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RHEOLOGICAL PROPERTIES AND MINERAL CONTENT OF BUCKWHEAT ENRICHED WHOLEGRAIN WHEAT PASTA

Article Highlights

- Wheat blend containing 20% LBF expressed the most similar rheological behavior to WWF as a control sample
- The BWWP pasta possessed higher contents of P, Mg, K and Zn compared to WWP
- The reduction in mineral content of BWWP during cooking was significantly higher compared to WWP
- The supplementation improved the mineral content of dry pasta, but not of cooked pasta

Abstract

Light buckwheat flour (LBF) was used to substitute 20% of whole wheat flour (WWF) in the formulation of wholegrain wheat pasta. Wholegrain wheat pasta (WWP) and buckwheat enriched wholegrain wheat pasta (BWWP) were produced on an industrial scale. The substitution level of buckwheat flour (20%) was based on previously conducted rheological tests on LBF/WWF blends, which were performed using 10, 20 and 30% of LBF. The obtained Mixolab profiles have indicated that wheat blend containing 20% LBF expressed the most similar rheological parameters to WWF. Proximate composition, cooking quality and mineral content of BWWP were analysed and compared with those of WWP. The substitution of WWF with LBF in the pasta formulation resulted in significantly increased ($P < 0.05$) contents of P, Mg, K and Zn compared to WWP in dry pasta. The reduction in mineral content of BWWP during cooking was significantly higher ($P < 0.05$) compared to WWP. The content of P, Mg and K were at same level in both type of pasta after cooking. The obtained results suggest that enrichment of WWP with LBF at the level of 20% did not improve the mineral content of cooked pasta, although an increase in minerals was observed in dry pasta.

Keywords: pasta, light buckwheat flour, dough rheology, Mixolab, mineral content.

Pasta products are consumed all over the world, and they are frequently manufactured from wheat flour, which is known to be the best raw material suitable for its production. The best properties of wheat flour for pasta production result from the protein structure of wheat that enables to form a matrix with encapsulated starch granules. On the other hand, wheat flour is characterized by relatively low lysine, methionine and threonine content, as well as some minerals and vitamins [1]. Fortification of wheat pasta in order to improve its nutritional quality and to produce functional pasta product has been described in the literature [2,3].

Buckwheat (*Fagopyrum esculentum* Moench) is an important pseudocereal known as a dietary source of protein containing high levels of essential amino acids [4], starch and dietary fibres [5], essential minerals [6] and trace elements [7]. This crop also contains antioxidant compounds, primarily rutin [8], which is responsible for beneficial health effects. There is some evidence that regular consumption of buckwheat containing products may reduce the risk of high blood pressure, prevents oedema and hemorrhagic

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diseases, prevents diabetes and reduces the risk of arteriosclerosis [9–11]. Also, buckwheat minerals have beneficial effects on health: magnesium may contribute to maintenance of normal muscle and nerve function, healthy immune function, and bone health; potassium may reduce the risk of high blood pressure and stroke, in combination with a low sodium diet; zinc is the component of many enzymes and its deficiencies lead to retarded development of children, skin affections, acne and weakening of taste; phosphorus is an essential component of bones and teeth [12,13].

Buckwheat flour has been used for supplementation of wheat pasta in order to produce functional pasta with nutritional benefits [14–17]. Furthermore, buckwheat bran has been incorporated into spaghetti formulation to improve its quality [18,19].

The majority of research of buckwheat enriched pasta has focused on its mechanical strength and cooking quality related to decreased gluten matrix [20] and sensory properties [17,20].

The production and cooking of pasta influence its nutritional quality. Therefore, the supplementation of pasta with functional ingredient(s) has to be followed by availability of added compounds that contribute to desirable nutritional benefits. The loss of amino acids, *i.e.*, lysine, during processing [21], as well as some minerals [19] and polyphenols [22] during cooking of pasta has been reported.

