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Antioxidant Capacity and Sensory Evaluation of Wheat Bakery Products Supplemented with Buckwheat and Oat Flour and Barley β-D-Glucan

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ABSTRACT

Wheat (*Tritium aestivum* L.) is the most important cereal crop of world in terms of production and consumption. However, wheat is considered nutritionally poor and therefore we decided to supplement wheat flour with whole buckwheat flour (variety 'Špačinská 1') and extruded oat flour (variety 'Avesta') in three different ratios: ratio of oat to buckwheat 1: 2 (15% addition), 1: 3 (20% addition) and 1: 4 (25% addition). Moreover, we tested the enrichment of bakery products with barley β-D-glucan, important for its hypocholesterolemic and radical scavenging effects. Supplemented bakery products exhibited higher antioxidant capacity evaluated by ABTS (2,2'-azinobis-[3-ethylbenzthiazoline]-6-sulphonic acid) and DPPH (2,2-diphenyl-1-picrylhydrazyl) tests, by EPR (electron paramagnetic resonance) spin trapping assay and β-carotene bleaching method, in comparison to the control wheat product. Total phenolic compounds in four kinds of the representative bakery products were also analysed. The increased ratio of buckwheat flour in bakery products lead to a statistically significant increase in the content of phenolic compounds. Sensory characteristics of suggested bakery products were determined by a panel of 14 judges who evaluated the form of products, crust colour, porosity, tackiness, colour and elasticity of crumb, odour, taste and overall acceptability. All tested characteristics were affected by the buckwheat and oat flour supplementation. The 15 and 20% addition improved positively the overall acceptability of studied products while the 25% addition showed no considerable improves.

Keywords: cereal antioxidants, functional products, phenolic compounds, sensory quality
Abbreviations: ABTS, 2,2'-azinobis-[3-ethylbenzthiazoline]-6-sulphonic acid; **DMPO**, 5,5-dimethylpyrroline-*N*-oxide; **DMSO**, dimethylsulphoxide; **DPPH**, 2,2-diphenyl-1-picrylhydrazyl; **EPR**, electron paramagnetic resonance; **RSC**, radical scavenging capacity, **TEAC**, Trolox equivalent antioxidant capacity

INTRODUCTION

Bread making is the most common flour processing technique used in human food production (Zieliński *et al.* 2008). Bread and bakery products have an important role in human nutrition, because they represent a good source of irreplaceable nutrients for human body. This is especially true for the products made from whole- or multi-grain flour, while products made from refined wheat flour are considered nutritionally poor (Škrbić and Filipčev 2008). Additionally, bread and other bakery products are ideal functional foods, since they constitute an important part of our daily diet (Flander *et al.* 2007). The addition of cereals and pseudocereals to wheat flour used for preparation of bakery products should lead to the improvement of nutritional, physiological and organoleptic properties of the final products (Ragaee *et al.* 2006). Moreover, some of the cereals and pseudo cereals are sources of unique antioxidants, e.g. oats contain the avenanthramides (*N*-cinnamoylanthranilate alkaloids) and avenalumic acids (ethylenic homologues of cinnamic acids) (Miller *et al.* 2000; Bryngelsson *et al.* 2002; Liu *et al.* 2004; Mattila *et al.* 2005) and buckwheat contains rutin (Holasová *et al.* 2002; Sun and Ho 2005) which are not present in other grains.

Oat (*Avena sativa* L.) additionally contains high amounts of other valuable nutrients such as proteins, unsaturated fatty acids, vitamins, minerals, water soluble β-D-glucans and antioxidants such as phenolic acids, tocopherols and tocotrienols, phytic acid and alk(en)ylresorcinols (Peterson 2001; Lyly *et al.* 2004; Johansson *et al.* 2004). Oat is mostly known for its high content of β-D-glucans, which varies between 3.1 and 4.7% (w/w) in covered oat varieties and between 5.8 and 6.8% (w/w) in naked oats, respectively (Brindzová *et al.* 2008). Buckwheat (*Fagopyrum esculentum* Moench) is well-known as a dietary source of phenolic acids, flavonoids and anthocyanins with various biological activities (Oomah and Mazza 1996; Holasová *et al.* 2002). The major flavonoid (flavonol) in buckwheat is quercetin (3′,4′-dihydroxyflavonol) existing predominantly in the glycosylated forms as rutin (quercetin-3-*O*-β-rutinoside). Other flavonoids are isovitexin, vitexin, orientin and isoorientin (Watanabe 2007). Buckwheat is also a rich source of vitamins B_1 and B_2, tocopherols, fatty acids, essential minerals; it has balanced amino acid composition and contains high amount of lysine (Sun and Ho 2005; Watanabe 2007).

