TITLE: Effect of processing and cooking on mineral and phytic acid content of buckwheat-enriched tagliatelle

AUTHORS: Jambrec Dubravka, Sakač Marijana, Jovanov Pavle, Mišan Aleksandra, Pestorić Mladenka, Tomović Vladimir, Mandić Anamarija

NOTICE: This is the author's version of a work that was accepted for publication in *Chemical Industry and Chemical Engineering Quarterly.* Changes resulting from the publishing process, such as peer review, editing, corrections, structural formatting, and other quality control mechanisms may not be reflected in this document. Changes may have been made to this work since it was submitted for publication. A definitive version was subsequently published in *Chemical Industry and Chemical Engineering Quarterly*, Volume 22, Issue 3, May 2016, Pages 319–326.
DOI: 10.2298/CICEQ150709046J.

CI&CEQ
Chemical Industry & Chemical Engineering Quarterly

Available on line at
Association of the Chemical Engineers of Serbia *AChE*
www.ache.org.rs/CICEQ
Chem. Ind. Chem. Eng. Q. 22 (3) 319–326 (2016)
CI&CEQ

DUBRAVKA JAMBREC[1]
MARIJANA SAKAČ[1]
PAVLE JOVANOV[1]
ALEKSANDRA MIŠAN[1]
MLADENKA PESTORIĆ[1]
VLADIMIR TOMOVIĆ[2]
ANAMARIJA MANDIĆ[1]

[1]University of Novi Sad, Institute of Food Technology, Novi Sad, Serbia
[2]University of Novi Sad, Faculty of Technology, Novi Sad, Serbia

SCIENTIFIC PAPER

UDC 664.69:633.12:664.641.2

DOI 10.2298/CICEQ150709046J

EFFECT OF PROCESSING AND COOKING ON MINERAL AND PHYTIC ACID CONTENT OF BUCKWHEAT-ENRICHED TAGLIATELLE

Article Highlights

- Tagliatelle was enriched with autoclaved and common whole buckwheat flour
- The mineral bioavailability was slightly improved by buckwheat flour addition
- The autoclaving significantly reduced phytic acid content of cooked tagliatelle
- Autoclaving represents a promising strategy for modifying phytic acid content
- Zinc bioavailability is not inhibited by phytate content

Abstract

Two types of buckwheat flour - non-treated (NBF) and autoclaved (TBF) - were used for the enrichment of whole wheat tagliatelle (control sample) at the level of 10-30%, and the produced tagliatelle samples (dry and cooked) were examined in terms of mineral and phytic acid (PA) content. Both NBF and TBF possessed significantly higher ($p < 0.05$) content of all investigated minerals compared to whole wheat flour (WWF), but significantly lower ($p < 0.05$) PA content. Cooked NBF-containing tagliatelle possessed significantly higher ($p < 0.05$) content of Mg, Zn, Mn and Fe compared to the cooked control sample, while mineral content of cooked TBF-containing tagliatelle samples was not significantly different from the control. Autoclaving significantly reduced ($p < 0.05$) PA content of cooked TBF-containing tagliatelle samples compared to cooked NBF-containing tagliatelle samples and the control sample. The mineral bioavailability defined through molar ratio of mineral to phytate was slightly improved in buckwheat-containing tagliatelle samples, but it still remains at low level. Regarding all results, the enrichment of whole wheat tagliatelle with NBF at higher levels of substitution (20-30%) resulted in significant increase in mineral content and bioavailability.

Keywords: mineral content, phytic acid, buckwheat, tagliatelle, mineral bioavailability, autoclaving.

Inadequate diets with insufficient content of nutrients may cause severe disorders (anemia, rickets, osteoporosis, and diseases of the immune system). Maintaining the mineral balance requires not only the intake of foods rich in minerals, but achieving the mineral bioavailability. The amount of mineral that is available to be absorbed can be affected by numerous factors such as the presence of antinutrients, polyphenols, fibres, competition with other nutrients [1], presence of proteins and fermentable carbohydrates, enzyme activity, intestinal pH, source of minerals and meal composition [2].

Phytic acid (PA) can be found in many cereals, legumes, oilseeds and other plants [3]. It is considered as an antinutrient due to its potential to reduce mineral absorption by binding of mineral divalent and trivalent ions such as calcium, magnesium, zinc, copper, iron and potassium into phytic acid-mineral complexes called phytates [4,5]. These complexes are insoluble at physiological pH and, consequently, they exhibit low bioavailability [2].

PA level of cereal seeds is low at early growth stages but it rapidly increases with starch synthesis during maturation and finally reaches the level of approximately 1-6% [5]. Depending on the diet habits, the daily intake of phytate can be 2000-2600 mg for

---

Correspondence: D. Jambrec, University of Novi Sad, Institute of Food Technology, Bulevar cara Lazara 1, Novi Sad, Serbia.
E-mail: dubravka.jambrec@fins.uns.ac.rs
Paper received: 9 July, 2015
Paper revised: 24 November, 2015
Paper accepted: 27 November, 2015

vegetarian and diets of inhabitants of rural areas in developing countries and 150-1400 mg for mixed diets [6]. These high phytate intakes are correlated with poor iron and zinc status in preschool children [7]. There have been a number of studies which deal with the determination of phytate content in different foods [1,5,8,9] as well as the methods of phytate content reduction. For that purpose, germination, soaking, cooking, and fermentation have been investigated [10,11].