Knowing that production and cooking influence the mineral content of pasta, the aim of this work was to investigate if there is a possibility to produce buckwheat enriched wholegrain wheat pasta with acceptable properties from the rheological point of view, and to determine the effect of processing and cooking on mineral content of pasta. The obtained information would be useful for optimization of process parameters that would provide the stability of nutritional components at the time of pasta consumption.

MATERIAL AND METHODS

Raw materials

Light buckwheat flour (LBF) was obtained from Hemija Commerce, Novi Sad, Serbia, and whole wheat flour (WWF) was purchased from Žitko, Bačka Topola, Serbia.

Pasta dough formulation

Wholegrain wheat pasta (WWP) was produced using WWF and buckwheat enriched wholegrain wheat pasta (BWWP) was obtained by substitution of WWF with LBF at the level of 20%. WWF or WWF-LBF mixture was hydrated with deionised water to 320 g kg^{-1} absorption in order to achieve proper dough consistency [18, 23].

Rheological characteristics of pasta dough

The rheological behaviour of whole wheat flour, as well as WWF/LBF blends containing 10, 20 and 30% LBF were examined using Mixolab (Chopin, Tripette et Renaud, Paris, France). All measurements were performed using the modified Mixolab "Chopin +" protocol and applied parameters were: initial equilibrium at 30 °C for 8 min, heating to 90 °C for 15 min (at a rate of 4 °C/min), holding at 90 °C for 7 min, cooling to 50 °C for 10 min (at a rate of 4 °C/min) and holding at 50 °C for 5 min. The mixing speed was kept constant at 80 rpm [24]. Modification of the "Chopin +" protocol is due to dough weight increase from 75 g to 90 g because of the specific nature of the buckwheat flour [25].

Industrial pasta production

Two types of pasta (WWP and BWWP) were produced on an industrial scale by using Ital past Mac 60 (Parma, Italy). WWF or WWF-LBF mixture was hydrated and mixed in pre-mixer for 12 min. After that, the entire quantity was transferred to a mixer and mixed for 6 min. The obtained dough was extruded at the extrusion speed of 42 rpm as tagliatella for 42 min. The extruded tagliatella was dried in a dryer (Ital past D200, Parma, Italy) for 13.5 h at the temperature of 41.3 °C. The humidity was controlled since the automatic mode was used, and the final relative humidity was between 75 and 77%.

Proximate composition

The proximate composition of WWF, LBF, WWP and BWWP was analyzed using AOAC methods [26] for determining the moisture (14.004), crude protein (14.142), ash (14.006), crude cellulose (7.065), crude fat (14.019) and starch content (14.031).

Mineral composition

The mineral composition (P, Mg, K, Zn, Fe and Mn) of WWF, LBF, WWP and BWWP (uncooked and cooked) was determined using a Varian Spectra AA 10 (Varian Techtron Pty Limited, 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.* [27].

Pasta cooking quality

Optimal cooking time. Pasta sample (100 g) was cooked in 1000 mL boiling and salted (5 g NaCl)

deionised water. Every 30 s, one noodle was taken out and pressed between two pieces of glass [28]. The cooking time was reached at the time when a white core could no longer be seen. This time was noted as an optimal cooking time and used for following evaluations.

Cooking loss. During cooking, some parts of pasta dissolve in water. This cooking loss was evaluated gravimetrically (90 min at 105 °C) by weighing the residues after evaporating a defined portion of cooking water [28]. Cooking loss was expressed as a percentage of the starting material.

Volume increase. The coefficient that represents the increase of pasta volume during cooking was calculated by dividing the volume of cooked sample with the uncooked sample. The volume measurement was performed by placing a certain amount of sample into a volumetric flask containing 1000 mL water and recording the height of water which represents the volume of the weighted sample [28].

Statistical analysis

All analyses were performed in triplicate, and the mean values with the standard deviations (S.D.) are reported. Analysis of variance and Duncan's multiple range test were used. Statistical data analysis software system Statistica (StatSoft, Inc. (2011), version 10.0) was used for analysis. P values < 0.05 were regarded as significant.