Even though oat and buckwheat are traditionally used as a food grains, they are not associated with bread or other bakery products. Oat is usually consumed in the from of oat flakes and is largely used as animal feed and buckwheat is known from buckwheat tea, buckwheat flour or semolina, buckwheat flakes, buckwheat noodles and buckwheat honey. In this context and in order to improve the quality of bakery products together with the intake of antioxidants and β-D-glucans we have enriched the wheat flour by buckwheat flour (variety 'Špačinská 1'), extruded oat flour (variety 'Avesta') and barley β-D-glucan addition. Finally multigrain bakery products were tested for antioxidant and radical scavenging capacity, amount of total phenolic com-

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pounds and were evaluated by a panel of judges with regards to the organoleptic characteristics and overall acceptability.

MATERIALS AND METHODS

Cereal samples

Grain samples of oat variety 'Avesta' and buckwheat variety 'Špačinská 1' were obtained from the gene bank of the Research Institute of Plant Production (Piešťany, Slovakia). Variety samples were grown in Vígľaš Pstruša (Slovakia) in the 2006 crop year. Whole grain of buckwheat and dehulled extruded oat were milled on industrial mill in Veľký Grob (Slovakia).

Preparation of bakery products (rolls)

The buckwheat flour, extruded oat flour and β-D-glucan (isolated from barley according to patent Kuniak *et al.* (1992) using modified method for isolation of β-D-glucan from oyster mushroom) were blended with wheat flour and processed into bakery products (rolls). The formula consisted of wheat flour T650 (1 kg – control sample), buckwheat flour (10, 15 and 20% substitute of wheat flour), oat flour (5% substitute of wheat flour), baker's yeast, sugar, salt, shortening, commercial improver 'Laktorex' and barley β-D-glucan (5 ml/100 g). Total weight of the dough batch was 1600 g, which was divided into forty 40 g pieces. The rolls were baked in an electric oven at 270°C for 15 min. **Fig. 1** shows the difference between all types of prepared bakery products.

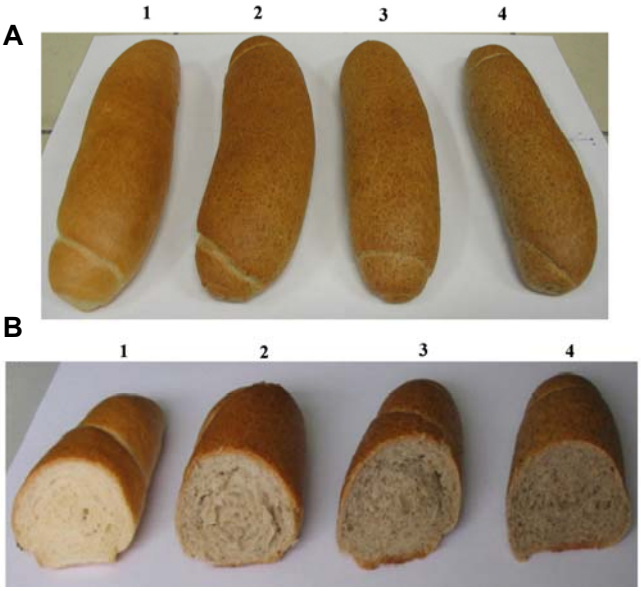

Fig. 1 Photos of the tested bakery products. (**A**) Bakery product samples two hours after baking. (**B**) Differences in cross-section of bakery products. **1** – Control sample (100 % wheat flour), **2** – Product with ratio of oat and buckwheat 1:2, **3** – Product with ratio of oat and buckwheat 1:3, **4** – Product with ratio of oat and buckwheat 1:4.

Defatting of samples

The bakery products were sliced (1 cm thickness), dried at laboratory temperature for 24 h, milled and ground to pass through a 0.5 mm screen. Moisture content was determined and all data were expressed on a dry weight basis. The fine flour (60 g) was transferred to an Erlenmeyer flask, defatted twice with hexane (p.a. purity, Mikrochem, Pezinok, Slovakia) at a 5:1 ratio (v/w) and kept on a mechanical shaker for 1 h at room temperature (Kim *et al.* 2006). The mixture was filtered through a Büchner funnel after each extraction step.

