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Buckwheat-Enriched Bread Production and its Nutritional Benefits

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ABSTRACT

Buckwheat wholegrain flour was added to wheat flour at 10, 20, 30, 40 and 50% (dry weight) to evaluate the technological, organoleptic and nutritional propoerties of the enriched bread. The bread that was produced was generally acceptable when up to 30% buckwheat was added to wheat flour. Regarding the technological quality, an increase in the level of buckwheat led to a decrease of the extensograph energy, resistance, extensibility as well as the ratio number (rheological parameters). Loaves prepared with buckwheat were of lower quality, negatively influencing loaf volume, specific volume, and bulk productivity of the bakery products. From a nutritional point of view, various nutritional parameters, such as rutin content and macro and microelements were determined and compared in the enriched and control bread. The elements which were quantitatively determined (zinc, copper, manganese, nickel) are important biogenic elements. The contents of these elements in bread to which 50% buckwheat was added were significantly higher than in the control wheat bread (from 115% for Mg to 338% for Ni). The rutin content in the bread increased as the amount of buckwheat increased from 14.1 mg.kg^{-1} DM (10% buckwheat) to 48.9 mg.kg^{-1} DM (50% buckwheat). The daily consumption of buckwheat-enriched bread (30% buckwheat, 200 g bread, 3.8 g rutin) during the clinical study (four weeks/eight weeks) caused a significantly increase in the iron level in the blood of volunteers and significantly decreased the triglyceride, HDL cholesterol, creatinine, calcium and magnesium levels. The decrease in total cholesterol, urea and chloride levels were insignificantly.

Keywords: baking test, nutritional and technological quality, clinical study, blood parameters
Abbreviations: AAS, atomic absorption spectrometry; **BU**, Brabender Unit; **DM**, dry mass; **DW**, in dry weight; **HDL**, high-density lipoprotein cholesterol; **TAS**, total antioxidant status

INTRODUCTION

The purpose of foodstuffs is not only to satisfy one's appetite and to stay alive; foodstuffs should also support one's health and under no circumstances should they be detrimental to consumer's health. Raw materials of plant origin, including cereals, pseudo cereals and legumes belong to one of the most important sources of nutrition. The most common basic products of cereals are bread, bakery and pastries. Their total consumption in Slovakia has been recently about 78 kg on average per person per year. This represents a significant group of foodstuffs in the consumption basket with a great influence on the health of the consumer.

Buckwheat is introduced into the diet as an alternative crop of renewed interest thanks to its nutritive and health-promoting value. Two buckwheat species are commonly cultivated: common buckwheat (*Fagopyrum asculentum* Moench) and tartary buckwheat (*Fagopyrum tartaricum* (L.) Gaernt.). These crops are not cereals, but the seeds are usually classified under cereal grains because of their similar usage. The grains are generally used as human food and as animal and poultry feed. Buckwheat has been utilized in food products as groats or flour. Two main methods are used for achenes husking: mechanical grinding of the husks or thermal treatment. The dehulled groats are cooked as porridge and the flour is used in the preparation of bread (mixed with wheat flour), pancakes, biscuits and noodles. The technological quality of common buckwheat is influenced by cultivars (Kalinová *et al.* 2002).

Researchers (Michalová 2000; Zeng *et al*. 2001; Michalová 2003; Quing-Fu 2008) suggest that buckwheat was introduced in Europe from south-west China via northern China and Siberia, and from there probably via Russia and Ukraine to Central Europe where it appeared around the year 1 400. From Central Europe buckwheat spread further to Western Europe (Michalová 2000). In Europe buckwheat is grown mainly in Russia, Ukraine, Poland, Belarus, France, Austria and Slovenia. To a lesser extent it is grown in Hungary and it is cultivated again in the Czech Republic, Luxembourg, northern Italy and Slovakia. In Slovakia it is currently grown on approximately 250 ha with two approved cultivars: "Pyra" and "Spacinska 1". Buckwheat is a low input plant (Kreft 1989) making it very suitable for organic farming.

At present, the demand for buckwheat is high because of its excellent properties and nutritional value based on its favourable composition. Common buckwheat grains and other tissues contain numerous nutraceutical compounds. They are rich in vitamins, especially those of the B group (Fabjan *et al.* 2003), they are an important source of microelements (Zn, Cu, Mn, Se) and macro elements (K, Na, Ca, Mg) (Bonafacia and Fabjan 2003; Stibilj *et al.* 2004) and they offer a high nutritional quality of proteins (Kreft *et al.* 1996; Watanabe 1998; Guo and Yao 2006; Christa and Soral-Smietana 2008), but have a relatively low true digestibility (Skrabanja *et al.* 2000). The amino acid composition is well balanced and of a high biological value. Buckwheat proteins are rich in arginine and lysine, the primary amino acids limiting the content of proteins in cereals, whereas the contents of methionine and threonine in buckwheat proteins are low (Christa and Soral-Smietana 2008). Buckwheat proteins have different characteristics in comparison to wheat,

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barley and rye prolamins enabling the application of buckwheat grains in prophylactics for gastrointestinal tract diseases, mainly celiac disease (Kreft *et al*. 1996).