Pasta has traditionally been produced from durum wheat and consumed worldwide. In the regions where durum wheat is not grown, bread wheat is used for pasta production, because of availability and lower prices. Durum wheat pasta is low in proteins, essential amino acids, vitamins and minerals [12] and, therefore, functional ingredients have been used to improve its nutritional and functional quality [13,14]. However, incorporation of functional ingredients increases the cost of the final product and detailed analysis of the market is necessary in order to make production profitable. For example, Vukoje *et al.* [15] showed that the difference in production costs between spelt and wheat pasta results mostly from the higher cost of spelt flour. On the Serbian market, wheat pasta costs from € 1.5 to 4.0 per kg depending on quality and manufacturers. On the other hand, whole grain wheat pasta costs from € 2.0 to 4.7 per kg, spelt pasta costs about € 5.5 per kg, buckwheat pasta from € 2.6 to 4.7 per kg, and rice pasta from € 10.5 to 21.0 per kg.

The strategy of functional ingredients incorporation into pasta formulation is also recognized as a good choice for overcoming nutrient deficiency caused disorders [16] since pasta is frequently consumed. Buckwheat flour has been proven as a functional ingredient for added-value pasta [17]. Although buckwheat flour represents a rich source of proteins, minerals, antioxidants and dietary fibres [18], its PA content may be high, especially when whole buckwheat flour is used for product enrichment since PA is highly concentrated in the bran [19]. However, whole buckwheat flour also provides four- to five-fold more minerals than refined flour [2] and, therefore, bioavailability data of buckwheat minerals are of interest [20].

Autoclaving is one of hydrothermal processes usually used to facilitate flaking of the groats or to prevent their rancidity during storage [21]. In addition to these, Jambrec *et al.* [22] and Yoo *et al.* [23] employed autoclaving in order to prevent the rutin loss and quercetin increase in a final product. Moreover, Avanza *et al.* [24] used autoclaving to reduce content of antinutritional components (tannins and phytic acid) in cowpeas.

The objective of the present paper was to study the effect of autoclaving on the phytate reduction and its influence on mineral bioavailability of whole buckwheat flour and buckwheat-enriched tagliatelle.

MATERIALS AND METHODS

Raw materials

Common whole wheat flour (WWF) (moisture 12.02%, protein (Nx5.7) 13.60%, fat 1.63, ash 1.20%, reducing sugars 1.55% and starch 72.00%) was purchased from the local market (Žitko, Bačka Topola, Serbia) and common buckwheat grains were purchased from Hemija Commerce, Novi Sad, Serbia. Non-treated whole buckwheat flour (NBF) (moisture 11.81%, protein (Nx5.7) 15.24%, fat 3.24, ash 2.65%, reducing sugars 2.30% and starch 71.60%) was obtained by grinding the whole buckwheat grains (with hull) on a stone mill (mill stone diameter 1000 mm; Rajica Topalović and son, Trstenik, Serbia). After grinding, the material was sieved (100-mesh screen) to obtain the flour with a very small portion of hull.

Autoclaving of buckwheat grains

Buckwheat grains were placed directly into an autoclave container and autoclaved at 120 °C and 0.2 MPa for 10 min (Autoclav STERICLAV - S AES-75, Raypa trade, Barcelona, Spain). After the treatment grains were spread out on trays and left overnight at 25 °C. The autoclaved whole buckwheat flour (TBF) (moisture 13.10%, protein (Nx5.7) 12.99%, fat 3.43, ash 2.38%, reducing sugars 1.89% and starch 69.92%) was obtained by grinding the autoclaved whole grains with hull on a stone mill (mill stone diameter 1000 mm; Rajica Topalović and son, Trstenik, Serbia) and sieved (100-mesh screen). The obtained buckwheat flour represented a mixture of ground aleuron seed layer, germ, and a very small portion of hull.

Tagliatelle production

Seven different types of tagliatelle (Figure 1) were produced on an industrial scale (capacity 80 kg/h) using single screw extruder (Ital past Mac 60 Pasta Maker Extruder, Parma, Italy) by substituting whole wheat flour with different amounts (10, 20 and 30 g/100 g) of NBF or TBF in tagliatelle formulation. Whole wheat tagliatelle was produced as a control.

Different types of flour were first mixed and hydrated with tap water in order to achieve proper dough consistency. The obtained dough was extruded and the tagliatelle was dried in a dryer (Ital past D200, Parma, Italy) using a low temperature drying procedure at approximately 50 °C for 13.5 h until the final relative humidity was between 75 and 77%.

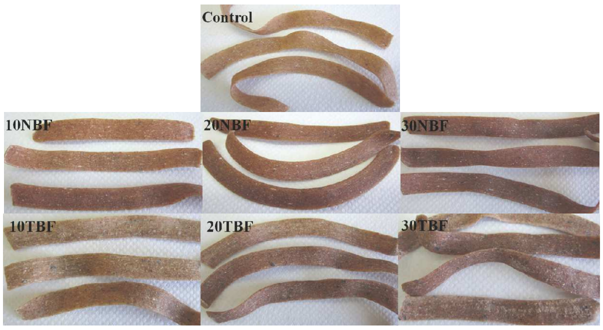

Figure 1. Dry whole wheat flour tagliatelle enriched with non-treated (NBF) and autoclaved (TBF) whole buckwheat flour. Control-whole wheat flour tagliatelle; 10NBF, 20NBF, 30NBF - 10, 20, and 30 g/100 g NBF supplemented whole wheat flour tagliatelle; 10TBF, 20TBF, 30TBF - 10, 20, and 30 g/100 g TBF supplemented whole wheat tagliatelle.

Tagliatelle cooking

Tagliatelle was cooked according to modified AACC [25] which implies cooking in distilled water without salt addition. Tagliatelle were cooked until the optimum cooking time was reached, after which it was drained and dried at 45 °C for 1 day. Drained cooked and uncooked tagliatelle were ground using 1095 Knifetec laboratory mill.