Preparation of extracts

Defatted flour was subjected to alkali treatment with 2 M NaOH (p.a. purity, Mikrochem) for 4 h at 50°C, acidified to pH 2 with 6 M HCl (p.a. purity, Mikrochem) and extracted 3 times with ethyl acetate (p.a. purity, Lachema, Brno, Czech republic) at a solvent to water phase ratio of 1: 1. The ethyl acetate extracts were dehydrated with anhydrous sodium sulphate (p.a. purity, Mikrochem), filtred and evaporated to dryness under vacuum at 40°C (Krygier *et al.* 1982; Deng and Zito 2003). Residues containing extracted antioxidants, particularly phenolic compounds, were dissolved in 5 ml of DMSO (purum, > 99.8%, Merck, Darmstadt, Germany) for determination of antioxidant effects. The same extract was prepared and residue was dissolved in 5 ml of 96% ethanol for the analysis of total phenolic content.

Determination of total antioxidant capacity

Antioxidant activity was measured by the ABTS test (Re *et al*. 1999; Arts *et al*. 2004) and by the DPPH test (Yen and Chen 1995). To prepare ABTS cation radical solution ($ABTS^{+\bullet}$) a potassium persulphate (p.a. purity, Merck) aqueous solution (3.3 mg $K_2S_2O_8$ in 5 ml distilled water) was added to 17.2 mg ABTS (purum, > 99%, Fluka, Munich, Germany) and the resulting solution was stored in dark for 14 hrs. 1 ml of final dark-green radical solution was then diluted with 60 ml of distilled water and used in the ABTS test, where 50 µl of cereal extract in DMSO was added to 2 ml of $ABTS^{+\bullet}$. To prepare DPPH radical solution a 120 mg DPPH (purum, > 95%, Sigma-Aldrich, Munich, Germany) was added to 100 ml 96% ethanol. In DPPH test 3 ml 96% ethanol and 1 ml DPPH radical solution were added to 1 ml of the extracts. The UV-Vis spectra were taken in 1-min intervals for 10 min using a UV-Vis 1700 spectrophotometer (Shimadzu, Kyoto, Japan). The difference in the absorbance in the 10^{th} min at 730 nm (ABTS test) and 517 nm (DPPH test) relative to the reference spectrum, ΔA, was used to calculate the percentage of scavenged ABTS cation radicals and radicals of DPPH by extracts relative to the reference sample (Katalinic *et al*. 2006). Using calibration curve of Trolox (Sigma-Aldrich) the values in % of scavenged radicals were recalculated to the Trolox equivalents (TEAC – Trolox Equivalent of Antioxidant Capacity) in mg Trolox/g of grain dry weight.

EPR/spin-trapping analysis

The radical scavenging ability of the samples was examined by the EPR/spin trapping method (Brindzová *et al.* 2009a; Zalibera *et al*. 2009). 200 µl of DMSO extract or pure DMSO in reference measurements was mixed with 25 µl of 0.2 M DMPO (5,5-dimethylpyrroline-N-oxide; purum, >97% (GC), Sigma-Aldrich, purified by vaccum distillation) in DMSO and 25 µl of 0.01 M $K_2S_2O_8$ and filled into a EPR flat cell (EPR X-band EMX spectrometer, Bruker, Rheinstetten, Germany). The thermal decomposition of $K_2S_2O_8$ in DMSO at 60°C was used as a source of reactive radicals. A time course of EPR spectra of the DMPO spin-adducts (3 scans for each spectrum) was recorded in 1-min intervals for 20 min at 60°C. The difference between the integral EPR intensities of the reference and the extracts in the 10^{th} and 20^{th} minutes characterizes the amount of radicals scavenged by the scavengers present in the corresponding sample. Radical Scavenging Capacity (RSC) was calculated as a percentage of scavenged radicals relative to the reference sample (DMSO).

