Buckwheat and Quinoa seeds as supplements in wheat bread production

Mirjana A. Demin[1], Biljana V. Vucelić-Radović[1], Nebojša R. Banjac[1], Neli Nikolaevna Tipsina[2], Mirjana M. Milovanović[1]

[1]*University of Belgrade, Faculty of Agriculture, Institute of Food Technology and Biochemistry, Belgrade, Serbia*
[2]*Krasnoyarsk State Agrarian University, Krasnoyarsk, Russia*

Abstract

The aim of this work was to compare the nutritional characteristics of wheat bread with those of bread produced of wheat flour supplemented with quinoa and buckwheat seeds. Bread making properties of these blends were analyzed in order to investigate their ability to make moulded bread. Quinoa (*Chenopodium quinoa* Will.) and buckwheat seeds were grown in the vicinity of Belgrade, Serbia. The addition of pseudocereal seeds (at levels of 30 and 40%) and a selected technological process, which included hydrothermal preparation of supplements, resulted in a valuable effect on the nutritive value of the breads. In comparison with the wheat bread that was used as the control sample, a protein increase of 2% and the increase of crude fiber content at around 0.5% in 30% supplemented breads were registered. Furthermore, the incorporation of both seeds mixture at a 40% level increased the content of protein by 2.5% and fiber content by 0.4%. In regard to the starch, fat, and ash contents there were no major differences. The investigated breads were nutritionally superior to the wheat bread. Chemical composition of the selected seeds was also investigated. The results showed that the blends containing either 30 or 40% of selected seeds expressed high potential for the production of molded breads as new baking products with enhanced nutritional composition. The applied technological procedure was modified in such way that for all blended combination of supplements it changed the rheological properties of the dough. Furthermore, it resulted in a good volume of breads with excellent sensory properties of aroma-odour and taste.

Keywords: quinoa, buckwheat, seeds, supplemented breads, technological properties.

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Quinoa (*Chenopodium quinoa* Willd., Chenopodiaceae), is an Andean pseudocereal. Once known to the Incas as "mother of all grains", today quinoa is receiving increasing attention because of its high nutritional quality, mainly the protein content, and also as a valuable source of micronutrients [1]. Quinoa seeds are higher in protein than standard wheat and corn seeds, ranging from 12 to 18%. Unlike wheat that is low in lysine, quinoa contains a balanced set of essential amino acids, making it an unusually complete plant protein source for humans. Also, quinoa is a good source of dietary fiber and phosphorus. It is high in magnesium and iron contents as well as in vitamins such as vitamin E and those of the group B [2,3]. Quinoa is gluten-free and considered easy to digest. Celiac and lactose-intolerant subjects should be also quinoa consumers because of its gluten-free nature and its rich protein levels, similar to that of milk casein quality [4]. In the literature, diverse reports can be found dealing with nutritional values of quinoa based foods. Particularly, the bread making ability of quinoa and wheat flour blends and the other aspects related to the technological application received less attention [5]. Common buckwheat (*Fagopurum esculentum* Möench) is a valuable source of proteins, fiber, as well as minerals. It was found that some components such as proteins showed valuable cholesterol lowering properties and remarkable health-promoting properties [6]. There are several reports dealing with the nutritional characteristics and the application of the buckwheat as functional food: wheat bread enriched with buckwheat flour [7], gluten-free egg pasta analogues containing buckwheat flour [8] as well as buckwheat flour as an ingredient in some biscuit formulations [9].

Particularly, studies on the breadmaking ability of quinoa seeds and wheat flour mixtures are not common in the literature. The objective of this study was to investigate the possibility of inclusion of quinoa and buckwheat seeds in various levels to wheat flour, in order to assess the optimal formulation and characterize the nutritional value of the molded breads. The evaluations of dough rheological characteristics, textu-

Correspondence: B. Vucelić-Radović, Faculty of Agriculture, Institute of Food Technology and Biochemistry, University of Belgrade, Nemanjina 6, 11080 Belgrade, Serbia.
E-mail: bvucelic@agrif.bg.ac.rs
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ral and sensory properties of the breads were also observed.

EXPERIMENTAL

Materials

Quinoa (*Chenopodium quinoa* Will.) and buckwheat (*Fagopurum esculentum* Möench) seeds were produced in the vicinity of Belgrade, Serbia in a field of the agroindustrial complex "Stara Pazova", harvest season 2010. The quinoa variety used for this investigation was Puno (KVL 37) provided by the University of Copenhagen. The variety has recently been registered as a new quinoa variety in Europe bread from Chilean landraces and selected for earliness and adaptation to European conditions. The estimated quality traits included the chemical composition of the pseudocereals and nutritional, rheological and sensory characteristics of the different breads.

Chemical compositions of the seeds

Quinoa purification. Prior to analyses, the raw quinoa seeds were manually dehulled to remove the pericarp. The manual dehulling was performed by using abrasive action in the pestle and mortar, and the hulls were separated carefully by sieving to avoid inclusion of other seed portions [10]. In the next step, the remaining dehulled seeds were washed so as to extract saponins. Washing was carried out by adding cold water in the ratio of quinoa:water 1:8, and by shaking vigorously for a few seconds; this was repeated until the formation of foam was no longer observed [11]. The purified seeds were dried at 45 °C, conditioned in an airtight container, and the portions were milled to obtain the flour for further examinations.

Buckwheat purification. The first step in buckwheat purification was calibration according to the size by sieving (sieve size 4.5–3.5 mm) in order to provide seeds of the similar size. In the next step, the seeds were dehulled by scouring using a pilot plant scourer constructed at the Faculty of Agriculture, University of Belgrade.