Mineral composition

Mineral composition (Ca, Mg, K, Zn, Fe, Cu, Mn and Na) of WWF, NBF, TBF and all pasta samples (uncooked and cooked) was determined using a Varian Spectra AA 10 (Varian Techtron Pty Ltd., Mulgrave Victoria, Australia) atomic absorption spectrophotometer equipped with a background correction (D2-lamp). The sample preparation consisted of a dry ashing procedure at 450 °C as described by Pavlović *et al.* [26].

Phytic acid

Phytic acid was determined by the method described by Haug and Lantzsch [27]. Phytic acid was extracted from 0.5 g of sample with 0.2 M HCl for 3 h followed by centrifugation at 3000 rpm (1006.2 g) for 30 min. The extract (0.5 mL) was mixed with 1 mL of ferric ammonium sulphate solution (0.2 g of $NH_4Fe(SO_4)_2\cdot 12H_2O$ in 100 mL 2 M HCl and made up to 1000 mL), incubated in a boiling water bath for 30 min and then cooled in an ice water bath until reached room temperature. After the cooling, 2 mL of 2,2′-bipyridine solution (1 vol.%) was added. The absorbance was measured immediately at 519 nm (6405 UV/Vis, Jenway, Stone, Staffordshire, UK) and phytic acid content was calculated using the calibration curve. Calibration was set up with the reference solutions prepared by diluting the stock solution (1.3 mg/mL phytic acid) with 0.2 M HCl in the range of 0.1 to 1.0 mg/mL.

Determination of mole ratio of phytate/mineral

The content of phytic acid and selected minerals was divided by its molar mass (PA: 660.04 g mol^{-1}; Fe: 55.85 g mol^{-1}; Zn: 65.01 g mol^{-1}; Ca: 40.08 g mol^{-1}) in order to convert it into amount of substance (mole). The mole ratios (PA/Fe, PA/Zn, PA/Ca, PA×Ca/Zn) were calculated by dividing moles of PA and appropriate mineral.

Statistical analysis

All analyses were performed in triplicate and presented as mean ± *SD*. Analysis of variance (ANOVA) and Tukey honestly significant difference test were performed to establish the significance of differences among samples. All measurements were performed with confidence of $p < 0.05$, and by using statistical software Statistica 12, (StatSoft, Inc., 1984-2013).

RESULTS AND DISCUSSION

Mineral composition

Both whole buckwheat flour samples (NBF and TBF) had significantly ($p < 0.05$) higher mineral content compared to the whole wheat flour (WWF, Table 1). Compared to the WWF flour, buckwheat flour samples contained more minerals, as follows: 120-140% for Mg, 20-44% for Ca, 30-38% for Zn, 61-71% for Cu, 58-112% for Mn, 69-74% for Fe and 42-46% for K. Similar results were reported by Bilgiçli [28] and Steadman *et al.* [19]. Comparing the mineral content of TBF and NBF, it can be concluded that NTF is superior in Ca, Cu, Mn and K content. The reduction of minerals during autoclaving of chickpea was also observed by Alajaji and El-Adawy [29].

Tagliatelle production had no significant effect on pasta mineral content in comparison to the flour samples. The negligible increase in minerals during pasta production can be addressed to minerals from tap water used for tagliatelle production (Table 1). Cubadda *et al.* [30] emphasized that the increase in minerals during pasta making resulted from minerals present in water used for dough preparation and equipment used in the pasta making process.

Although both whole buckwheat flour (NBF and TBF) had higher mineral content in comparison to WWF, the enrichment of tagliatelle formulation using NBF and TBF led to the significant increase ($p < 0.05$)

Table 1. Phytic acid (PA) and mineral (mg/100 g dw) content of flour, uncooked and cooked tagliatelle; means ± SD (n = 3) within a column followed by the same letter are not significantly different (p < 0.05); dw - dry weight; PA - phytic acid, WWF - whole wheat flour, NBF - non-treated whole buckwheat flour, TBF - autoclaved whole buckwheat flour; Control - whole wheat flour tagliatelle; 10NBF, 20NBF, 30NBF - 10, 20, and 30 g/100 g NBF supplemented whole wheat flour tagliatelle; 10TBF, 20TBF, 30TBF - 10, 20, and 30 g/100 g TBF supplemented whole wheat tagliatelle