Starch is the major carbohydrate in buckwheat. The starch content in the whole grain of buckwheat varies from 59 to 70% of the dry mass with fluctuations in function of the variable climatic and cultivation conditions (Qian and Kuhn 1999). Buckwheat starch shows a higher amylase content, a water-binding capacity and a peak viscosity, and it had a lower intrinsic viscosity when compared with corn and wheat starches (Qian *et al*. 1998).

The dietary fibre content may vary from 5–11%. Buckwheat products may have an important content of retrograded starch (Skrabanja and Kreft 1998) and could thus be very suitable for diabetic patients and the prevention of colon cancer. From the nutritional point of view there are three fractions of starch existing, including resistant starch. Resistant starch is not absorbed in the small intestine and is partly or completely available for fermentation by micro flora in the large intestine. It could show a similarity to dietary fibre. Uncooked grains contain 33–38% of total starch, but after cooking only 7–10% (Christa and Soral-Smietana 2008). Suitable textural properties for pasta and other products could be achieved by the balance of other proteins and starch (Ikeda *et al.* 1997).

Buckwheat grains and hull consist of some components with healing properties and biological activity, i.e.: flavonoids and flavon, phenolic acid, condensed tannins, phytosterols and fagopyrins. Flavonoids are a class of secondary plant phenolic compounds with significant antioxidant and chelating properties. Their cardio protective effects stem from the ability to inhibit lipid peroxidation, chelate redox-active metals, and attenuate other processes involving reactive oxygen species (Heim *et al.* 2002). The biological activities of flavonoids are related to their antioxidative effects. The propensity of a flavonoid to inhibit free-radical mediated events is governed by its chemical structure. Buckwheat contains many flavonoid compounds known for their effectiveness in reducing the blood cholesterol, keeping capillaries and arteries strong and flexible, and assisting in the prevention of a high blood pressure (Santos *et al.* 1999). Rutin is a flavonol glycoside composed of the flavonol quercetin and disaccharide rutinose. The antioxidant power of rutin was corroborated by several studies; however, some studies report its pro-oxidant activity and the ability to generate reactive oxygen species, ascribed to aglycon quercetin (Watanabe *et al.* 1997; Watanabe 1998; Quettier-Deleu *et al.* 2000; Cotelle 2001; Rice-Evans 2001). Antioxidant activity is a fundamental property important for life. Many biological functions, such as antimutagenity, anticarcinogenity and antiaging, among others, originate from this property (Cook and Samman 1996).

The content of vitamins, protein, minerals, fibre, and starch with reduced speed of digestion, rutin and other flavonoids make buckwheat products favourable for a healthy nutrition. Buckwheat is used for pasta products, for blended bread (in combination with wheat, corn and other cereals) and for different types of other flour foods.

In this study we have investigated the possibilities of buckwheat use for bread production with favourable technological and organoleptic properties and the influence of such bread consumption on the protective effect on blood components, e.g. on chosen microelements contents, such as cholesterol, triglycerides and other important components.

MATERIALS AND METHODS

In buckwheat seeds the content of the following basic components was determined: starch content (according by Ewers), ash content (weight method by burning in muffle kiln), crude protein (by Kjeldahl's method, f = 6,25), rutin content (by a chromatograph, column Lichrospher 100RP-18, 250-4, 5 μm). The buckwheat wholegrain flour (from winnowed seeds) was mixed with wheat flour T 512 in different portions (10, 20, 30, 40 and 50% in dry weight before baking) for the production of buckwheat bread. The analysis of the rheological property changes caused by different portions of buckwheat has been provided by means of the Farinograph-E and Extenzograph-E (Brabender OhG, Duisburg). The selected parameters loaf volume (cm^3), specific loaf volume (cm^3.100 g^{-1} loaf), volume efficiency (cm^3.100 g^{-1} flour), crumb acidity (titration method), ash and crude protein content in bread have been evaluated during an experimental baking test.

The samples of bread were analyzed for their Zn, Cu, Ni content and other micro and macro elements (the analytical method used for these analyses was AAS (AAS Varian AA spctrDUO 240fs/240z/UltrAA).

