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EVALUATION OF THE CONTENT AND THE POTENTIAL BIOAVAILABILITY OF MINERALS FROM GLUTEN-FREE PRODUCTS*

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ABSTRACT

Introduction. Gluten-free products usually contain low amounts of protein and minerals. However, the information about their nutritional quality is limited. The objective of this study was to determine the content and release of minerals from selected gluten-free products.
Material and methods. The content and release of Ca, Mg, Fe, Zn and Cu from selected gluten-free products was determined. The samples were subjected to enzymatic digestion under *in vitro* conditions. The content of minerals in samples before and after enzymatic digestion was determined by the flame atomic absorption spectrometry.
Results. The content of minerals varied considerably among the types of foods. The amount of calcium in gluten-free products ranged (mg/100 g d.w.) from 3 in corn porridge to 45 in peas puff, magnesium: from 13 in peas puff to 33 in corn porridge, iron: from 1.1 in bread to 2.6 in pasta, zinc: from 0.8 in biscuits to 6.3 peas puff and copper: from 0.07 in bread to 0.4 in pasta. Among analysed products the significant higher release of calcium (~68%) and zinc (~62%) was found in corn porridge. The highest potential bioavailability for magnesium (~54%) in peas puff, for iron (~58%) in biscuits and for copper (~63%) in bread was observed. The relative low bioavailability of minerals was found in pasta (from 7% for Ca to 27% for Fe).
Conclusions. The content and amount of released minerals from gluten-free products are relatively low. The release of minerals from gluten-free products depends on the element and composition of the analysed product.

Key words: minerals, gluten free, food, bioavailability

INTRODUCTION

Celiac disease is a common disease with a genetic intolerance to wheat gliadins and other prolamins, like secalin of rye, hordein of barley, and possibly avenein of oat [Krupa-Kozak et al. 2011]. In the clinical studies was observed that this digestive systemic disease often was associated with malnutrition in patients. The intestinal lesion caused by celiac disease leads to various deficiencies of nutrients, protein, vitamins and minerals [Bardella et al. 2000, García-Manzanares and Lucendo 2011]. Some studies shown that diet based on gluten-free products is often characterized by a low contents of some nutritional components especially proteins, minerals and also dietary fibre [Krupa-Kozak et al. 2011]. The occurrence of malnutrition in patients

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with celiac disease affects internal factors-abnormal absorption of nutrients and external factors, especially the poor diet deficient in certain nutrients.

There are few studies assessing the nutritional value of gluten-free products, and bioavailability of nutrients from these foods. The aim of this study was to estimate of the content and the potential bioavailability of minerals from selected gluten- free food products.

MATERIAL AND METHODS

The materials studied were five selected gluten-free products (Table 1). All the food products were purchased from the local market (the city of Poznań, October-December 2011). Depending on the package volume, its content was mixed and homogenized in an electric grinder. Finely ground food product was transferred to plastic bags and stored frozen (–20°C) until analysed.

Enzymatic digestion *in vitro* was performed according to the method developed by Skibniewska et al. [2002]. Samples (approx. 2 g) of finely ground food product were weighed in conical beakers and treated with deionised water (20 ml) and shaked for 10 min. In order to create suitable conditions for pepsin action, pH was brought to 2 using 0.1M HCl aqueous solution (Suprapure, Merck), than pepsin solution (0.5 ml/100 ml) was added to the homogenate. Subsequently samples were placed in a thermostat shaker (37°C) for 2 hours. During the incubation process, pH was assured or corrected by addition of 6M HCl aqueous solution, when necessary. After 2 hours, digested samples were treated with 6% $NaHCO_3$ aqueous solution (Extrapure, Merck) to bring pH to 6.8-7.0, and subjected to pancreatin solution (10 ml/40 ml of homogenate), and placed in a thermostatic shaker (37°C) for 4 hours.

Afterwards, digested samples were centrifuged for 10 min (3.800 r/min), and clear solution was quantitatively transferred to qwartz cruicibles, and treated with a mixture of concentrated nitric (65% w/w) and perchloric (70% w/w) acids (10 ml:5 ml; Suprapure, Merck). Crucibles with samples were placed in a thermostatic block and heated until complete mineralization.

In order to determine the total content of calcium, magnesium, iron, zinc and copper in native products, food samples (2 g) were ashed in a muffle furnace at 450°C until complete mineralization.

The content of minerals in digested and native food products was determined by the flame atomic absorption spectrometry method (AAS-3, Zeiss spectrometer). The accuracy of the method was assured by simultaneous determination of minerals in the reference material (*Virginia Tabacco Leaves, CTA-VTL-2*), which reached 95.5%, 99.2%, 96.7%, 94.2% and 102.2% for Ca, Mg, Fe, Zn and Cu, respectively.