Sample	PA	Ca	Mg	Zn	Cu	Mn	Fe	K	Na
Flour									
WWF	$415.9^{b}\pm13.0$	$26.68^{a}\pm1.73$	$96.46^{a}\pm4.70$	$1.88^{a}\pm0.10$	$0.38^{a}\pm0.00$	$2.24^{a\pm}0.17$	$4.76^{a}\pm0.02$	$257.7^{a}\pm1.43$	$11.97^{a}\pm1.88$
NBF	$310.5^{a}\pm16.9$	$38.43^{c}\pm0.61$	$233.0^{b}\pm6.32$	$2.60^{b}\pm0.00$	$0.65^{c}\pm0.00$	$4.76^{c}\pm0.06$	$8.30^{b}\pm0.12$	$401.1^{c}\pm3.12$	$7.09^{a}\pm0.24$
TBF	$300.6^{a}\pm10.7$	$31.90^{b}\pm0.39$	$214.8^{b}\pm11.25$	$2.44^{b}\pm0.13$	$0.61^{b}\pm0.00$	$3.53^{b}\pm0.24$	$8.04^{b}\pm0.05$	$365.7^{b}\pm5.23$	$11.89^{a}\pm1.75$
Uncooked tagliatelle									
Control	$349.8^{a}\pm20.1$	$31.21^{ab}\pm0.92$	$109.7^{ab}\pm0.84$	$2.07^{a}\pm0.03$	$0.44^{abc\pm}0.03$	$2.54^{ab}\pm0.11$	$6.04^{ab}\pm0.16$	$274.4^{ab}\pm 4.74$	$11.10^{d}\pm1.24$
10NBF	$457.7^{b}\pm8.40$	$29.41^{a}\pm1.12$	$112.2^{bcd}\pm3.63$	$2.37^{bcd}\pm0.05$	$0.44^{abc\pm}0.03$	$2.52^{ab}\pm0.15$	$6.41^{bc}\pm0.02$	$259.8^{a}\pm10.43$	$3.68^{a}\pm0.69$
20NBF	$378.3^{a}\pm10.5$	$33.55^{bc}\pm2.10$	$127.4^{f}\pm1.82$	$2.41^{cde}\pm0.03$	$0.47^{abc\pm}0.02$	$3.14^{c}\pm0.06$	$2.83^{d}\pm0.17$	$273.7^{ab}\pm 0.39$	$5.57^{ab}\pm0.44$
30NBF	$361.4^{a}\pm10.1$	$37.01^{d}\pm0.15$	$122.1^{ef}\pm1.74$	$2.36^{bc}\pm0.07$	$0.48^{bc}\pm0.03$	$2.84^{bc}\pm0.13$	$10.42^{e}\pm0.10$	$276.9^{ab}\pm 5.15$	$8.26^{c}\pm0.24$
10TBF	$331.5^{a}\pm9.10$	$31.8^{ab}\pm0.21$	$109.8^{abc}\pm0.85$	$1.99^{a}\pm0.10$	$0.42^{abc\pm}0.00$	$2.41^{a}\pm0.10$	$5.63^{a}\pm0.13$	$282.9^{b}\pm3.26$	$6.03^{abc}\pm0.12$
20TBF	$331.8^{a}\pm26.8$	$30.84^{ab}\pm0.17$	$117.4^{cde}\pm0.32$	$2.06^{a}\pm0.02$	$0.44^{abc\pm}0.00$	$2.60^{ab}\pm0.04$	$5.87^{ab}\pm0.39$	$275.7^{ab}\pm 0.64$	$11.05^{d}\pm0.19$
30TBF	$340.6^{a}\pm13.0$	$30.72^{ab}\pm0.25$	$126.4^{f}\pm3.37$	$2.04^{a}\pm0.02$	$0.47^{abc\pm}0.01$	$2.52^{ab}\pm0.12$	$5.75^{ab}\pm0.11$	$283.0^{b}\pm6.17$	$7.36^{bc}\pm0.54$
Cooked tagliatelle									
Control	$430.3^{abc}\pm15.5$	$35.09^{b}\pm1.00$	$103.9^{a}\pm1.79$	$2.23^{ab}\pm0.09$	$0.34^{a}\pm0.11$	$2.63^{ab}\pm0.14$	$6.15^{a}\pm0.05$	$144.0^{b}\pm0.23$	$6.47^{c}\pm0.36$
10NBF	$472.8^{bc}\pm26.8$	$36.18^{b}\pm0.09$	$118.2^{de}\pm1.89$	$2.64^{c}\pm1.00$	$0.44^{abc}\pm0.02$	$2.82^{bc}\pm0.09$	$6.90^{b}\pm0.07$	$135.8^{a}\pm2.34$	$3.60^{a}\pm0.13$
20NBF	$464.7^{bc}\pm9.20$	$36.46^{b}\pm0.38$	$126.8^{f}\pm0.08$	$2.51^{bc}\pm0.00$	$0.56^{c}\pm0.06$	$3.08^{cd}\pm0.06$	$8.80^{c}\pm0.16$	$134.8^{a\pm}0.54$	$4.46^{ab}\pm0.20$
30NBF	$431.2^{abc}\pm25.5$	$36.20^{b}\pm0.39$	$135.8^{f}\pm1.14$	$2.78^{c}\pm0.06$	$0.48^{abc}\pm0.03$	$3.27^{d}\pm0.02$	$11.69^{d}\pm0.37$	$130.0^{a}\pm2.42$	$8.86^{d}\pm0.39$
10TBF	$398.3^{a}\pm8.40$	$31.88^{a}\pm0.12$	$104.0^{a}\pm1.75$	$2.68^{c}\pm0.00$	$0.43^{abc}\pm0.03$	$2.46^{a}\pm0.12$	$5.88^{a}\pm0.02$	$133.4^{a}\pm1.13$	$4.83^{a}\pm0.17$
20TBF	$393.2^{a}\pm4.40$	$31.72^{a}\pm0.03$	$116.5^{bcde}\pm0.53$	$2.06^{a}\pm0.08$	$0.40^{ab}\pm0.00$	$2.56^{ab}\pm0.04$	$6.15^{a}\pm0.10$	$150.4^{b\pm}1.74$	$3.79^{b}\pm0.09$
30TBF	$411.4^{ab}\pm31.5$	$31.89^{a}\pm0.74$	$127.2^{g}\pm2.89$	$2.13^{a}\pm0.15$	$0.45^{abc}\pm0.00$	$2.75^{abc}\pm0.03$	$6.21^{ab}\pm0.21$	$162.0^{c}\pm2.34$	$8.44^{d}\pm0.28$

in some minerals (Ca, Mg, Zn and Fe) only at the higher level of substitution (20 and 30%) with NBF (Table 1).

Since the nutritional benefit of some nutrient can be achieved if it is available at the time of consumption, a decline of mineral content occurring during pasta cooking should be as small as possible. There are studies examining influence of different cooking approaches and effects of specific medium on mineral content [31]. In the present study, tagliatelle was cooked in distilled water without salt addition in order to identify mineral content influenced only by buckwheat flour enrichment.