Method of β-carotene bleaching

Antioxidant activity (AA) using the β-carotene linoleate model system was evaluated in terms of bleaching of β-carotene (purum, > 97%, Fluka), measured as the decrease of absorbance at 470 nm (Amin *et al*. 2004). β-carotene (2 mg) was dissolved in 10 ml chloroform (p.a. purity, Mikrochem) and 1 ml of this solution was added to 0.02 ml linoleic acid (purum, > 99%, Fluka) and 0.2 ml Tween 20. The chloroform was removed under vacuum at 40°C and distilled water (100 ml) was added and solution was mixed well. 5 ml of the β-carotene/linoleic acid emulsion were mixed with 200 µl of the extracts. Oxidation of the emulsion was monitored spectrofotometrically (Shimadzu, Kyoto, Japan) at 15-min intervals for 120 min at 45°C. AA was calculated according to formula: $AA = [1-(A_0-A_t)/(A^0_0-A^0_t)].100$, where A_0 and A^0_0 are the absorbance values measured at zero time of the incubation for test

Table 1 Antioxidant capacity expressed as Trolox equivalent (TEAC) and content of phenolic compounds expressed as gallic acid equivalent (GAE) in bakery products.

Bakery products	ABTS test (mg Trolox/g ± SD)	DPPH test (mg Trolox/g ± SD)	Total phenolics (mg GAE/g ± SD)
Control sample (100 % wheat flour)	0.378 ± 0.005	0.621 ± 0.006	0.125 ± 0.009
Ratio of oat: buckwheat 1:2	0.521 ± 0.002	2.518 ± 0.036	0.347 ± 0.007
Ratio of oat: buckwheat 1:3	0.706 ± 0.011	3.512 ± 0.021	0.491 ± 0.005
Ratio of oat: buckwheat 1:4	0.859 ± 0.011	5.265 ± 0.033	0.622 ± 0.021

Significance differences at $p \leq 0.05$ were found for all measurements

sample and A_t and A^0_t are the absorbance values measured in the test sample after incubation for 120 min. The results were express in % of inhibition.

Determination of total phenolic content

Total amount of phenolic compounds was measured in the ethanolic extracts with a standard Folin-Ciocalteu reagent (Yu *et al.* 2004). The reaction mixture containing sample extracts, Folin-Ciocalteu reagent (Merck) and sodium carbonate was mixed on a vortex mixer and diluted with distilled water to final volume of 10 ml. After 2 h reaction, the absorbance at 765 nm was determined and used to estimate the phenolic contents using the calibration curve of gallic acid (purum, > 97%, Sigma-Aldrich). The total phenolic contents are expressed in mg of gallic acid equivalent (GAE) per 1 gram dry weight of sample.

Sensory evaluation

The fresh bakery product samples (two hours after baking) were sliced mechanically to 1.5 cm thickness, coded, presented randomly and evaluated by 14 trained judges (all holding accredited certificate of judge) for the form of products, colour, porosity and tackiness of crumb on a 4-point hedonic scale (Ragaee and Abdel-Aal 2006); for the colour of crust, elasticity of crumb and overall acceptability using continuous unstructured, graphical scales (10 cm in length) ranging from like extremely/highest intensity (100%) to dislike extremely/lowest intensity (0%) (Zieliński *et al*. 2008); for odour and taste using graphical profile method (modified method from ISO 13299 2003). The judges received a cup of room temperature water for neutralizing their taste together with the samples.

Statistical analysis

All tests were carried out in triplicate and mean values ± standard deviations (SD) are presented. Statistical analysis was performed using Student's *t*-test and significance differences were declared at $p \leq 0.05$. The correlation analysis was also performed. Statistical analyses were processed in MS Excel.

RESULTS AND DISCUSSION

Based on our previous screening of 36 crop varieties (four cereals and six pseudocereals) for the antioxidant and radical scavenging properties (Brindzová *et al*. 2009b), we selected buckwheat variety 'Špačinská 1' and oat variety 'Avesta' to supplement the wheat flour for preparation of bakery products. Buckwheat was selected as the grain with the highest amount of phenolic compounds and oat with black hulls because of the best radical scavenging capacity found among the analysed crops. As the extrusion process increases the amount of free phenolic compounds in oat samples (releasing phenolics from bounded forms) (data not shown), the oat was extruded before the addition to wheat flour. Additionally, the barley β-D-glucan, important for its radical scavenging effects, was added to the products.

The extracts of all types of bakery products were examined for their antioxidant and radical scavenging capacity using four independent assays, because a combination of several tests and methods can provide a more reliable assessment of the antioxidant capacity. ABTS and DPPH tests are based on electron-transfer reaction and were used for determination of total antioxidant capacity, EPR/spin trapping method is based on the thermal decomposition of $K_2S_2O_8$ and estimated the reactive radical scavenging capacity of samples while inhibition of linoleic acid oxidation (β-carotene) involves hydrogen atom transfer reactions (Rapta *et al.* 2005; Gorinstein *et al*. 2007).