RESULTS AND DISCUSSION

Proximate composition of flours

The proximate compositions of the commercially available WWF and LBF are presented in Table 1.

The protein content was significantly higher (P < < 0.05) for LBF compared to WWF, followed by higher ash and fat content. The results obtained in the present study are comparable with the published data [5,7,29].

The pseudocereals are reported to contain higher levels of minerals in comparison to wheat [29]. Therefore, the contents of P, Mg and K in LBF were found to be much higher compared to WWF (Table 1). Bilgiçli [15] has detected that buckwheat flour was rich in K, Mg and P contents. It was reported that the levels of Mg, Zn, K, P and Cu in buckwheat flour were higher when compared with other cereals [30]. The obtained mineral contents of WWF and LBF are within the ranges reported by Steadman *et al.* [6] and Bonafaccia *et al.* [7].

Rheological characteristics of pasta dough

Physical and chemical changes take place at microstructural levels in dough when some part of wheat flour in the formulation is replaced with another type of flour [31], for example buckwheat flour. It has already been concluded that rheological tests on dough can predict material's performance during processing [32]. Therefore, the rheological properties of wholegrain wheat dough and dough enriched with LBF were investigated using the Mixolab, which measures dough behaviour during mixing and heating in a

Table 1. Proximate composition (%, dry basis) and minerals (mg/100 g) of whole wheat flour (WWF) and light buckwheat flour (LBF). Nitrogen-to-protein conversion factors are: 5.7 for WWF and 6.25 for LBF in case of crude protein (Nxfactor). Values are means of three determinations ± standard deviation. Values of the same row with the same superscript are not statistically different (P < 0.05)

Proximate composition	WWF	LBF
Moisture	11.7±0.02^{a}	12.1±0.02^{b}
Crude protein (Nxfactor)	13.6±0.12^{a}	15.8±0.19^{b}
Ash	1.46±0.01^{a}	2.00±0.0^{b}
Crude cellulose	1.55±0.03^{b}	0.87±0.01^{a}
Crude fat	1.52±0.02^{a}	2.49±0.11^{b}
Starch	66.6±0.18^{b}	58.5±0.01^{a}
Others	3.57±0.05	8.24±0.06
Minerals		
P	253±4.26^{a}	447±18.15^{b}
Mg	81.9±1.38^{a}	177±1.77^{b}
K	272±5.38^{a}	535±4.68^{b}
Zn	2.09±0.11^{a}	2.38±0.02^{b}
Fe	3.51±0.09^{a}	4.20±0.08^{b}
Mn	2.79±0.11^{b}	1.72±0.02^{a}

single test simulating the mixing and baking processes. Hence, by using Mixolab it is possible to monitor both the protein and starch behaviour during processing, and it is well known that pasta dough rheology and cooking quality greatly depend on protein content and nature, as well as amylose content and ratio of small starch granules [33-35].

Therefore, the feasibility of buckwheat flour as pasta ingredient was investigated by substituting 10, 20 and 30% of whole wheat flour for buckwheat flour. Higher levels of substitution were not performed since the results obtained by Maeda [36] revealed that addition of light buckwheat flour above 30% distinctly decreased the dough strength and sensory properties.

Mixolab curves of WWF enriched with 10, 20 and 30% of LBF are presented in Figure 1, while the parameters are summarized in Table 2.

The first part of a Mixolab curve describes the protein characteristics of dough expressed as dough