The sensory characteristics of the baked loaves have been evaluated with scoring points using an intensive scale prepared by our team (scale 1-5) for the crust colour, crumb colour and crumb porosity and a hedonic scale (1-9) for the surface appearance, crumb appearance, taste, flavour and the complex evaluation (overall acceptability). The breads with a high scale were preferred.

A clinical study based on a daily consumption of 200 g of enriched bread (30% in dry weight buckwheat) was conducted on the group of volunteers (33) during a period of four weeks, after which the selected parameters in their blood were evaluated. Three intravenous blood samples were taken: before the clinical study, immediately after it (after four weeks of consuming enriched bread) and after another four-week period. The blood parameters (Ca, Mg, Fe, creatinine, urea, chloride, cholesterol, and triglyceride level) were measured with the analyser LISA 200 (Biocode-Hycel). The statistical analysis of the data was performed by means of the student's *t*-test. The differences were considered as statistically significant at $P<0.01$.

RESULTS AND DISCUSSION

The used buckwheat was grown in an ecological way and distributed to the market chain. The analysis of the ground groats by thermal treatment indicated that the buckwheat used contained 72.9% starch, 14.16% crude protein and 1.83% ash content in dry mass. The content of crude protein (11.1%) and ash content (1.48%) in the used wheat flour was lower and the content of starch (82.86%) higher (Bojňanská *et al*. 2009a).

Baking test

Buckwheat is not commonly used as a bakery raw material because there is no glutenin and gliadin fraction (Guo and Yao 2006) for gluten formation. The influence of the addition of buckwheat on dough processing and on the quality of the baked goods was observed. The rheological properties of the dough changed when the amount of buckwheat in the blend was increased. The farinograph curve confirmed the prolongation of the dough development time from 2.3 min (wheat flour T 512) to 10.5 min in case of a buckwheat addition of 10 and 20% in dry weight (DW), and the raise of the energy input demands for kneading dough with an optimal consistency after increasing the addition of buckwheat. The degree of softening of the dough after 12 min measured from maximum increased from the previous 54 BU in case of flour T 512 to 85 BU for the sample with a buckwheat addition of 20%. The farinograph quality number was noticeably higher for samples with buckwheat addition (150) compared to T 512 (58). That cannot be related to the better baking quality, rather than to the prolonged dough development time due to the decreased gluten fraction. The extensograph indicated the decrease of the dough resistance and its stability during mixing. The increased addition of buckwheat decreased the extensograph energy, the resistance, the extensibility as well as the ratio number. This means that the increased addition of buckwheat caused a lower dough resistance and its instability during mixing (Bojňanská *et al.* 2009a). According to Přihoda *et al.* (2003) this is the presupposition for the decrease of loaf volume, which was also confirmed by the baking test. The amylolytic activity in the enzymatic complex of flour in suspension showed the maximum increase of the gelatinization tempe-