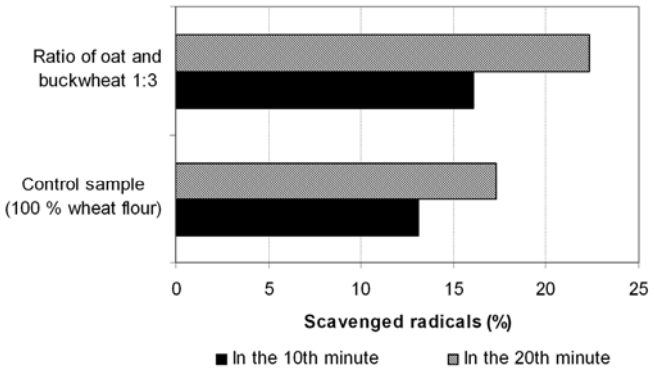

Fig. 2 Radical scavenging capacity (RSC) of samples expressed as the percentage of scavenged radicals relative to the reference sample, determined by EPR spin-trapping method.

Significant differences in total antioxidant capacity, investigated with ABTS and DPPH tests, among bakery products containing three different ratios of oat and buckwheat flour – ratio of oat and buckwheat 1: 2 (15% addition), 1: 3 (20% addition) and 1: 4 (25% addition), were observed (**Table 1**). The antioxidant capacity increased with an increase in the content of buckwheat flour. Samples with a ratio of oat and buckwheat 1: 4 showed 2.3 times higher Trolox equivalent antioxidant capacity (TEAC) in the ABTS test and 8.5 times higher TEAC in the DPPH test than the control sample based on wheat flour. The incorporation of buckwheat and oat also increased the radical scavenging capacity (RSC) of the products as evaluated by the EPR/spin-trapping method. Comparison of the RSC of sample with ratio of oat and buckwheat 1: 3 and control sample is presented in **Fig. 2**. RSC of the supplemented product in the 10th minute of the measurement was about 23% higher than that of control sample. In the 20th minute of the experiment the RSC of the supplemented product was about 29% higher than the RSC of control sample; this means that the product with added buckwheat, oat and β-D-glucan contains more antioxidants effective against the highly reactive radicals and that they could probably also scavenge the radicals in humans. The antioxidant properties of samples examined as the retardation of β-carotene decolourization in the 120th minute of measurement also improved with increasing addition of buckwheat flour. The absorbance of all emulsions decreased with time (**Fig. 3**). The rate of absorbance decrease for emulsion samples with extracts from supplemented products were significantly lower than for the sample with extract from control product. Antioxidant activities, expressed as percentage of bleaching inhibition in the 120th minute of experiment for samples with ratio of oat and buckwheat 1: 2, 1: 3 and 1: 4 and the control sample were 46, 57, 66 and 40%, respectively.

The supplemented wheat bakery products also exhibited a higher amount of total phenolic compounds when compared to the control sample (**Table 1**). The content of phenolics changed due to the replacement of the part of wheat flour with buckwheat. The products supplemented with buckwheat and oat flour contained higher amounts of total

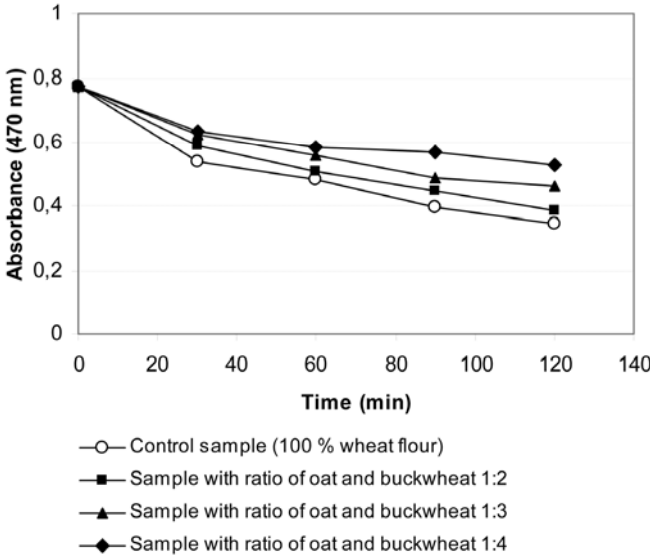

Fig. 3 Change of absorbance at 470 nm with time for bakery product extracts in β-carotene/linoleic acid emulsion.