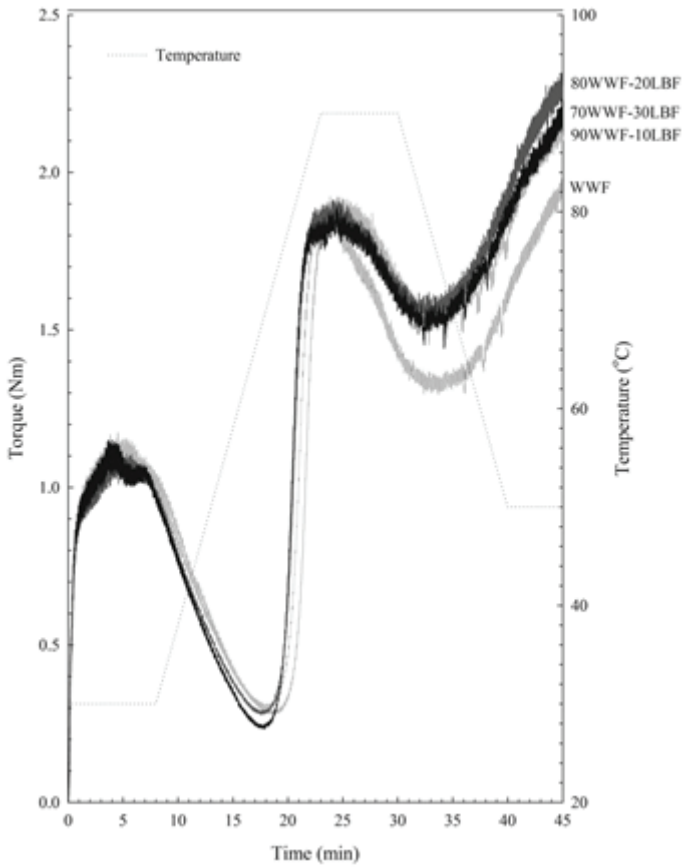

Figure 1. Mixolab profiles of dough systems made by using whole wheat flour (WWF) and mixtures of whole wheat flour and light buckwheat flour at the level of 10, 20 and 30% (90WWF-10LBF, 80WWF-20LBF and 70WWF-30LBF).

Table 2. Mixolab properties of dough systems made by using whole wheat flour (WWF) and mixtures of whole wheat flour and light buckwheat flour at the level of 10, 20 and 30% (90WWF-10LBF, 80WWF-20LBF and 70WWF-30LBF). C2 - minimum consistency; C3 - peak torque; C3-C4 - breakdown torque; C5-C4 - setback torque. Values are means of three determinations ± standard deviation. Values of the same column with the same superscript are not statistically different (P < 0.05)

Dough type	Water absorption, %	Development time, min	Stability time min	C2 torque N m	Pasting temperature, °C	C3 torque N m	Peak temperature, °C	C3-C4 torque N m	C5-C4 torque N m
100WWF	64.77±0.23^{d}	5.20±0.55^{b}	7.68±0.09^{b}	0.32±0.01^{b}	55.9±0.46^{a}	1.91±0.04^{b}	76.33±1.15^{a}	0.54±0.03^{c}	0.64±0.03^{a}
90WWF-10LBF	64.07±0.12^{c}	4.54±0.68^{ab}	6.96±0.23^{a}	0.23±0.02^{a}	55.83±0.55^{a}	1.78±0.04^{a}	75.37±0.91^{a}	0.44±0.05^{b}	0.64±0.01^{a}
80WWF-20LBF	63.07±0.12^{b}	4.15±0.05^{a}	7.03±0.21^{a}	0.30±0.02^{b}	57.2±0.9^{b}	1.92±0.04^{b}	78.97±0.15^{b}	0.34±0.02^{a}	0.68±0.03^{a}
70WWF-30LBF	62.50±0.17^{a}	3.72±0.03^{a}	6.82±0.21^{a}	0.23±0.02^{a}	56.7±0.1^{ab}	1.73±0.03^{a}	78.07±1.05^{b}	0.31±0.03^{a}	0.64±0.05^{a}

