Utilisation of Non-Traditional Forms of Cereals in Bakery Production

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Abstract

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One form of common wheat with yellow coloured grain, two forms of emmer wheat, and two forms of barley with hulless grain were used for the preparation of bread with enhanced nutritional quality. The following mill products were prepared from the cereal grains: wholemeal flour, break flour, barley grits, and break bran. The contents of thiamin, niacin, pyridoxine, total polyphenols, and total dietary fiber were studied in these raw materials and bread samples. Further, in the bread samples, the antioxidant activity was assessed and sensory evaluation was performed. As a result, the utilisation of the non-traditional forms of cereals improved nutrient contents of bread while maintaining very good sensory characterising and processing quality.

Keywords: common wheat; emmer; barley; mill fractions; bread

Cereals are a traditional part of human nutrition. In terms of vitamins, cereals safisfy mainly the need of thiamin, niacin, and pyridoxine. At the same time, they are a significant source of dietary fiber. For human nutrition, cereal grain is treated by milling; the obtained fractions are graded according to the particle size, contents of mineral substances, and cereal used (Kučerová 2004).

Wheat is the most popular cereal in Europe, it is the most common cereal used in the bakery industry (Příhoda *et al*. 2003). Wheat grain is used for the production of pearls and flour which is the basic raw material for the production of bread and bakery products, pastas and patisseries. Due to the milling of ground and degermed grain without husks which contain most vitamins, mineral substances, and beneficial fats for health, a considerable part of important nutrients is lost for consumers and the nutrition value of bakery products and pastas is thus much lower than that in the wholemeal variants (Insel *et al*. 2005; Capozzi *et al.* 2012). In Europe, the most commonly used white flour has a lower biological value compared to other mill cereal products. According to the extraction rate, white flours contain e.g. only ca 20–30% of the original content of B-group vitamins, ca 60% of fats, ca 70–80% of proteins and ca 40% of fiber (Truswell 2002). Progressive westernisation of the diet and the use of white wheat flour nearly excluded some of the cereals previously traditionally grown in the Czech Republic, others were strongly reduced. Bakery technologies have thus adapted to the requirements of average consumers and economic indicators.

Nutritional recommendations of many countries encourage a higher consumption of cerealswhole-

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meal products. The main reason is the results of numerous studies prove the inversion relationship between the intake of wholemeal food products and the incidence of cardiovascular diseases, type 2 diabetes, some types of cancer, and the BMI value (Frolich *et al.* 2012).

The enlargement of the range of cereal products with a higher proportion of whole grain components is one of the key issues within the outlined nutrition goals for Europe in the area of food production. The current trend of enhanced consumption of cereal products beneficial for health thus provides the bakery industry with great possibilities for the development and innovation of a wide assortment of new products with the use of non-traditional forms of cereals (Laknerová *et al.* 2010, 2011; Doblado-Maldonado *et al.* 2012).

The aim of this study was to develop suitable bakery formulas for the preparation of bread on the basis of non-traditional cereal forms and to assess their nutritional benefits as compared to the traditional bakery products from common wheat.