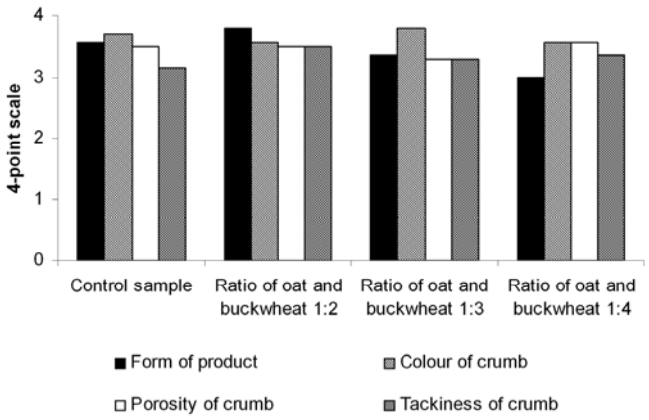

Fig. 4 Sensory evaluation of the form of products, colour, porosity and tackiness of crumb of bakery products on a 4-point hedonic scale by 14 trained judges.

phenolic compounds (0.347-0.622 mg GAE/g d.m.) when compared to the total content of phenolics in product formulated on wheat flour (0.125 mg GAE/g d.m.). The maximum supplementation dose increased the total phenolic content up to 4.9 times in comparison to the control sample. All these findings were significantly different statistically.

Total phenolics and antioxidant activity investigated by the ABTS test, the DPPH test and by β-carotene bleaching highly correlated to each other (the correlation coefficients were r = 0.9870, r = 0.9923 and r = 0.9679, respectively). Our results are in a good agreement with the results provided by other authors; for example, the correlation coefficient for total phenolic compounds and antioxidant capacity of cereals determined by the ABTS test was r = 0.996 (Ragaee *et al.* 2006) and r = 0.952 (Gorinstein *et al.* 2007); for total phenolics and antioxidant capacity of cereals determined by the DPPH test, r = 0.970 (Beta *et al.* 2005), r = 0.998 (Ragaee *et al.* 2006) and r = 0.872 (Gorinstein *et al.* 2007) and for total phenolics and antioxidant capacity of cereals determined by the β-carotene bleaching method r = 0.906 (Gorinstein *et al.* 2007). High correlations were also found between total phenolics and antioxidant capacity of other natural samples (Pekkarinen *et al.* 1999; Awika *et al.* 2004; Park *et al.* 2006; Saura-Calixto and Goňi 2006). This provides strong evidence that the predominant source of antioxidant activity derives from phenolic compounds in bakery products, while non-phenolic compounds occurring in the products, such as β-D-glucan, might contribute considerably to the antioxidant activity and should also be taken into account.

At present there is a growing interest in the health aspects of whole- or multi-grain products, but the good sensory properties still remain a key priority as a consumer choice criterion (Ragaee and Abdel-Aal 2006). The sensory evaluation of our samples showed sensory differences between the bakery products baked with different ratios of buckwheat and oat flour when compared to the control. The rating scale for the form of products ranged from 0 (unacceptable) to 4 (excellent/good vaulted); for crumb colour it ranged from 0 (unacceptable/pale or burned) to 4 (typical for bakery product); for crumb porosity it ranged from 0 (small/without poruses) to 4 (uniform poruses); for crumb tackiness it ranged from 0 (more tacky) to 4 (easy tacky). Results are presented in **Fig. 4**. The form and crumb tackiness of product with a ratio of oat to buckwheat of 1: 2 obtained better scores (3.79 and 3.50 units, respectively) than the control samples (3.57 and 3.14 units, respectively). The crumb colour of products with a ratio of oat to buckwheat of 1: 3 was evaluated as the best and obtained the score of 3.79 units, followed by the control samples (3.70 units) and then the samples with a ratio of oat to buckwheat of 1: 3 and 1: 4 (both samples 3.57 units). The porosity of samples was similar. Sensory evaluation of supplemented products (**Table 2**) also showed that, as the amount of buckwheat flour increased, the elasticity of crumb and overall acceptability decreased, while the crust colour was not significantly affected by the increasing addition of buckwheat flour. The addition of buckwheat, oat and β-D-glucan significantly decreased the crumb elasticity of supplemented products compared to the control sample. The crust colour of supplemented products received higher scores than that of the corresponding control sample. Crust colour of samples varied, depending on the amount of non-wheat cereal incorporated in the wheat flour. All supplemented samples had a darker crust due to the higher content of dark outer layers of whole buckwheat. In addition, the intensity of crust colour may be significantly affected by the baking temperature. The overall acceptability was categorized as "excellent, tasteful" for all tested products. In addition, products with different proportions of buckwheat and oat flour, enriched with β-D-glucan, showed better or similar overall acceptability, 92, 86 and 84%, respectively, when compared with the control sample (83%). An example of a graphical profile of sensory attributes odour and taste of the product with an oat: buckwheat ratio of 1:3 and control sample is shown in **Fig. 5**. Taste of the control sample and all supplemented products was evaluated by the judges as typical for bakery products (93, 89, 86 and 83%, respectively). In products with an oat: buckwheat ratio of 1:3 and 1:4 the judges also registered other tastes – slightly sweet and poppy taste. The typical odour of products decreased in this order: control sample (89%), product with ratio of oat and buckwheat =