development time, water absorption, stability time and C2 value. Dough development time represents the time required to achieve appropriate consistency, which was defined as a torque of 1.1 N m. Stability (time until the loss of consistency is lower than 11% of the maximum consistency reached during mixing) indicates the dough resistance to kneading, while the C2 value represents the ability of the protein network to withstand both mechanical (kneading) and thermal (heating) influences. As it can be seen in Table 2, addition of buckwheat flour led to decrease in water absorption and dough development time. The high water absorption of the whole wheat flour is mainly related to the presence of water absorbing arabinoxylans [37]. Moreover, it was estimated that whole wheat flour was characterized with higher level of crude cellulose than buckwheat flour (Table 1). It was also found that the addition of LBF resulted in two peaks in the Mixolab curve at 30% substitution level. The same phenomenon was noticed by Maeda [36]. However, while in the research performed by Maeda [36] peaks have become prominent at 50% addition level, in this study the peaks were noticeable at lower substitution level (30%), which was probably influenced by the difference in the used wheat flours (white wheat flour versus whole wheat flour). In general, Farinograms of strong wheat flours show a second peak after dough development time, since flour with weak gluten in which gliadin fraction prevail will express early dough development, while glutenin as a predominant fraction of strong flour will lead to dough stiffening [38]. Since buckwheat flour is characterized by absence of gluten, the second peak observed in this study could not be ascribed to increase in glutenin fraction relative to gliadin, but probably to the nature of buckwheat hydrocolloids, which express slower hydrating process [39]. The addition of buckwheat flour to WWF resulted in lower stability, *i.e.*, ability to resist deformation for longer time. However, although buckwheat flour possesses lower quality proteins from the technological point of view [40], the substitution of WWF with LBF at the level of 20% did not significantly affect the protein weakening (C2 parameter). In general, noncontinuous variation of the rheological parameters can be interpreted as the result of interactions between system components [41]. Torbica *et al.* [25] have indicated the possibility of interactions between buckwheat and rice flour ingredients. In pasta processing, proteins of good mechanical properties that could resist extrusion process are required. In general, during extrusion, extrusion auger kneads the dough and forces it through the die, which leads to friction and heat generation. Therefore, the C2 value could be the indicator of dough behaviour during extrusion, since it involves a combination of mechanical and thermal stresses.

The second part of the curve follows the changes in dough structure caused by temperature increase and mechanical forces of mixing. Following parameters were recorded: pasting and peak temperatures, maximum torque at C3 point, C3-C4 value and C5-C4 value. Concerning the pasting properties, the C3 value, which represents the peak torque, was higher for wheat flour formulation compared to formulation containing 10 and 30% buckwheat flour, while the pasting temperature was lower in comparison to 20% LBF, probably due to lower lipid content of wheat flour (Table 1). According to Jane [42], lipids are known to form stable complexes with starch chains which restrict granule swelling. Difference in the behaviour of flour containing 20% buckwheat flour in comparison to 10 and 30% substitution level could be ascribed to possible interactions between composite flour components. The C3-C4 value (breakdown torque) is related to hot paste stability and enzymatic activity. It can be seen that wheat flour possessed a significantly higher ($P < 0.05$) C3-C4 value in comparison to buckwheat flour mixtures due to higher α-amylase activity in wheat flour. Ikeda *et al.* [43] proved that buckwheat seed contains an α-amylase inhibitor and therefore the addition of buckwheat flour resulted in lower C3-C4 values. The C5-C4 (setback torque) value represents the degree of starch retrogradation. The addition of buckwheat flour in dough formulations resulted in no significant changes in C5-C4 value, since pure buckwheat flour has only slightly lower setback torque in comparison to WWF [44].

Based on the results presented in Table 2, as well as the excellent matching of control and 20% LBF curves (Figure 1), it can be concluded that the rheological behaviour of these two investigated systems was the most similar. Therefore, further investigations on pasta nutritional and technological quality were performed with the sample containing 20% of light buckwheat flour. Moreover, it was shown that the production of buckwheat enriched wholegrain wheat pasta (BWWP) in industrial conditions without modifying equipment and process parameters of whole wheat pasta production could be enabled.