MATERIAL AND METHODS

Cereals, mill fractions and bakery products. Common wheat (*Triticum aestivum* L.) with yellow coloured grain – cv. Citrus (representative in the CR-Hanácká osiva, s.r.o.), emmer wheat (*Triticum dicoccum*) – cvs Tapioszele and Rudico (breeder VÚRV, Prague, Czech Republic), barley with hulless grain (*Hordeum vulgare* L.) – cv. AF Lucius (breeder Agrotest fyto, s.r.o., Kroměříž, Czech Republic), and breeding line KM1057 were used in the current study. The unconventional wheat and barley forms were grown under the standard field conditions at the localities of Kroměříž and Praha-Ruzyně in 2011. The grains of the selected materials were milled to wholemeal flour, particle size ≤ 500 µm (Cyclotec Sample Mill 1093; Foss, Hillerod, Denmark). The mill CD1 (CHOPIN Technologies, Villeneuve-la-Garenne, France) was used for the preparation of 3 mill fractions – break flour (further only flour, particle size ≤ 140 µm), barley grits (particle size ≤ 710 µm), and break bran (further only bran, particle size > 710 µm). The individual mill cereal products from the non-traditional forms of cereals and their use in bread formulas creation are given in Table 1. The control sample was prepared with the use of fine white wheat flour (further commercial wheat flour), the supplier Penam, PN-M-25-01. Non-traditional forms of cereals often have gluten of worse technological quality therefore they are not used alone in the bakery production. In most bread formulas, 40–68% of commercial wheat flour was replaced with 2–3 mill fractions of non-traditional forms of cereals. In bread F with 100% replacement of wheat flour and in bread E with the addition of 30% of barley grits the reduced volume and worsened quality of crumb were rectified by the addition of 0.66% wt of dried gluten. Other components in the bread formula were instant yeast (0.66% wt), salt (1.75% wt), caraway (0.53% wt), bread improving preparation K – Kvasík světlý (JH GROUP spol. s r.o., Jindřichův Hradec, Czech Republic; 2.00–2.33% wt) and water. The amounts of the individual ingredients were related to the mass of the mill cereal products.

Breads aerated with yeast were prepared under the laboratory conditions in the home baker Eta Duplica Vital (ETA a.s., Prague, Czech Republic) in program 2, loaf size 1400 g, dark crust.

Analytical methods. Non-traditional cereals, mill fractions and bakery products were analysed for the key nutritional components. A brief summary of the methods employed are given below.

Table 1. Profile of the individual mill cereal products in bread formulas (wt%)

Cultivar	Mill fractions	Bread						
		control	A	B	C	D	E	F
Wheat cultivar mixture	commercial wheat flour	100.0	31.6	33.3	50.0	0.0	60.0	0.0
	break flour	0.0	0.0	0.0	0.0	60.0	0.0	60.0
Citrus	wholemeal flour	0.0	31.6	33.3	20.0	0.0	0.0	0.0
	break bran	0.0	5.2	0.0	0.0	0.0	0.0	0.0
Rudico	wholemeal flour	0.0	0.0	0.0	0.0	40.0	0.0	0.0
Tapioszele	wholemeal flour	0.0	31.6	33.3	15.0	0.0	10.0	20.0
AF Lucius	grits	0.0	0.0	0.0	0.0	0.0	30.0	0.0
KM1057	wholemeal flour	0.0	0.0	0.0	0.0	0.0	0.0	20
	break bran	0.0	0.0	0.0	15	0.0	0.0	0.0

Thiamin – HPLC method according to the standard ČSN EN 14122:2004.

Niacin and pyridoxine – microbiological methods according to ČSN 560051:1988 or ČSN EN 14166:2009.

Total polyphenols (TP) – spectrophotometric method using Folin-Ciocalteu reagent (measuring at the wavelength of 765 nm) according to Lachman *et al*. (1997).

Total dietary fiber (TDF) – enzymatic-gravimetric method according to AOAC Method 985.29.

Total antioxidant activity (AA) – measured in methanol extracts (90%) using DPPH (Brand-Williams *et al*. 1995) and FRAP (Benzie & Strain 1996) spectrophotometric methods. The results were expressed as µg Trolox/g.

Sensory analysis. Assessor panel – 11 highly trained panellists, scoring method with a graphic scale (assessment of appearance, porosity, elasticity, flavour, taste, aftertaste, texture, and total impression), abscissas 100 mm long with a mark identifying a position corresponding to the intensity of the parameter studied (Pokorný 1993).