Table 2 Sensory evaluation of crust colour, crumb elasticity and overall acceptability of bakery products using continuous unstructured, graphical scales (10 cm in length) by 14 trained judges (expressed as mean in % ± SD).

Bakery products	Crust colour	Crumb elasticity	Overall acceptability
Control sample	81 ± 0.8 a	87 ± 1.0 c	83 ± 0.6 a
Ratio of oat and buckwheat 1: 2	85 ± 0.7 b	80 ± 1.5 b	92 ± 0.8 c
Ratio of oat and buckwheat 1: 3	86 ± 1.0 b	76 ± 2.2 ab	86 ± 1.0 b
Ratio of oat and buckwheat 1: 4	87 ± 1.3 b	73 ± 2.1 a	84 ± 1.1 ab

Different letters within the same column indicate significantly different means ($p \leq 0.05$)

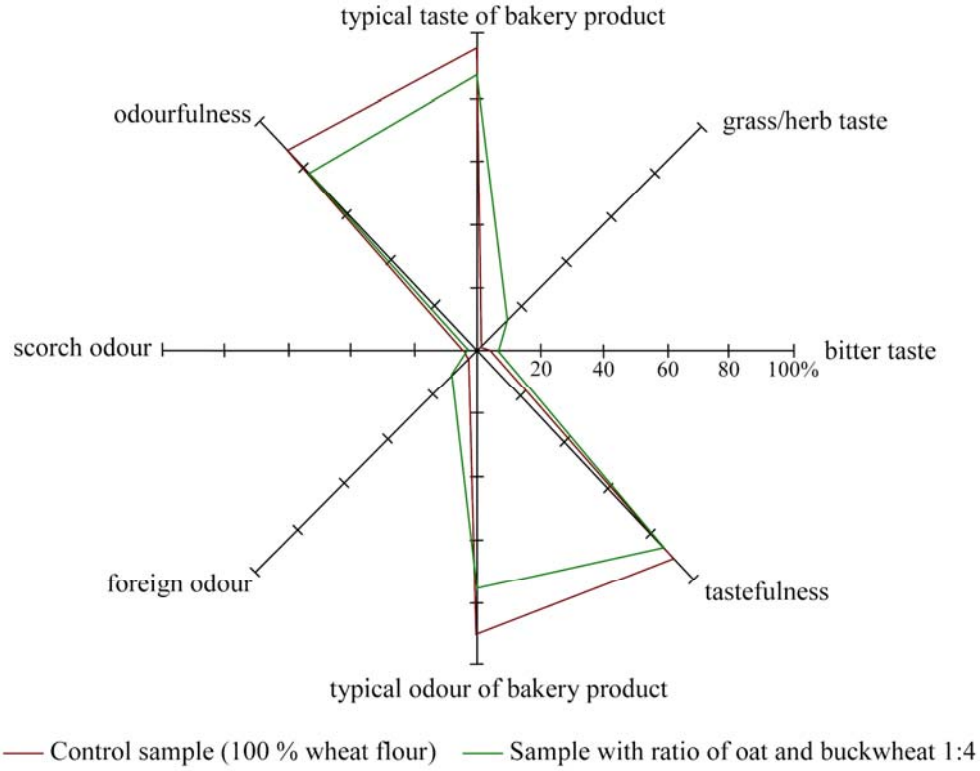

Fig. 5 Sensory evaluation of odour and taste of bakery products using graphical profile method by 14 trained judges (expressed as mean in %). Red lines = control sample; green lines = Sample with ratio of oat and buckwheat 1:3.