Proximate composition of pasta

The proximate composition of wholegrain wheat pasta (WWP) and buckwheat enriched wholegrain wheat pasta (BWWP) are presented in Table 3. The pasta containing LBF is superior in protein, ash and

Table 3. Proximate composition (% dry basis) and cooking quality of wholegrain wheat pasta (WWP) and buckwheat enriched (20%) wholegrain wheat pasta (BWWP). Values are means of three determinations ± standard deviation. Values of the same column with the same superscript are not statistically different (P < 0.05)

Pasta sample	Moisture	Crude protein	Ash	Crude cellulose	Crude fat	Starch	Optimal cooking time, min	Cooking loss, %	Volume increase
WWP	11.3±0.03^b	13.1±0.11^a	1.30±0.03^a	1.46±0.01^b	1.30±0.01^a	65.9±0.18^b	9.10±0.32b	7.83±0.65^a	2.86±0.24^a
BWWP	11.1±0.01^a	14.1±0.08^b	1.59 ±0.02^b	1.36±0.02^a	1.58±0.08^b	64.1±0.01^a	8.05±0.12^a	9.33±0.40^b	3.07±0.46^a

fat content than WWP due to higher content of these nutrients in LBF compared to WWF (Table 1). The obtained results were expected as buckwheat flour was reported to contain higher protein and mineral content than wheat flour.

Pasta cooking quality

Optimal cooking time was shorter for BWWP when compared to WWP (Table 3). This may be due to the physical disruption of gluten matrix which provided water absorption into the buckwheat enriched wholegrain wheat pasta. Similar observations were reported by Manthey *et al.* [18] and Chillo *et al.* [17]. The weakening of the gluten matrix in BWWP caused the significant increase in cooking loss of enriched pasta (Table 3).

Alamprese *et al.* [45] and Bilgiçli [14] also found that matter loss in cooking water was higher in pasta containing buckwheat. The obtained results could be considered as an acceptable cooking loss level and are in agreement with those reported by Dick and Youngs [46].

Moreover, Alamprese *et al.* [45] detected that buckwheat-containing pasta had a significantly higher weight increase during cooking than white wheat pasta. These authors explained this observation underlining the high non-starch polysaccharide content of buckwheat with high water absorption capacity and the structure of buckwheat starch granules with irregular structure containing more amorphous areas than those of white wheat. However, the results of this study (Table 3) show that the volume increase for WWP and BWWP is not significantly different. This can be explained by the fact of low substitution level in this pasta formulation.

Mineral content of pasta

Mineral contents of wholegrain wheat pasta (WWP) and buckwheat enriched wholegrain wheat pasta (BWWP) are presented in Table 4.

The substitution of WWF with LBF in the pasta formulation at the level of 20% resulted in significantly increased (P < 0.05) contents of P, Mg, K and Zn, which were expected considering the mineral content of WWF and LBF (Table 2). Previous studies showed that high K, Mg and P contents of buckwheat flour increased the mineral content of tarhana [14], gluten-free tarhana [47] and eriste [15], which were produced following the modified formulations that included buckwheat flour instead of a part of wheat flour. The increasing amount of buckwheat flour in gluten-free breads was resulted in increased macroelements content (Ca, Mg, P and K) [48].

Processing of dough into both types of pasta (WWP and BWWP) had little or no effect on mineral content (Tables 1 and 4). This finding was in accordance with observation of Manthey and Hall [19], who reported that pasta processing did not influence the mineral composition of pasta.

During cooking some amount of material is released into the cooking water. The loss of materials for nontraditional pasta is greater than for wheat pasta due to the weak gluten matrix of nontraditional pasta that permits a greater leaching of nutrients into the cooking water [20]. The reduction in mineral content of BWWP during cooking was significantly higher

Table 4. Effect of cooking on mineral content (mg/100 g dry basis) of wholegrain wheat pasta (WWP) and buckwheat enriched (20%) wholegrain wheat pasta (BWWP). Values are means of three determinations ± standard deviation. Values of the same column with the same superscript are not statistically different (P < 0.05)

