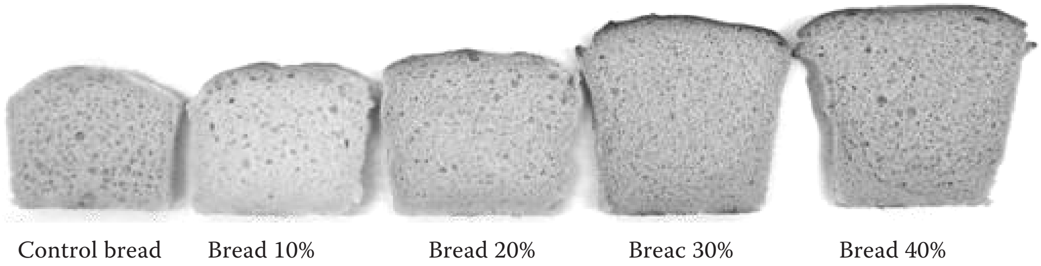

Figure 1. Gluten-free breads with increasing amount of buckwheat flour

ash content, was low and reached 1.66% d.m. Out of the microelements determined in the control bread, the contents of iron and zinc were the highest while those of copper and manganese were low (Table 3). Wronkowska and Soral-Śmietana (2008) analysing two polish commercial gluten-free formulas, "Niskobiałkowa" and "Mleczna", indicated similar low proteins contents (1.53% d.m. and 1.60% d.m., respectively). Ash contents in these commercial formulas (0.14 and 0.49% d.m. in "Niskobiałkowa" and "Mleczna", respectively) were even lower than in the control bread examined. Often the commercial gluten-free breads and other baking products exhibit a low nutrition quality and poor mouthfeel. Buckwheat flour was incorporated in the experimental gluten-free formulas as the ingredient enriching them with valuable proteins and minerals (Christa & Soral-Śmietana 2008). The analysed buckwheat flour contained 12.61% d.m. of proteins and 1.74% d.m. of total minerals. The content of iron (25.14 g/g) predominated over those of zinc (17.89 μg/g), manganese (10.20 μg/g), and copper (4.29 μg/g).

In comparison to the control bread, the substitution of 10% of the experimental gluten-free formula by buckwheat flour caused more than double increase in the proteins content (Table 3). The growing percentage of buckwheat flour in the experimental breads affected the proportional enrichment in proteins. The highest proteins level was observed in bread with 40% buckwheat flour, in which it reached 7.5% d.m. Similarly, Wronkowska and Soral-Śmietana (2008) ascertained that buckwheat flour increases significantly the proteins content in gluten-free bread obtained with the use of commercial formulas. In analysing the influence of increasing amounts of buckwheat flour on the microelements contents in experimental gluten-free breads, gradual growth was observed in the amounts of all microelements analysed (Table 3). The most significant changes were noticed in the bread with 40% buckwheat flour where the content of copper increased four times and that of manganese – nine times.

In general, the addition of buckwheat flour to the experimental gluten-free batters affected the improvement of quality parameters and nutritional compounds of bread. The results obtained agree with the findings by Wronkowska *et al.* (2008), who observed that the substitution of commercial gluten-free formulas by buckwheat flour resulted in the enrichment with nutrients, especially with

Table 3. Proteins, ash and microlements content in buckwheat flour and crumb of gluten free breads with increasing amount of buckwheat flour

	Proteins (% d.m.)	Ash (% d.m.)	Microelements (μg/g)			
			Fe	Zn	Cu	Mn
Control bread	$1.38^{A} \pm 0.07$	$1.66^{A} \pm 0.02$	$42.72^{A} \pm 0.42$	$5.77^{A} \pm 0.10$	$0.51^{A} \pm 0.02$	$0.45^{A} \pm 0.01$
Bread 10%	$3.03^{B} \pm 0.01$	$1.75^{B} \pm 0.02$	$45.96^{B} \pm 0.38$	$7.92^{B} \pm 0.12$	$0.88^{B} \pm 0.01$	$1.42^{B} \pm 0.03$
Bread 20%	$4.53^{C} \pm 0.15$	$1.90^{C} \pm 0.02$	$49.76^{C} \pm 0.32$	$10.06^{C} \pm 0.10$	$1.75^{C} \pm 0.01$	$2.38^{C} \pm 0.02$
Bread 30%	$6.09^{D} \pm 0.04$	$1.96^{D} \pm 0.01$	$52.46^{D} \pm 0.48$	$12.44^{D} \pm 0.19$	$1.88^{D} \pm 0.01$	$3.34^{D} \pm 0.03$
Bread 40%	$7.51^{E} \pm 0.03$	$2.20^{E} \pm 0.03$	$54.28^{E} \pm 0.47$	$13.05^{E} \pm 0.13$	$2.27^{E} \pm 0.01$	$4.26^{E} \pm 0.01$

Mean ± SD; $^{A-E}$values followed by the same letter in the same column are not significantly different ($P < 0.05$)

proteins and elements, improving the overall sensory quality of bread with buckwheat.

CONCLUSIONS

Buckwheat flour applied as a component of gluten-free formulas improves the nutritional value and technological parameters of experimental gluten-free bread. It affects positively the bread specific volume index and loaf size. Buckwheat flour enriched gluten-free bread with proteins and microelements, especially with copper and manganese, but also with iron and zinc. Therefore, based on the results obtained, the utilisation of buckwheat flour both as a valuable nutrient and a factor improving technological properties of gluten-free bread can be highly recommended.

Acknowledgements. The authors wish to thank to Dr. Kazimierz Markiewicz, Dr. Emilia Markiewicz, and MSci. Elżbieta Tońska from University of Warmia and Mazury in Olsztyn for their help in AAS analysis.

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Received for publication April 16, 2010
Accepted after corrections August 30, 2010

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