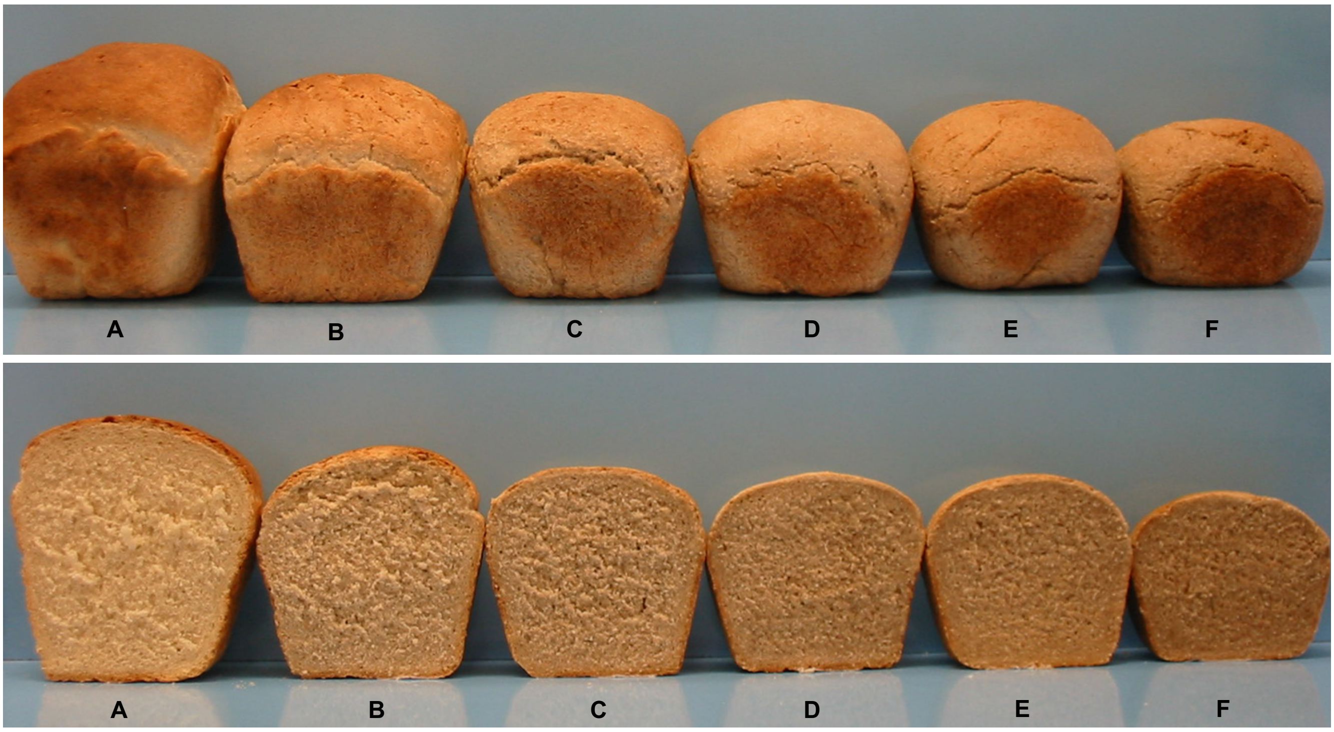

Fig. 1 Loaves prepared with an addition of buckwheat. (**A**) Control bread. (**B**) Bread with an addition of buckwheat of 10%. (**C**) Bread with an addition of buckwheat of 20%. (**D**) Bread with an addition of buckwheat of 30%. (**E**) Bread with an addition of buckwheat of 40%. (**F**) Bread with an addition of buckwheat of 50%. Percentage based on dry weight before baking.

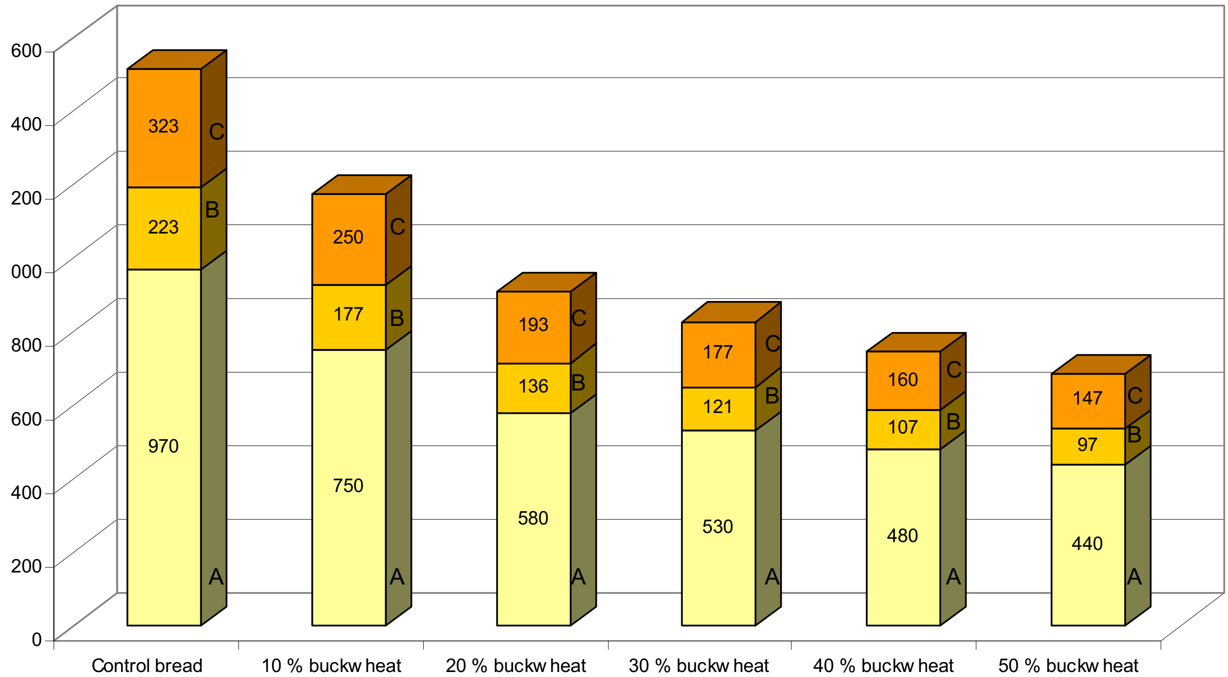

Fig. 2 Evaluated parameters during the experimental baking test (I.). (**A**) Loaf volume, cm^3. (**B**) Specific loaf volume, cm^3 on 100 g bread. (**C**) Volume efficiency, cm^3 on 100 g flour.

rature from 86.6°C (T-512) to 87.3°C (20% DW buckwheat addition) and the maximum decrease of the gelatinization viscosity from 646 BU (T 512) to 497 BU (20% DW buckwheat addition).