Pasta sample	P	Mg	K	Zn	Fe	Mn
			Uncooked			
WWP	268±0.83^a	94.5±2.81^a	277±0.32^c	2.03±0.01^a	3.92±0.12^a	3.53±0.14^a
BWWP	345±16.5^b	125±5.20^b	402±8.48^d	2.32±0.01^b	4.09±0.28^a	2.82±0.07^b
			Cooked			
WWP	253±12.1^a	96.8±2.62^a	47.7±0.02^a	2.06±0.10^a	3.92±0.10^a	3.58±0.08^a
BWWP	268±7.39^a	96.0±1.09^a	68.6±1.87^b	2.43±0.16^b	4.08±0.07^a	2.87±0.09^b

(P < 0.05) compared to WWP (Table 4). The reduction in P, Mg and K in BWWP was 22, 23 and 88%, respectively. On the contrary, there were no significant reduction in P and Mg for WWP, but the reduction in K was 83%. These results are in agreement with average reduction in minerals of about 28% in spaghetti containing 25% buckwheat bran flour published by Manthey and Hall [19]. These authors reported that the major reduction was detected for K (62%). Other literature data suggest that the decline of 10-30% in minerals during cooking of traditional pasta was typical, with the exception of K that leached out by 67% [49].

In contrast, the contents of Zn and Fe in both types of pasta were unaffected by cooking (Table 4). In general, the increased contents of P, Mg and K in enriched dry pasta that had been achieved by substitution of WWF with LBF were decreased and reached the same levels as in WWP after cooking. This implies that enrichment of WWP with LBF at the level of 20% did not improve the mineral content of cooked pasta, although increase in minerals was observed in dry pasta.

CONCLUSION

The substitution of WWF with LBF in the pasta formulation at the level of 20% resulted in significantly increased (P < 0.05) contents of P, Mg, K and Zn compared to the control pasta (WWP). The increased contents of these minerals in buckwheat enriched wholegrain wheat pasta (BWWP) declined and reached the same levels as in WWP after cooking. The obtained results suggest that enrichment of WWP with LBF did not result in significant improvement in mineral content of cooked pasta, although an increase in minerals was observed in dry pasta.

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NAUČNI RAD

REOLOŠKA SVOJSTVA I SADRŽAJ MINERALNIH MATERIJA U INTEGRALNOJ PŠENIČNOJ TESTENINI OBOGAĆENOJ HELJDINIM BRAŠNOM

Belo heljdino brašno (LBF) korišćeno je za supstituisanje integralnog pšeničnog brašna (WWF) u formulaciji za integralnu pšeničnu testeninu na nivou od 20%. Integralna pšenična testenina (WWP) i integralna pšenična testenina obogaćena heljdinim brašnom (BWWP) proizvedene su u industrijskim uslovima. Primenjeni nivo supstitucije (20%) zasnovan je na prethodno sprovedenim reološkim ispitivanjima testa smeša LBF/WWF, koje su sadržale 10, 20 i 30% LBF. Dobijeni Mixolab parametri ukazali su da je testo sa 20% LBF najsličnije testu od WWF po reološkim parametrima. Osnovni hemijski sastav, svojstva pri kuvanju i sadržaj mineralnih materija određeni su u ispitivanim testeninama (WWP i BWWP). Supstitucija WWF korišćenjem LBF u formulaciji za testeninu rezultirala je signifikantnim porastom (P < 0,05) sadržaja P, Mg, K i Zn u nekuvanoj WWP testenini. Redukcija sadržaja mineralnih materija u BWWP tokom kuvanja signifikantno je viša (P < < 0,05) u poređenju sa WWP. Sadržaji P, Mg i K bili su na istom nivou u obe ispitivane testenine nakon kuvanja. Dobijeni rezultati ukazuju da obogaćivanje WWP korišćenjem LBF na nivou od 20% ne povećava sadržaj mineralnih materija kuvane testenine, mada je porast sadržaja minerala zabeležen u nekuvanoj testenini.

Ključne reči: testenina, belo heljdino brašno, reologija testa, Mixolab, sadržaj mineralnih materija.