Although Manthey and Hall [32] and Nedeljković *et al.* [33] reported detrimental effect of cooking on the content of K, Cu and Zn, in our study only the distinct reduction of K content was noticed in all cooked tagliatelle samples by about 50%, while the contents of Zn, Fe and Ca were higher by about 11, 10 and 16% in cooked NBF-containing tagliatelle, respectively, and by about 19, 6 and 4% in cooked TBF-containing tagliatelle, respectively. The loss of K might be related to the loss of water soluble albumin during cooking [32]. Calcium increase reported in some studies [30] was a consequence of pasta cooking in tap water with or without salt addition. However, considering that tagliatelle in this study was cooked in distilled water without salt addition, the increased content of Ca can be explained as a result of leaching of starch and soluble proteins, which resulted in changed proximate composition of cooked tagliatelle [19].

According to the obtained results, it seems that the enrichment of tagliatelle formulation with NBF and TBF was only useful in the case of NBF-containing tagliatelle, which possessed significantly higher ($p < 0.05$) content of Mg, Zn, Mn and Fe after cooking compared to the cooked control sample. Mineral content of all cooked TBF-containing tagliatelle samples was at the level of the control sample indicating that autoclaving did not improve the mineral content of the final products.

Phytic acid content

Phytic acid content of flour and tagliatelle samples is presented in Table 1. Both whole buckwheat flour samples (NBF and TBF) had significantly lower ($p < 0.05$) PA content compared to whole wheat flour (WWF). Bilgiçli [24] reported opposite results but comparing wholegrain buckwheat flour (without hulls) and white wheat flour. Contrary to Bilgiçli [28], we used whole wheat flour for tagliatelle production, which is known to possess higher content of phytic acid than white wheat flour because of the bran presence [5,34,35].

In general, all examined flour samples can be considered as flour types with low phytic acid content. PA content of whole wheat flour is comparable with data published by Febles *et al.* [8] who analysed PA content of 100 different types of whole wheat flour and determined that 9% of the samples were with low phytic acid content (400-600 mg/100 g) and 33% were with moderate phytic acid content (600-800 mg/100 g). However, there are many results of PA content of whole wheat flour which are superior to ours (960-2200 mg/100 g by García-Estepa *et al.* [35]; 4491 mg/100 g by Frontela *et al.* [36]). PA content of both examined whole buckwheat flour types was lower than that reported by other researchers (920--1620 mg/100 g by Greiner and Konietzny [37]; 1565 mg/100 g by Bilgiçli [28]). In addition to application of different analytical methods, the differences in PA content may result from using different milling fractions and even different milling procedures [19]. For instance, Steadman *et al.* [19] reported that flour obtained by milling whole grains with intact achene contains higher content of phytic acid (694 mg/100 g) than flour obtained from dehulled and milled whole grains (194 to 380 mg/100 g). On the contrary, bran from first dehulled whole grain possesses higher PA content (from 3487 to 3833 mg/100 g) than bran from grain milled with hulls (2687 to 3807 mg/100 g). Genetics, soil type, year, fertiliser application, environmental fluctuation, and even particle size may contribute to the differences in PA content [19,35].

Tagliatelle production, that implies extrusion of dough and drying, did not influence PA content of all investigated tagliatelle samples, with the exception of the control sample, which possessed significantly lower ($p < 0.05$) amount of PA (Table 1). TBF-containing tagliatelle samples had slightly lower PA content (6-28%) than their NBF-containing counterparts, indicating that autoclaving is able to hydrolyse phytates. Namely, phytase is inactive in dry seeds, but during autoclaving seeds are steamed and moistened and, therefore, phytase can be activated [38]. Phytic acid content reduction caused by autoclaving was also reported by Avanza *et al.* [24], Demir *et al.* [39], Ertaş [40] and Shimelis *et al.* [41]. Moreover, reduction of phytate content may be a consequence of protein reduction during autoclaving since phytate forms strong complexes with some proteins [4]. Although some authors reported about phytase inactivation at temperature above 80 °C, our results correspond with the finding of Ma and Shan [38], who discovered that the loss of phytase activity was no more than 13.6% when wheat was heated at 100 °C for 1 h.

Relatively low increase in PA content of maximum 23% (19.3-23% in NBF- and 18.5-21% in TBF--containing tagliatelle samples) was observed during pasta cooking. Comparing cooked NBF-containing tagliatelle samples with those made with TBF, it can be concluded that autoclaving of buckwheat achenes prior to tagliatelle production resulted in pasta with lower PA content (5-16%, Table 1). The registered increase in PA content of cooked pasta samples compared to dry ones may be addressed to leaching of some pasta components, first of all starch and proteins [17], that result in obtaining new material balance of the food components.

Mole ratios

Although buckwheat bran is a good source of minerals, the presence of phytic acid could reduce their absorption [19]. The amount of each mineral provided by a standard serving size of produced tagliatelle (80 g of the uncooked product) was calculated and compared with the population reference intake (*PRI*) established by European Scientific Committee for Food (1993) and with recommended dietary allowance (RDA) established by U.S. Food and Nutrition Board (http://www.nutri-facts.org/eng/minerals, Table 2). All examined tagliatelle types can be considered as a valuable source of Mg, Fe and Zn, wherein buckwheat-containing tagliatelle, especially those with NBF, was generally assessed as a better source of minerals compared to the control sample. However, the obtained amounts of minerals should be considered as approximate indicators of mineral intake due to the presence of phytates, which greatly affect bioavailability of the present minerals.