The baking test confirmed this, too. The loaves prepared with an addition of buckwheat were evaluated to be of a lesser quality from the technological viewpoint when compared with pure wheat loaves (**Fig. 1**). The additions negatively influenced the loaf volume, the specific volume and the bulk productivity of the bakery products (**Fig. 2**) and increased the crumb acidity, the crude protein content and the ash content (**Fig. 3**). The loaf volume, specific volume and volume efficiency decreased with an increased addition of buckwheat as a result of the decrease of the gluten fraction and the lower capability of gas retention during dough fermentation. The titration acid (crumb acidity) of the buckwheat products increased significantly with the addition of buckwheat (from 48 $mmol.kg^{-1}$ in the control sample to 74 $mmol.kg^{-1}$ in the sample with an addition of buckwheat of 50% DW) what indicates their better quality as far as taste is concerned.

Through the addition of these raw materials the content of nitrogenous substances with a positive biological value in bread has increased, as well as the content of vitamins,

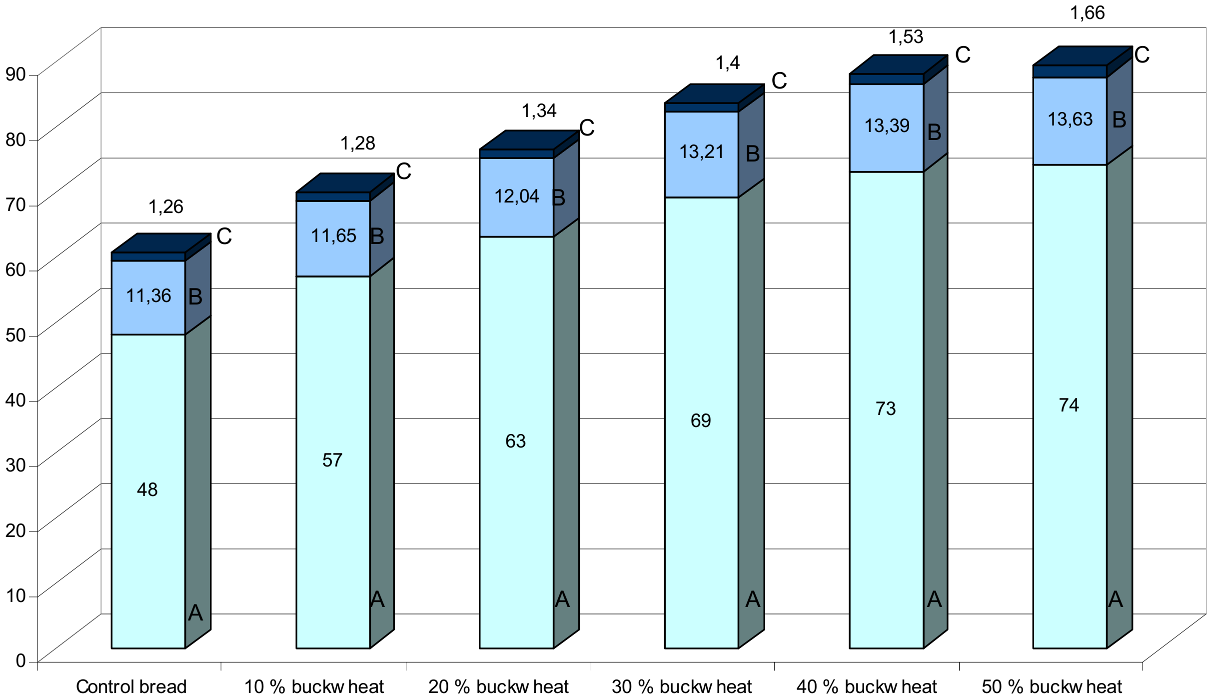

Fig. 3 Evaluated parameters during the experimental baking test (II.) (**A**) Crumb acidity, mmol.kg-1. (**B**) Crude protein, %. (**C**) Ash content, %.

minerals and resistant starch. The antioxidant activity has also increased.

Macro and microelements content in bread

The elements which were determined quantitatively (zinc, copper, manganese, nickel) are listed in tables with recommended nutritional rations. Zinc is an important biogenic element which is part of many enzymes. It plays an important role in the synthesis of proteins, influences the metabolism of saccharides and lipids and supports the immune system (Melicherčík and Melicherčíková 1997). The daily recommended amount of zinc ranges from 5 to 16 mg depending on age, gender and the work load. In general cereals do not have a high Zn content, but based on our results, buckwheat can be considered as a source of Zn (Bonafaccia and Fabjan 2003). For a man performing average strenuous work the daily demand amounts to 12 mg, what can be covered for approximately 20% by the daily consumption of a loaf of bread of 250 g, to which 50% DW of buckwheat has been added.