The release of a mineral from products (expressed as the percentage of the total mineral content) was calculated using the following formula: the amount of

Table 1. Composition of the products

Product	Ingredients
Bread	cornstarch, water, uncured vegetable fat, sugar, thickener: guar gum, E 464, glucose, yeast, salt, fiber, raising agent: sodium bicarbonate, acidity regulator: E 575
Biscuits	corn starch, vegetable fats (cured and uncured), potato starch, gluten-free wheat starch, sugar, corn syrup, dietary fiber, thickener: guar gum, emulsifier: mono and diglycerides of fatty acids, jelly, egg yolks, raising agents: ammonia, sodium bicarbonate, coloring: caramel, flavour
Pasta	corn starch, water, pea protein isolate, salt, thickener: E 464, emulsifier: mono and diglycerides of fatty acids, acidity regulator: E 575, coloring: beta-carotene
Corn porridge	corn porridge
Peas puff	corn starch, wheat gluten free, eggs, fat, thickener: guar gum, pectin, emulsifiers: lecithin and mono and diglycerides of fatty acids, fiber, acidity regulator: citric acid

a mineral released in enzymatic digestion (mg/100 g d.w.)/the total mineral content in product (mg/100 g d.w.) × 100%.

The experimental results were given as mean ±SD of three parallel measurements. The statistical analysis was carried out using the STATISTICA 7.0 software and the ANOVA test at the significance level $\alpha = 0.05$.

RESULTS AND DISCUSSION

The results of the content of minerals in the gluten-free food products and the release of these minerals after enzymatic digestion are presented in Tables 2 and 3.

As it can be seen, the content of minerals varied considerably among the types of foods. Among the analysed products bread and peas puff were characterised by a high content of calcium and zinc. Relatively high amount of magnesium was measured in corn porridge and bread. The highest content of iron and copper was found in pasta. The lowest content of calcium was observed in corn porridge, magnesium – in peas puff, zinc – in biscuits and iron and copper in bread (Table 2).

Winiarska-Mieczan and Kwiecień [2011] found higher amounts of magnesium (24.1-152.2 mg/100 g d.w.), iron (2.95-5.84 mg/100 g d.w.) and copper (0.36--0.90 mg/100 g d.w.) in bread produced from wheat and rye flour in comparison with gluten-free bread analysed in this study. In mentioned study the content of calcium (10.5-31.7 mg/100 g d.w.) and zinc (0.85-4.53 mg/100 g d.w.) was rather on comparison level than our results. In our previous study we analysed minerals content in maize groat and we observed higher

Table 2. Content of minerals in the products, mg/100 g d.w.

Products	Ca	Mg	Fe	Zn	Cu
	X ±SD				
Bread	44.62 ±0.54^{c}	31.40 ±2.03^{c}	1.14 ±0.03^{a}	2.46 ±0.02^{c}	0.07 ±0.00^{a}
Pasta	18.96 ±0.24^{b}	19.70 ±0.45^{ab}	2.66 ±0.06^{c}	1.75 ±0.12^{b}	0.41 ±0.02^{c}
Corn porridge	3.43 ±0.18^{a}	33.10 ±0.72^{c}	1.29 ±0.03^{a}	1.63 ±0.05^{b}	0.09 ±0.00^{a}
Peas puff	45.80 ±2.16^{c}	13.61 ±1.01^{a}	1.85 ±0.01^{b}	6,37 ±0.04^{d}	0.18 ±0.02^{b}
Biscuits	25.70 ±0.48^{b}	15.73 ±1.41^{a}	1.40 ±0.02^{ab}	0.83 ±0.01^{a}	0.08 ±0.00^{a}

Values are presented as mean ±standard deviation.
^{a,b,c,d}Significant differences between products.

Table 3. Potential bioavailability of minerals from products, %

Products	Ca	Mg	Fe	Zn	Cu
	X ±SD				
Bread	8.48 ±0.98^{a}	20.98 ±1.72^{a}	37.94 ±3.28^{b}	50.24 ±4.15^{b}	62.62 ±7.38^{c}
Pasta	7.72 ±0.25^{a}	23.51 ±1.23^{a}	27.76 ±1.48^{a}	26.17 ±5.08^{a}	11.07 ±0.12^{a}
Corn porridge	68.09 ±1.73^{d}	44.26 ±1.85^{c}	27.76 ±1.08^{a}	61.56 ±6.04^{c}	22.06 ±3.83^{b}
Peas puff	21.86 ±0.07^{b}	54.25 ±2.44^{d}	35.83 ±4.11^{b}	26.83 ±0.78^{a}	18.56 ±0.52^{ab}
Biscuits	40.62 ±0.93^{c}	32.01 ±4.48^{b}	58.53 ±0.56^{c}	53.83 ±3.05^{b}	56.82 ±1.83^{c}

Values are presented as mean ±standard deviation.
^{a,b,c,d}Significant differences between products.

content of calcium (14.5 mg/100 g d.w.) and lower content of iron (0.75 mg/100 g d.w.) and zinc (0.76 mg/100 g d.w.) than in this study in corn porridge [Suliburska and Krejpcio 2011]. Level of magnesium was comparable in both studies.