Statistical analysis. The variability of the nutrient contents in the control bread sample and bread with the addition of mill fractions from non-traditional forms of cereals was assessed by the single-factor analysis of variance while the differences were assessed by the LSD test at 0.05 level of probability using the GLM procedure of Statistica 8.0 software (StatSoft Inc., Tulsa, USA). The assumption of normal distribution of the input data obtained from the sensory analysis was checked by the Shapiro-Wilk test, the outliers have been determined by Dean-Dixon test (Q_{krit} = 0.392, Q_{krit} = 0.412, Q_{krit} = 0.437 pro n = 11, n = 10, n = 9). The STATVYD Version 2.0 beta (TBU, Zlín, Czech Republic) was used, the probability level was P = 0.95.

RESULTS AND DISCUSSION

Six formulas for making bread with a higher nutritional value utilising mill fractions of non-traditional forms of wheat with coloured grain, emmer wheat and barley with hulless grain were developed. The proportions of the individual mill fractions in the formulas used and nutritional evaluation of the studied mill cereal products are given in Tables 1 and 2. For the comparison of the contents of the studied nutritional factors, control bread sample from commercial wheat flour was used.

Analyses of basic raw materials. Based on the study of the nutritional composition of the given materials of non-traditional forms of cereals (Laknerová 2010), new formulas with the conceived increase in the contents of the selected B-group vitamins, antioxidant activity, and dietary fiber were constructed. The contents of thiamin, niacin, pyridoxine, total polyphenols, and total dietary fiber in the basic raw materials used were determined. It is evident from Table 2 that all wholemeal mill fractions and bran were better sources of the analysed nutrients compared to those in commercial wheat flour. Wheat bran of the variety Citrus was the most significant source of thiamin, niacin, pyridoxine and total di-

Table 2. Content of some B-group vitamins (mg/100 g DM), total dietary fiber (g/100 g DM) and total polyphenols (g GAE/kg DM) in raw materials (means ± SD)

Cultivar	Mill fractions	Thiamin	Niacin	Pyridoxin	Total dietary fiber	Total polyphenols
Common wheat						
Cultivarmixture	commercial wheat flour	0.19 ± 0.01	1.6 ± 0.1	0.09 ± 0.00	3.5 ± 0.0	0.75 ± 0.04
	wholemeal flour	0.44 ± 0.02	5.8 ± 0.1	0.44 ± 0.00	9.8 ± 0.0	1.81 ± 0.04
Citrus	break flour	0.19 ± 0.01	2.4 ± 0.1	0.15 ± 0.02	2.9 ± 0.0	1.05 ± 0.01
	break bran	0.70 ± 0.01	21.6 ± 1.2	1.52 ± 0.02	30.7 ± 1.1	3.17 ± 0.03
Emmer wheat						
Rudico	wholemeal flour	0.39 ± 0.01	9.4 ± 0.1	0.38 ± 0.01	9.5 ± 0.3	2.37 ± 0.05
Tapio-szele	wholemeal flour	0.42 ± 0.01	8.5 ± 0.1	0.37 ± 0.00	11.2 ± 0.1	2.19 ± 0.07
Barley						
AF Lucius	grits	0.29 ± 0.01	9.2 ± 0.5	0.43 ± 0.01	8.1 ± 0.0	2.87 ± 0.05
KM1057	wholemeal flour	0.36 ± 0.01	9.2 ± 0.2	0.69 ± 0.01	17.6 ± 1.4	3.47 ± 0.03
	break bran	0.37 ± 0.03	13.0 ± 0.1	0.75 ± 0.01	26.9 ± 0.5	4.08 ± 0.02

Table 3. Means of the content of some nutrients in new and control bakery products control bakery products