Copper is another biogenic element. Its daily recommended consumption should be between 0.5 and 2.5 mg, what is possible through consuming cereal products, mainly bread enriched by buckwheat, an important source of Cu. The recommended daily consumption of bread – 250 g (provided that it is prepared with an addition of 50% DW of buckwheat) would guarantee the daily intake of approximately 0.5 mg of Cu. A shortage of Cu in the organism can cause pathological changes; an overdose of Cu however is toxic as it blocks the transfer through the membranes (Melicherčík and Melicherčíková 1997). The Food Codex of the SR, second part, chapter 10 defines the highest acceptable amounts of contaminants in foodstuffs valid in the Slovak Republic. Cu is among the chemical elements listed there. Its highest acceptable amount in cereal products is 10 $mg.kg^{-1}$. This limit was not exceeded in any of the evaluated products.

Another chemical element, which is essential from the physiological point of view, is manganese. It plays a role in the metabolism of lipids, saccharides, proteins and amino acids, influences the immune system and the central nervous system. The content of Mn in bread with buckwheat addition increased from 9.8 $mg.kg^{-1}$ dry mass (DM) to 11.25 $mg.kg^{-1}$ DM.

The essential importance of nickel is a certainty but this element can cause acute or chronic poisoning in case of a high intake and unwanted skin problems can occur in case of contact with Ni compounds. Based on our results (**Table 1**) it has been confirmed that the content in bread with a buckwheat addition of 50% DW was three times higher than in a wheat bread.

From the nutritive point of view the addition of buckwheat also increased the content of the important flavonoid rutin. The content of rutin in buckwheat crush added to bread dough amounted to 79.9 $mg.kg^{-1}$ DM representing a

Table 1 Content of important elements in bread.

	Control bread	**10% BWA[c]**	**20% BWA[c]**	**30% BWA[c]**	**40% BWA[c]**	**50% BWA[c]**
Zn, $mg.kg^{-1}$ DM[a]	9.45	10.10	12.00	13.50	13.85	15.45
Zn, $mg.kg^{-1}$ CF[b]	5.19	5.55	6.60	7.43	7.62	8.50
Cu, $mg.kg^{-1}$ DM[a]	2.45	2.00	2.70	3.00	3.10	3.65
Cu, $mg.kg^{-1}$ CF[b]	1.35	1.10	1.49	1.65	1.71	2.01
Mn, $mg.kg^{-1}$ DM[a]	9.80	8.90	9.35	10.60	10.65	11.25
Mn, $mg.kg^{-1}$ CF[b]	5.39	4.90	5.14	5.83	5.86	6.19
Ni, $mg.kg^{-1}$ DM[a]	0.65	0.50	0.85	1.15	1.35	2.20
Ni, $mg.kg^{-1}$ CF[b]	0.36	0.28	0.47	0.63	0.74	1.21
Rutin, $mg.kg^{-1}$ DM[a]	5.2	14.1	22.1	27.6	36.8	48.9
Rutin, $mg.kg^{-1}$ CF[b]	2.86	7.76	12.16	15.18	20.24	26.90

[a] dry mass
[b] consumable form
[c] buckwheat addition

significant nutritive content although according to Holasová *et al.* (2002), the content of rutin in dehulled buckwheat seeds might reach 184 $mg.kg^{-1}$ DM. The content of rutin in the prepared bread increased accordingly after the addition of buckwheat from 14.1 $mg.kg^{-1}$ DM in bread with an addition of buckwheat of 10% DW to 48.9 $mg.kg^{-1}$ DM in bread with an addition of buckwheat of 50% DW. We should bear in mind though that the bread was not consumed in a dry state and that the amounts of rutin in fresh bread (consumable form) are lower (**Table 1**).

The success of a product on the market is ultimately influenced by the sensory acceptance of the product, an important factor from the consumer's point of view. The organoleptic evaluation of the bread revealed that as the portion of buckwheat flour was increased, the bread crust colour changed from light brown to chestnut brown. The crust texture, the flavour and the taste also changed. Taking into account the overall acceptability rating, it was concluded that bread with an addition of up to 30% DM of buckwheat could be baked with satisfactory results.