The inhibitory effects of phytic acid on mineral bioavailability have been extensively investigated [36]. The negative effects of phytic acid should be discussed not only over the content of phytic acid, but also through the mole ratios of phytic acid and mineral. The mole ratios, which indicate the adequate Zn, Fe and Ca bioavailability, are given in Table 3. Ratios above the proposed critical values indicate that the bioavailability of the mineral is low and highly affected by the phytate content.

Regarding the PA/Zn ratio, the produced tagliatelle samples showed moderate to low Zn bioavailability, since molar ratio for all examined samples was in the range from 15 to 20. According to the WHO

Table 2. Nutritional information per serving size of cooked tagliatelle; Control- whole wheat flour tagliatelle; NBF - non-treated buckwheat supplemented whole wheat flour tagliatelle; TBF - autoclaved buckwheat supplemented whole wheat flour tagliatelle

Mineral	Daily requirements^{a}, mg		Daily requirements, %		
			Control	NBF tagliatelle (range)	TBF tagliatelle (range)
Ca	Europe	700	4.0	4.1-4.2	3.6
	U.S.	1000	2.8	2.9	2.5
Mg	Europe (lower limit)	150	55.4	63.0-72.4	55.5-67.8
	Europe (upper limit)	500	16.6	18.9-21.7	16.6-20.4
	U.S. (male)	400	20.8	23.6-27.2	20.8-25.4
	U.S. (female)	310	26.8	30.5-35.0	26.8-32.8
K	Europe	3100	3.7	3.4-3.5	3.4-4.2
	U.S.	4700	2.4	2.1-2.3	2.3-2.8
Na	Europe	575	0.9	0.5-1.2	0.5-1.2
	U.S.	1200	0.4	0.2-0.6	0.3-0.6
Fe	Europe (male)	9	54.7	61.3-103.9	52.3-55.2
	Europe (female)	15	32.8	36.8-62.4	31.4-33.1
	Europe (pregnant)	30	16.4	18.4-31.2	15.7-16.6
	U.S. (male)	8	61.5	69.0-116.9	58.8-62.1
	U.S. (female)	18	27.3	30.7-52.0	26.1-27.6
	U.S. (pregnant)	27	18.2	20.4-34.6	17.4-18.4
Zn	Europe (male)	9.5	18.8	21.1-23.4	17.4-22.6
	Europe (female)	7	25.5	28.7-31.8	23.5-30.6
	U.S. (male)	11	16.2	18.3-20.2	15.0-19.5
	U.S. (female)	8	22.3	25.1-27.8	20.6-26.8

[a] These are mainly reference values for informational purposes. Most of these values are based on a 2000 cal intake for people of 4 or more years of age

Table 3. Moleratios of phytate to mineral in uncooked and cooked tagliatelle samples together with recommended critical values

Sample	PA/Fe	PA/Zn	PA/Ca	PA×Ca/Zn
Critical values				
	< 1 [44]	5-15 [42]	<0.17 [45], <0.24 [44]	< 200 [45]
Uncooked tagliatelle				
Control	4.90^{c}±0.13	16.61^{a}±0.26	0.68^{ab}±0.02	129.3^{ab}±5.88
10NBF	6.04^{d}±0.02	19.03^{b}±0.43	0.94^{c}±0.04	139.6^{b}±2.16
20NBF	3.56^{b}±0.07	15.45^{a}±0.18	0.68^{b}±0.04	129.3^{ab}±6.63
30NBF	2.94^{a}±0.03	15.08^{a}±0.43	0.59^{a}±0.00	139.3^{b}±3.41
10TBF	4.98^{c}±0.12	16.40^{a}±0.86	0.63^{ab}±0.00	130.2^{ab}±5.97
20TBF	4.78^{c}±0.32	15.85^{a}±0.17	0.65^{ab}±0.00	122.0^{a}±0.64
30TBF	5.01^{c}±0.10	16.43^{a}±0.14	0.67^{ab}±0.01	126.0^{ab}±0.08
Cooked tagliatelle				
Control	5.92^{d}±0.04	19.03^{b}±0.79	0.74^{ab}±0.02	166.6^{c}±2.22
10NBF	5.80^{cd}±0.06	17.62^{ab}±0.64	0.79^{c}±0.00	159.0^{c}±6.18
20NBF	4.47^{b}±0.08	18.26^{b}±0.05	0.77^{bc}±0.01	166.1^{c}±2.12
30NBF	3.13^{a}±0.10	15.29^{ab}±0.31	0.72^{a}±0.01	138.0^{b}±4.31
10TBF	5.73^{cd}±0.02	14.65^{a}±0.02	0.76^{abc}±0.00	116.5^{a}±0.62
20TBF	5.41^{c}±0.09	17.95^{b}±0.71	0.75^{abc}±0.00	149.0^{bc}±5.47
30TBF	5.62^{cd}±0.19	18.23^{b}±1.33	0.78^{bc}±0.02	151.9^{bc}±7.05

[42], 55% of Zn content of foods is expected to be absorbed if PA/Zn ratio of foods is less than 5, but only 35% of Zn would be absorbed if the ratio is 5-15 and less than 15% would be absorbed if the ratio is higher than 15. However, for foods relatively high in phytic acid and calcium, some authors [9] suggested

the PA×Ca/Zn mole ratio is more useful for assessing zinc bioavailability. In this context, these two cations act synergistically to increase the amount of phytate precipitation [4] and Zn availability. At high PA/Zn mole ratio Ca displaces Zn from phytate-binding sites thereby increasing the amount of free Zn [43]. According to Wise [43], the amount of free Zn is directly proportional to the Ca concentration. According to the calculated PA×Ca/Zn mole ratio (Table 3), it seems that zinc absorption from all analyzed cooked tagliatelle samples could not be inhibited by the presence of phytic acid since molar ratio was below critical value (< 200).