Factor	Bread						
	control	A	B	C	D	E	F
Thiamin*	0.16 ± 0.01[a]	0.32 ± 0.01[e]	0.31 ± 0.01[e]	0.28 ± 0.01[d]	0.22 ± 0.01[b]	0.24 ± 0.01[c]	0.23 ± 0.01[bc]
Niacin*	1.9 ± 0.1[a]	6.7 ± 0.2[d]	5.7 ± 0.2[bc]	5.6 ± 0.2[bc]	5.9 ± 0.2[cd]	5.1 ± 0.3[b]	5.4 ± 0.1[bc]
Pyridoxine*	0.11 ± 0.00[a]	0.38 ± 0.01[f]	0.36 ± 0.00[e]	0.34 ± 0.00[d]	0.25 ± 0.00[c]	0.24 ± 0.01[bc]	0.23 ± 0.01[b]
Dietary fibre$^{\Delta}$	5.7 ± 0.1[a]	7.4 ± 0.3[c]	7.4 ± 0.1[c]	7.3 ± 0.0[c]	6.6 ± 0.1[b]	7.6 ± 0.0[c]	7.2 ± 0.1[c]
TP	0.67 ± 0.02[a]	1.36 ± 0.02[d]	1.25 ± 0.01[c]	1.53 ± 0.01[f]	1.05 ± 0.03[b]	1.44 ± 0.01[e]	1.47 ± 0.03[e]
AA_{DPPH}	89 ± 5[a]	234 ± 6[d]	198 ± 2[c]	271 ± 18[e]	149 ± 2[b]	294 ± 2[f]	263 ± 10[e]
AA_{FRAP}	132 ± 5[a]	372 ± 32[d]	303 ± 4[c]	377 ± 31[d]	226 ± 24[b]	356 ± 3[d]	383 ± 25[d]

*mg/100 g DM, $^{\Delta}$g/100 g DM, #g/GAE/kg DM, °µg Trolox/g DM, means ± SD; TP – total polyphenols, AA – antioxidant activity; [a–e]data within rows followed by different letters differ statistically at P = 0.05

etary fiber. Compared to commercial wheat flour, as much as 14 times more niacin was found here. Mill cereal products from barley KM1057 were interesting materials in terms of nutrition, exhibiting higher contents of pyridoxine, total polyphenols, and total dietary fiber (Table 2).

Analyses of bakery products. The results of chemical analyses of the final products showed that the used materials of non-traditional forms of cereals can serve as significant natural fortificants. The knowledge of the nutrition compositions and technological characteristics of the individual initial raw materials enabled the targeted construction of bread formulas so that the final products exhibited higher nutritional quality while retaining sensory and technological parameters. The development of the bakery products formulas mainly focused on the preparation of breads with higher contents of the studied B-group vitamins, antioxidant activity, and total dietary fiber.

The single-factor analysis of variance proved that the formula of a bakery product was a significant factor of variance for all the studied nutritionally valuable substances. The mean values of all the analysed substances were statistically significantly lower in the control sample in comparison to all the new formulas which also differed significantly between one another (Table 3). According to the results of chemical analyses (Table 3), in terms of the contents of thiamin, niacin, pyridoxine, the combination of commercial wheat flour, wholemeal flour, and wheat bran Citrus and wholemeal flour from emmer Tapioszele was nutritiously the richest (var. A). The average thiamin content in bread A was roughly 2 times higher, the values of niacin and pyridoxine contents compared to the control sample were even 3.5 times higher. This bread belonged to the products with a high content of total dietary fiber. In bread samples C, E, and F, where one of the raw materials was barley mill fraction, 2.3 times higher content of total polyphenols was found as compared to the control sample. Considering a generally very good correlation between polyphenol contents and antioxidant activity values, these products also showed higher values of antioxidant activity (the correlation coefficient r = 0.966** for AA_{DPPH} and 0.983** for AA_{FRAP}). The values of antioxidant capacity, determined by the DPPH method, in the bread samples with barley fractions (var. C and E) differed statistically significantly from the other new formulas. By the FRAP method a high value of antioxidant activity was found in bread A as well. Compared to the control sample, 2.7–3.3 times higher values were found.

A 100 g portion of final bakery products with the highest contents of the studied nutritionally valuable substances can cover roughly 25% of the recommended daily intake (RDI) of niacin and 17% of thiamin and pyridoxine. The values of the recommended daily intake of vitamins from the Annex 5 of the regulation 352/2009 Coll. were used as the basis for the data evaluation.