1:2 (80%), product with ratio of oat and buckwheat = 1:3 (78%) and product with ratio of oat and buckwheat = 1:4 (75%). According to many reports, amino acids affect the taste and odour of bakery products through the non-enzymatic Maillard reaction, Strecker degradation or by heat degradation (Zieliński *et al.* 2008). The grass/herb taste and foreign odour in products to which oat, buckwheat and β-glucan were added were pronounced attributes in comparison to the control sample. The increasing addition of buckwheat flour to wheat flour resulted in an increase of the grass/herb taste in products with ratio of oat and buckwheat = 1: 2, 1: 3 and 1:4 (7, 11 and 15%, respectively) compared to the control sample (1%) and foreign odour (10% for all supplemented products) compared to the control sample (3%). Since grass/herb taste and foreign odour are often perceived as negative, it is likely that the addition of buckwheat and oat flour to bakery products in high amounts would have a lower acceptance among consumers than would products containing only wheat flour. Bitter taste and scorch odour were evaluated as similar for all tested products (5-8% for bitter taste and 3-5% for scorch odour). The control sample and the product with a oat: buckwheat ratio of 1: 2 showed similar overall taste (up to 90%) and overall odour (up to 85%), as well as the products with a oat: buckwheat ratio of 1: 3 or 1: 4 (overall taste 85% and overall odour 79% for both products). These results indicate that the sensory attributes were influenced by amount of buckwheat flour in products, rich in polyphenolic compounds. All supplemented bakery products had higher amount of phenolics when compared to the control sample. This correlates well with the sensory evaluation, since phenolic compounds are reported to have a bitter and astringent taste (Lesschaeve and Noble 2005; Holtekjolen *et al*. 2008) and could be also responsible for the grass/herb taste and other aftertastes. Products supplemented with oat, buckwheat and β-glucan could offer not only health-beneficial nutrients, but also provide a new product with good sensory quality for the consumers of wheat bakery products. Furthermore, the addition of oat flour to wheat bread or to other bakery products might have a role in maintaining the stability of final products by preventing or retarding the oxidation of free fatty acids (Peterson 2001); moreover, oat has also excellent moisture retention properties that keep products fresh for longer periods of time (Flander *et al.* 2007).

CONCLUSIONS

Supplementation of wheat flour with selected varieties of buckwheat and oat as well as the addition of barley β-D-glucan led to a significant increase in the antioxidant capacity of the final bakery products. The antioxidant capacity improved proportionally to the increasing ratio of buckwheat in the wheat flour. In addition, the bakery products prepared with the addition of buckwheat, extruded oat and barley β-D-glucan contained significantly more total phenolics compared to products made from wheat only. Phenolic compounds are associated with possible health-benefit effects as well as with important functional properties. On the other hand, the idea of their incorporation into bakery products will only be successful if the final product can be accepted by consumers/public. Phenolic compounds contribute to product quality in terms of colour, flavour and texture. The substitution of wheat flour with buckwheat, oat and β-D-glucan had a marked effect on the quality of products. Their addition into the baking formula showed very little effect on product crumb porosity, while the product specific form and crumb tackiness of rolls with a ratio of oat: buckwheat of 1: 2 and the crumb colour of rolls with a ratio of oat: buckwheat of 1: 3 received higher scores than the control sample. The crust colour of supplemented products was not significantly affected by the increasing addition of buckwheat flour, but was evaluated as darker than the control sample. The additions of oat, buckwheat and β-D-glucan decreased the crumb elasticity as well as typical bakery product taste and odour, but the addition of oat and buckwheat in a 1: 2 and 1: 3 ratio improved positively the overall acceptability of supplemented product and the sample with a ratio of oat: buckwheat of 1:4 showed similar overall acceptability as the control sample. Finally, summarizing, we were able to show that the tested addition of buckwheat, oat and barley β-D-glucan helped to improve the nutritional quality of final bakery products, resulting in

a higher dietary intake of health-benefit compounds, as well as sensory quality of the products. Consequently, they have a good potential to serve as functional food ingredients in wheat-based food products.

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