Clinical study

Such enriched bread is considered to have a high nutritive value and to be acceptable from a sensory point of view. The baking experiment was followed by a clinical study during which the bread enriched by 30% DW of buckwheat was prepared and consumed on a daily basis. The loaves with an addition of buckwheat of 30% DW contained 3.8 g rutin in 200 g of bread in a consumable form; this equals the daily dosage of rutin in the clinical study provided that the experimental subjects consume the complete dosage.

In this study we are presenting the results of a clinical study realised in 2008. Volunteers consumed buckwheat enriched bread on a daily basis. Otherwise their diet was not specially adjusted. Prior to consumption a blood sample was taken and later on compared with blood samples taken after four and eight weeks to see the changes of the evaluated elements due to the consumption of buckwheat enriched bread. With regard to the evaluated elements, we recorded the decrease of the calcium and magnesium content in the blood of the volunteers (**Table 2**): calcium in average from 2.81 ± 0.16 $mmol.l^{-1}$ to 2.65 ± 0.13 $mmol.l^{-1}$, and magnesium from 0.91 ± 0.06 $mmol.l^{-1}$ to 0.85 ± 0.07 $mmol.l^{-1}$, representing statistically significant differences (at significance level $\alpha = 0.01$). Calcium has an important influence on the permeability of the cell membrane and the activation of enzymes (Keller *et al.* 1993) and its amount in the blood should be between 2.25–2.75 $mmol.l^{-1}$, thus the decrease showed in our study was not important or risky from the health point of view. The situation was similar with magnesium where the average values were within the limits of the recommended dosages (0.66–1.03 $mmol.l^{-1}$). The positive influence of buckwheat bread consumption can be seen in the increase of the iron content in the blood which was statistically significant after four weeks of consumption and continued to increase until the end of the clinical study. A shortage of iron represents the most common deficiency disease affecting a wide population which can evolve into an iron deficiency anaemia. The iron amount in the organism depends on its intake through food and its biological disposability influenced by its chemical form, the existence of other biologically active elements in food as well as the way meals are prepared (Žourek *et al.* 2007). Based on the findings buckwheat consumed in the form of enriched bread might be considered as a suitable source of acceptable iron.

With regard to the other evaluated elements, the decrease of their values was expected due to the buckwheat consumption. A statistically significant decrease of the creatinine content was confirmed with a decrease of the values from 71.94 ± 13.05 $\mu mol.l^{-1}$ to 64.56 ± 12.78 $\mu mol.l^{-1}$ (second sample taking) to 61.21 ± 10.36 $\mu mol.l^{-1}$ (third sample taking) thanks to the positive influence of the buckwheat consumption. Creatinine indicates a worsened function of the kidneys, most often caused by metabolic diseases (diabetes) and a high blood pressure (Dzúrik and Spustová 1999). The decrease of triglycerides between the first sampling and the last one after eight weeks (from 2.15 ± 0.91 to 1.78 ± 0.71 $mmol.l^{-1)}$ is similarly to the creatinine content a very positive decrease, mainly when taking into account the influence of the high level of triglycerides on the development of a coronary heart disease (Patrick 2007).

The high level of blood cholesterol is also one of the most important risk factors in relation with coronary heart disease and atherosclerosis. The total cholesterol, low-density lipoprotein (LDL) and high-density lipoprotein (HDL) cholesterol levels in blood were determined. The average decrease of the total cholesterol content in the volunteers' blood was insignificant (**Table 2**), but the decrease of the HDL level was significant what is considered as non desirable. The HDL values should be above 1.6 $mmol.l^{-1}$ what decreases the risk of a coronary heart disease and atherosclerosis. This finding was rather surprising as the experiments with hamsters (Lin *et al.* 2008) confirmed that the level of serum low-density lipoprotein cholesterol was significantly suppressed by all buckwheat meals and the serum high-density lipoprotein cholesterol levels were increased, in an insignificant way however. The total cholesterol, triglyceride and LDL cholesterol levels also significantly decreased in rats that were administered rutin when compared with the control group (Lim *et al.* 2006; Ziaee *et al.* 2009). López-Revuelta *et al.* (2006) analysed the influence of rutin and quercetin on the cholesterol content in rabbits with positive results. Despite an insignificant decrease of cholesterol the results showed that we can recommend the consumption of buckwheat mainly because of its high antioxidant effect. The powerful antioxidant activity of flavonoids in buckwheat suggests that these compounds could play a protective role in oxidative stress-mediated diseases (Rice-Evans 2001). The total flavonoid intake from dietary sources is estimated to be several hundred milligrams per day (Ross and Kasum 2002). They have been shown to possess multiple biological properties, including vasodilatory, anti-inflammatory, antiviral, antioxidant, and anticarcinogenic

Table 2 Results of selected blood parameters volunteers (n = 33).