None of the analyzed tagliatelle samples showed mole ratio of PA/Fe and PA/Ca below appropriate critical values (PA/Fe < 1; PA/Ca < 0.24) indicating that phytate level is likely to decrease the iron and calcium absorption. Within cooked tagliatelle samples, the control sample showed the highest PA/Fe mole ratio (5.92), while NBF-containing tagliatelle had lower mole ratio compared to their TBF-containing counterparts (Table 3). These findings indicate that autoclaving is likely to deteriorate iron bioavailability, which is in agreement with Alajaji and El-Adawy [29].

CONCLUSION

Both whole buckwheat flour (NBF and TBF) possess significantly higher ($p < 0.05$) content of Ca, Mg, Zn, Cu, Mn, Fe and K compared to whole wheat flour (WWF). The supplementation of tagliatelle formulation is effective only in the NBF-containing tagliatelle, which possesses significantly higher ($p < 0.05$) content of Mg, Zn, Mn and Fe after cooking compared to the cooked control sample. Autoclaving of buckwheat achenes prior to tagliatelle production does not improve mineral content of cooked pasta. On the other hand, autoclaving significantly reduces ($p < 0.05$) PA content of cooked TBF-containing tagliatelle samples compared to cooked NBF-containing tagliatelle samples and the control sample. Therefore, this type of pre-treatment represents a promising strategy for modifying PA content in pasta production. Furthermore, the mineral bioavailability defined through mole ratio of mineral to phytate content is slightly improved in buckwheat-containing tagliatelle samples, but it still remains at low level. However, based on the results, zinc absorption is not inhibited by phytate content since molar ratio PA×Ca/Zn is below critical value (< 200) for all cooked tagliatelle samples.

Acknowledgements

This paper is a result of the research within the National project TR31029 financed by the Ministry of Education, Science and Technological Development, Republic of Serbia.

REFERENCES

[1] N. Me, N.F.A. Aw, Malays. J. Nutr. **15** (2009) 213-222

[2] H.W. Lopez, F. Leenhardt, C. Coudray, C. Remesy, Int. J. Food Sci. Tec. **37** (2002) 727-739

[3] A. Fardet, Nutr. Res. Rev. **23** (2010) 65-134

[4] V. Kumar, A.K. Sinha, H.P.S. Makkar, K. Becker, Food Chem. **120** (2010) 945-959

[5] M. Tavajjoh, J. Yasrebi, N. Karimian, V. Olama, J. Agric. Sci. Technol. **13** (2011) 743-755

[6] A.M.R. Afify, H.S. El-Beltagi, S.M. Abd El-Salam, A.A. Omran, PLoS One **6** (2011) e25512

[7] T. Lind, B. Lönnerdal, L.Å. Persson, H. Stenlund, C. Tennefors, O. Hernell, Am. J. Clin. Nutr. **78** (2003) 168-175

[8] C.I. Febles, A. Arias, A. Hardisson, C. Rodrígues-Alvarez, A. Sierra, J. Cereal Sci. **36** (2002) 19-23

[9] C.E. Lazarte, N.G. Carlsson, A. Almgren, A.S. Sandberg, Y. Granfeldt, J. Food Comp. Anal. **39** (2015) 111-119

[10] O. Buddrick, O.A.H. Jones, H.J. Cornell, D.M. Small, J. Cereal Sci. **59** (2014) 3-8

[11] R. Greiner, M. Muzquiz, C. Burbano, C. Cuadrado, M.M. Pedrosa, C. Goyoaga, J. Agric. Food Chem. **49** (2001) 2234-2240

[12] F.A. Manthey, C.A. Hall, J. Sci. Food Agr. **87** (2007) 2026-2033

[13] A.R. Islas-Rubio, A.M. Calderón de la Barca, F. Cabrera-Chávez, A.G. Cota-Gastélum, T. Beta, LWT - Food Sci. Technol. **57** (2014) 217-222

[14] C. Martínez, P. Ribotta, M.C. Añón, A.E. León, Food Sci. Technol. Int. **20** (2014) 127-135

[15] V. Vukoje, Đ. Psodorov, J. Živković. Econ. Agric. **60** (2013) 265-275

[16] J.R. Díaz, A. de las Cagigas, R. Rodríguez, Eur. J. Clin. Nutr. **57** (2003) S70-S72

[17] P. Rayas-Duarte, C.M. Mock, L.D. Satterlee, Cereal Chem. **73** (1996) 381-387

[18] I. Sedej, M. Sakač, A. Mandić, A. Mišan, M. Pestorić, O. Šimurina, J. Čanadanović-Brunet, LWT-Food Sci. Technol. **44** (2011) 694-699

[19] K.J. Steadman, M.S. Burgoon, B.A. Lewis, S.E. Edwardson, R.L. Obendorf, J. Sci. Food Agr. **81** (2001) 1094-1100

[20] J. Suliburska, Z. Krejpcio, J. Food Sci. Tech. Mys. **51** (2014) 589-594

[21] S. Bringelsson, L.H. Dimberg, A. Kamal-Eldin, J. Agric. Food Chem. **50** (2002) 1890-1896

[22] D. Jambrec, M. Sakač, A. Mišan, A. Mandić, M. Pestorić, J. Cereal Sci. **66** (2015) 1-9

[23] J. Yoo, Y. Kim, S.H. Yoo, G.E. Inglett, S. Lee, Food Chem. **132** (2012) 2107-2111

[24] M. Avanza, B. Acevedo, M. Chaves, M. Anon, LWT-Food Sci. Technol. **51** (2013) 148-157