Krupa-Kozak et al. [2011] measured content of iron, zinc and copper in gluten-free bread and found 42.7 μg/g Fe, 5.8 μg/g Zn and 0.5 μg/g Cu in fresh mass of bread. Mentioned authors suggested that gluten-free bread had low content of minerals and they used buckwheat flour to enriched bread with microelements especially with copper, iron and zinc.

Other studies indicated that oat and barley products which contain gluten had a higher contain of calcium, magnesium, copper and iron than gluten-free products analysed in this study [Suliburska and Krejpcio 2011, Skibniewska et al. 2002]. Zinc amount was comparable in gluten and free-gluten products. It was observed that the mineral content of the corn products is rather low in comparison with other cereals [Szefer and Grembecka 2007, Suliburska and Krejpcio 2011]. It should be noted that corn flour is a common ingredient of gluten-free products (Table 1).

In this study relatively low bioavailability of minerals from gluten-free products was observed. Among analysed products the significant higher release of calcium (~68%) and zinc (~62%) was found in corn porridge. The highest potential bioavailability for magnesium (~54%) in peas puff, for iron (~58%) in biscuits and for copper (~63%) in bread was observed. The relative low bioavailability of minerals was found in pasta (from 7% for Ca to 27% for Fe) (Table 3). In our previous study in corn porridge we found comparable potential bioavailability for calcium and iron, in turn the release of zinc was higher (85 vs 61%) and magnesium much lower (6 vs 44%) than in this study. Due to the rather small amount of studies it is difficult to compare the results of the bioavailability of minerals from products containing gluten and gluten-free products. Based on the literature review it can be observed that the degree of release of minerals in *in vitro* enzymatic digestion from variety of products depends on the elements and composition of the food products [Suliburska et al. 2009, Suliburska and Krejpcio 2011, Nalepa et al. 2012]. Skibniewska et al. [2002] found that potential bioavailability of zinc and iron was much lower (1-2%) and for copper much higher (80-90%) from oat products than in products analysed in this study. The release of magnesium and calcium from oat products was rather comparable to our results. In the previous our study the release for minerals from barley product was rather low (2% for Mg, 6% for Fe, 30% for Zn and 32% for Ca) [Suliburska and Krejpcio 2011].

CONCLUSION

The contain of minerals in gluten-free products is relatively low. The potential bioavailability of minerals from gluten-free products is in the range 10-70%, and depending on the element and the composition of the analysed product. It should be consider the enrichment of gluten-free products in minerals.

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OCENA ZAWARTOŚCI I POTENCJALNEJ BIODOSTĘPNOŚCI SKŁADNIKÓW MINERALNYCH Z ŻYWNOŚCI BEZGLUTENOWEJ

STRESZCZENIE

Wstęp. Produkty bezglutenowe zawierają zwykle małe ilości białek i składników mineralnych. Niewiele jest jednak informacji na temat jakości odżywczej tego rodzaju żywności. Stąd celem niniejszej pracy jest określenie zawartości i uwalniania składników mineralnych z wybranych produktów bezglutenowych.
Materiał i metody. Określono zawartość oraz uwalnianie wapnia, magnezu, żelaza, cynku i miedzi z wybranych produktów bezglutenowych. Próby poddano trawieniu enzymatycznemu w warunkach in vitro. Zawartość składników mineralnych określono przed i po trawieniu enzymatycznym z użyciem metody płomieniowej spektrofotometrii atomowo-absorpcyjnej.
Wyniki. Zawartość składników mineralnych różniła się w poszczególnych produktach bezglutenowych, wahała się od 3 mg/100 g s.m. w kaszy kukurydzianej do 45 w groszku ptysiowym; magnezu było od 13 w groszku ptysiowym do 33 w kaszy kukurydzianej; żelaza oznaczono od 1,1 w chlebie do 2,6 w makaronie, cynku – od 0,8 w herbatnikach do 6,3 w groszku ptysiowym i miedzi – od 0,07 w chlebie do 0,4 w makaronie. Spośród analizowanych produktów znacząco wyższy stopień uwalniania wapnia (68%) i cynku (62%) stwierdzono w kaszy kukurydzianej. Zaobserwowano znacząco większą potencjalną biodostępność: magnezu z groszku ptysiowego (54%), żelaza z herbatników (58%), miedzi z chleba (63%). Relatywnie mała biodostępność składników mineralnych charakteryzowała makaron (od 7% Ca do 27% Fe).
Wnioski. Względnie mała jest zawartość i potencjalna biodostępność składników mineralnych z produktów bezglutenowych. Uwalnianie składników mineralnych z produktów bezglutenowych zależy od analizowanego pierwiastka oraz od składu produktu.

Słowa kluczowe: składniki mineralne, żywność bezglutenowa, biodostępność

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