	First sample[1]	Second sample[2]	Third sample[3]
Ca, $mmol.l^{-1}$	2.81 ± 0.16 a	2.72 ± 0.15 ab	2.65 ± 0.13 bc
Mg, $mmol.l^{-1}$	0.91 ± 0.06 a	0.87 ± 0.08 ab	0.85 ± 0.07 bc
Fe, $\mu mol.l^{-1}$	30.09 ± 7.94 a	39.38 ± 7.30 b	48.41 ± 6.70 c
Kreatinin, $\mu mol.l^{-1}$	71.94 ± 13.05 a	64.56 ± 12.78 b	61.21 ± 10.36 c
Urea, $mmol.l^{-1}$	4.61 ± 0.99 a	4.37 ± 1.19 a	4.18 ± 0.97 a
Chloride, $mmol.l^{-1}$	105.41 ± 5.08 a	103.06 ± 4.11 a	102.13 ± 7.25 a
Cholesterol total, $mmol.l^{-1}$	5.96 ± 1.20 a	5.87 ± 1.28 a	5.78 ± 1.28 a
HDL cholesterol, $mmol.l^{-1}$	1.27 ± 0.22 a	1.18 ± 0.20 bc	1.17 ± 0.23 c
LDL cholesterol, $mmol.l^{-1}$	3.47 ± 0.78 a	3.43 ± 0.79 a	3.36 ± 0.84 a
Triglyceride, $mmol.l^{-1}$	2.15 ± 0.91 a	2.02 ± 0.63 ab	1.78 ± 0.71 bc

[1] before the clinical study
[2] after four weeks of consuming enriched bread
[3] after another four-week period
[a,b,c] For each row, values with different letters, are significantly different (P<0.01)

effects, as well as being inhibitors of phospolipase A_2, cyclooxigenase, lipoxygenase, glutathione reductase and xanthine oxidase (Rice-Evans 1996). The already published article (Bojňanská *et al.* 2009b) states the positive increase of the serum antioxidant capacity in humans thanks to the consumption of enriched bread (30% DW buckwheat). The most remarkable increase of the TAS values was found with experimental persons, who consumed the complete daily dosage (200 g). The most significant increase in comparison to the initial state was found with experimental persons with an initially low TAS, the increase reached nearly 40%. The highest TAS level (initially as well as finally) was found with younger experimental persons between 18 and 34 years old, the lowest with people between 35 and 54 years old. These data suggested that buckwheat was a significant antioxidant as TAS in human plasma and that the increased TAS level through doses of buckwheat bread could be useful as a free radical scavenger. It appeared that the TAS of the plasma of the volunteers who consumed buckwheat enriched bread daily during the period of four weeks was significantly higher than before its consumption.

CONCLUSIONS

Based on the obtained results we can conclude that the buckwheat addition worsens the technological parameters of the blends used for the baking test. The rheological properties of the dough changed when the amount of buckwheat in the blend was increased. It means that the increased addition of buckwheat caused a lower dough resistance and its instability during mixing. The baking test confirmed this, too. The loaves prepared with an addition of buckwheat were evaluated to be of a lesser quality. The overall acceptability rating lead to the conclusion that bread could be baked with satisfactory results after an addition of buckwheat of up to 30% DW.

The macro and microelement content in bread with an addition of buckwheat has increased. Zn, Cu, Mn, Ni are important biogenic elements. Based on our results it has been confirmed that the contents of these elements in bread with a buckwheat addition of 50% DW and more were higher than in the control wheat bread, in the case of Zn by 163%, Cu by 149%, Mn by 115% and Ni by 338%.

From the nutritive point of view the addition of buckwheat has increased the content of the important flavonoid rutin, too. The content of rutin in the prepared bread increased accordingly with the addition of buckwheat from 14.1 $mg.kg^{-1}$ DM in bread with an addition of buckwheat of 10% to 48.9 $mg.kg^{-1}$ DM in bread with an addition of buckwheat of 50%.

The daily consumption of buckwheat enriched bread during the clinical study by volunteers led to a significant increase of the iron level in the blood and a significant decrease of calcium and magnesium. The significant decrease of the HDL cholesterol level was surprising as well as non desirable. On the other hand the expected and welcome decrease of the total cholesterol was statistically insignificant. Among the positive changes there was a significant decrease of the triglyceride and creatinine level and an insignificant decrease of the chloride and urea level.

In general it can be concluded that the regular consumption of buckwheat enriched bread brings nutritional benefits to the consumers and with long-term consumption can have a protective effect thanks to the numerous nutraceutical compounds of buckwheat. It is not realistic, though, to expect that the consumption of buckwheat bread would solve the health problems related to an unhealthy life style and bad eating habits in general.

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