[25] AACC, Approved Methods of the American Association of Cereal Chemists (9th ed.), American Association of Cereal Chemists, St. Paul, MN, 1995

[26] A. Pavlović, Ž. Kevrešan, D. Kelemen-Mašić, A. Mandić, Micro and toxic elements in skin meat and gills of grass carp (*Ctenopharyngodon idella*), in Proceedings of the 8th Symposium on Analytical and Environmental Problems, Szeged, Hungary, 2001, pp. 117-122

[27] W. Haug, H-J. Lantzsch, J. Sci. Food Agr. **34** (1983) 1423-1426

[28] N. Bilgiçli, LWT-Food Sci. Technol. **42** (2009) 514-518

[29] S.A. Alajaji, T.A. El-Adawy, J. Food Comp. Anal. **19** (2006) 806-812

[30] F. Cubadda, F. Aureli, A. Raggi, M. Carcea, J. Cereal Sci. **49** (2009) 92-97

[31] A.A.E. Yaseen, Nahrung **37** (1993) 449-455

[32] F.A. Manthey, C.A. Hall, J. Sci. Food Agr. **87** (2007) 2026-2033

[33] N. Nedeljković, M. Sakač, A. Mandić, Đ. Psodorov, D. Jambrec, M. Pestorić, I. Sedej, T. Dapčević-Hadnađev, Chem. Ind. Chem. Eng. Q. **20** (2014) 135-142

[34] N. Bilgiçli, A. Elgün, E.N. Herken, S. Türker, N. Ertaş, Ş. İbanoğlu, J. Food Eng. **77** (2006) 680-686

[35] R.M. García-Estepa, E. Guerra-Hernández, B. García-Villanova, Food Res. Int. **32** (1999) 217-221

[36] C. Frontela, G. Ros, C. Martínez, J. Cereal Sci. **54** (2011) 173-179

[37] I. Egli, L. Davidsson, M.A. Juillerat, D. Barclay, R. Hurrell, J. Food Sci. **68** (2003) 1855-1859

[38] X. Ma, A. Shan, Asian Austral. J. Anim. **15** (2002) 1036-1039

[39] M.K. Demir, A. Elgun, J. Food Sci. Technol. **51** (2014) 59-66

[40] N. Ertaş, J. Food Quality **38** (2015) 184-191

[41] E.A. Shimelis, S.K. Rakshit, Food Chem. **103** (2007) 161-172

[42] WHO, World Health Organization, Trace Elements in Human and Health Nutrition. World Health Organization, Geneva, 1996

[43] A. Wise, Nutr. Abstr. Rev. **53** (1983) 791-806

[44] G. Ma, Iron and zinc defninciencies in China: Existing problems and possible solutions. Dissertation, Wageningen University, The Netherlands, 2011

[45] M. Umeta, C.E. West, H. Fufa, J. Food Compos. Anal. **18** (2005) 803-817.

DUBRAVKA JAMBREC[1]
MARIJANA SAKAČ[1]
PAVLE JOVANOV[1]
ALEKSANDRA MIŠAN[1]
MLADENKA PESTORIĆ[1]
VLADIMIR TOMOVIĆ[2]
ANAMARIJA MANDIĆ[1]

[1]Univerzitet u Novom Sadu, Naučni institut za prehrambene tehnologije u Novom Sadu, Bulevar cara Lazara 1, 21000 Novi Sad
[2]Univerzitet u Novom Sadu, Tehnološki fakultet Novi Sad, Bulevar cara Lazara 1, 21000 Novi Sad

NAUČNI RAD

UTICAJ PROCESA PROIZVODNJE I KUVANJA NA SADRŽAJ MINERALNIH MATERIJA I FITINSKE KISELINE U TALJATELAMA OBOGAĆENIM HELJDINIM BRAŠNOM

Obogaćivanje integralne pšenične testenine (kontrolni uzorak), sprovedeno je supstituisanjem dela pšeničnog brašna (od 10 do 30%) sa dve vrste integralnog heljdinog brašna - netretiranim (NBF) ili autoklaviranim (TBF) integralnim heljdinim brašnom. U proizvedenim taljatelama ispitani su sadržaj mineralnih materija i fitinske kiseline (PA). Oba uzorka integralnog heljdinog brašna (NBF i TBF) imala su značajno (p < 0,05) viši sadržaj svih analiziranih minerala u poređenju sa uzorkom integralnog pšeničnog brašna (WWF), ali značajno (p < 0,05) niži sadržaj fitinske kiseline. Uzorci taljatela koji su sadržali NBF, nakon kuvanja su imali značajno (p < 0,05) viši sadržaj Mg, Zn i Fe u poređenju sa kontrolnim uzorkom, za razliku od uzoraka taljatela sa TBF, kod kojih se sadržaj mineralnih materija nije značajno (p < 0,05) razlikovao od kontrolnog uzorka. Proces autoklaviranja značajno (p <0 ,05) je smanjio sadržaj fitinske kiseline u uzorcima taljatela sa TBF u poređenju sa svim ostalim uzorcima taljatela. Biroaspoloživost minerala, izražena kao odnos sadržaja minerala i fitinske kiseline, donekle je poboljšana dodatkom heljdinog brašna u formulacijama taljatela, ali je i dalje veoma mala. Uzimajući u obzir sve rezultate, može se zaključiti da se obogaćivanjem formulacije taljatela sa 20-30% NBF-a, postiže značajno (p < 0,05) povećanje sadržaja minerala i povećava se njihova biraspoloživost.

Ključne reči: sadržaj mineralnih materija, fitinska kiselina, heljda, taljatele, bioraspoloživost minerala, autoklaviranje.