Sensory analysis. Sensory properties of breads with the addition of non-traditional cereals are presented in Figure 1.

The appearance, elasticity, flavour, taste, aftertaste, texture and total impression evaluation of all samples were favourable, none of the studied sensory descriptors exceeded the limit of 50 points, the values of descriptors ranging between 18–46 points. Bread C gained the highest evaluation for appearance (22 points). The crumb was soft, homogenous with balanced distribution of pores without big hollows, in all breads sufficiently elastic although due to the addition of wholemeal flour or bran it was

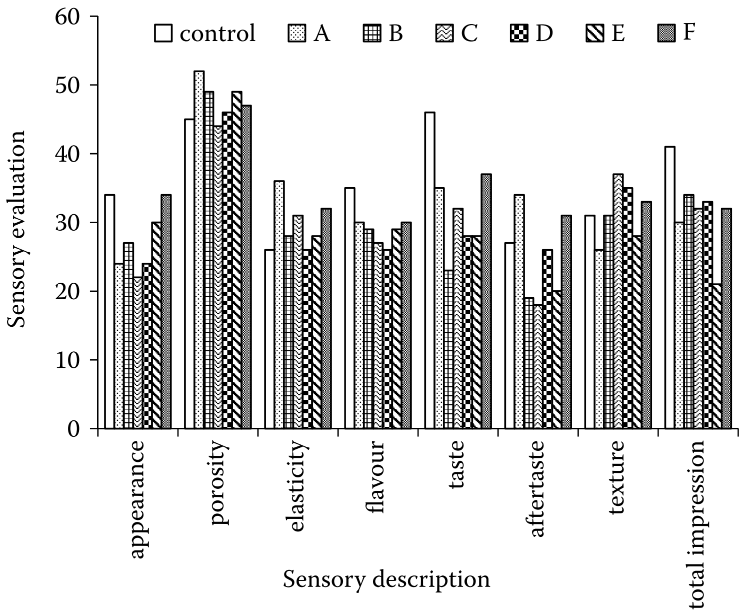

Figure 1. Sensory evaluation of bread with the addition of non-traditional forms of cereals after elimination of outliers by Dean-Dixon test – appearance, flavour, taste, texture, total impression (0–100 points: 0 = excellent, 100 = very poor); porosity (0–100 points: 0 = dense pore structure, 100 = open pore structure); elasticity (0–100 points: 0 = high elasticity, 100 = crumbly); aftertaste (0–100 points: 0 = absent, 100 = very strong)

assessed as slightly tougher. The values of porosity or elasticity of the crumb ranged from 44 to 52 points and from 26 to 36 points, respectively. The highest flavour evaluation was assigned to bread D (26 points). According to the assessors, the most tasteful bread was bread B (23 points). Breads C and B were assessed as samples with the lowest intensity of aftertaste (18 and 19 points, respectively). Most assessors liked the texture of bread A (26 points). Bread E achieved the best score in the assessment of the total impression (21 points).

CONCLUSION

Nutritional contribution of 40–100% substitution of common wheat flour by mill fractions of non-traditional cereal forms in bakery products was statistically proven. In breads with various portions of non-traditional cereal forms, higher contents of thiamin, niacin, total polyphenols, and total dietary fiber, and higher values of antioxidant activity were found compared to the control sample. The highest values of the B-group vitamins were found in the bakery product A with the content of commercial wheat flour (PENAM), wholemeal flour, and bran from wheat Citrus and wholemeal flour from wheat Tapioszele (68% addition of non-traditional cereals). In bread samples C, E, and F, where one of the basic raw materials was barley mill fraction, higher contents of total polyphenols and significantly higher antioxidant activity than in the control sample were found. In the sensory assessment, bread E with the addition of emmer and barley with hull-less grain had the best assessment in the descriptor total impression.

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