Nutritional value. After purification, the pure seeds were milled by a Cemotek Sample Mill Foss, Sweden and the flours were further examined. Standard AOAC methods [12], numbers 925.10, 923.03 and 920.87 were used to determine moisture, ash and protein (Kjeltec 2300 system) content, respectively. For protein content of both seeds, a conversion factor of 6.25 was used. An automatic extraction method, AOAC number 920.39, was used to determine oil content (Foss-Tekator Soxtec Avanti). A Fibertek system was used to describe the cellulose (crude fiber) content, using ISO 6865/2004 standard (AOAC number 962.09). Finally, the content of Ca was determined according to the ISO 6490-1/1985 standard and AOAC methods numbers 965.17 for P and 930.23 for NaCl were used. According to the estimation of the Grosso *et al*. [13], the total starch contents were calculated.

Chemical characteristics of the breads

The same standard AOAC methods as described below were used for the determination of the nutritional value of the wheat breads supplemented with blends of quinoa and buckwheat seeds. After drying in the storage conditions, the breads were milled using the Knifetec, Germany model of mill. The results are mean values of triplicates of the same sample. To determine the protein content in the examined breads, a nitrogen conversion factor of 6.25 was used.

Bread making process

Commercial wheat flour (type T-500) containing 12.6% moisture, 0.51% ash, 11.04% protein and 25.5% wet gluten was used for bread making. The breads were prepared according to a three phase procedure, using soft wheat flour, quinoa and buckwheat seeds supplemented in total levels of 30 and 40%, with additions of 3% yeast and 2% salt. In the first phase, the seeds were overflowed with boiling water (1:1.5; W/V). In the next phase, after cooling to 30–40 °C, flour, seeds and additives were mixed for 4 minutes using a Taddy mixer with finishing touches by hand for around 1 min. Water was added in amount to produce dough with acceptable handling characteristics. The dough consistency and stickiness were subjectively estimated by an experienced baker. Short-term fermentation at room temperature took 15 min before the dough was divided and kneaded into loaves and put in greased molds. The loaves were left to prove (Bongard fermentation chamber) at 34–35 °C for 55–60 min at a relative humidity of 80%. Finally, in the third phase, the loaves were baked in a rotary kiln (Bongard) at 200–220 °C for 21 min. Three loaves were prepared per each studied case.

Rheological analyses of the dough

Dough rheological measurements were performed using a farinograph (Brabender OHG, Duisburg, Germany) according to an ICC, No 115/1 standard method [14] at 30±0.2 °C. In the farinograph, the dough was prepared under standardized conditions from 300 g of wheat flour. Different dough types from wheat flour with the addition of variable quantities of quinoa and buckwheat seeds (20–10%; 10–20%; or 20–20%, respectively) were prepared. Three replicates were carried out in all cases.

Quinoa and buckwheat seeds were separately treated with boiling water in a ratio of 1:1.5 (W/V) and left for 30 min. The modification included the addition of treated seeds to flour at the begging of the mixing

period just before the addition of water. The quantity of water used to soak the seeds was taken into account when expressing the water absorption.

Sensory analyses of the breads

Sensory evaluations of breads were carried out 6–8 h after baking by 3 trained panelists using the relevant ISO standards [15]. Sensory evaluations included the selected, representative, or dominant attributes of bread qualities: appearance (shape, crust color, nuance, brightness and uniformity), crust texture, crumb texture, aroma-odour of crust and crumb and aroma-taste of crust and crumb. The scores for each attribute ranged from 1 to 5 (differing for 0.25). Quality category was determined in dependence of score spans. Products evaluated with less than 2.5 points were considered as unsatisfactory, i.e. as unacceptable. Scores within limits of 2.5–3.5 characterized good quality products, within 3.5–4.5 – very good, and those within 4.5–5 – excellent products**.**

Statistical analyses

Data were analysed using analysis of variance (Anova, Stat), and treatment means were compared with Student's *t*-test using software Sigma Plot 6.0 for Windows – SPW 6.0, Jandel Scientific, Erckhart, Germany.

RESULTS AND DISCUSSION

Chemical characteristics of the quinoa and buckwheat seeds

Quinoa and buckwheat seeds as bread supplements that have a high nutritional value were also chosen as gluten-free pseudo cereals. The quinoa seeds, also known as Inca-rice, were traditionally used as a basic component of the diet. Most varieties of quinoa contain saponins, bitter tasting triterpenoid glycosides, which are concentrated in the seed pericarp and must be removed before consumption. The most favored traditional method involves dehulling and washing with water. Industrial methods, such as abrasive dehulling, also have been devised to debitter the seeds [16]. As we recently reported, the purification procedures, which were taken to remove bitter taste, also influenced the nutritional value slightly diminishing majority of the seed chemical constituents [17]. After purification procedures (dehulling, washing and drying) the quinoa seeds were further analyzed. The buckwheat seeds were also purified as described in the experimental section.

The chemical components (g per 100 g of dry weight basis) of the selected seeds that were estimated included: moisture, protein, ash, starch, fat, crude fiber and some minerals (Table 1). The moisture content was 11–12% in the both examined seeds. Starch was the main constituent representing over 50% of the total dry weight in quinoa and buckwheat seeds. The protein content of quinoa seeds was higher than in other pseudo cereals and ranged from 14 to 18% of crude protein, compared with buckwheat or wheat with 12––16%. Furthermore, the main characteristic of the quinoa seeds is special quality of its essential amino acid composition [2,4,17]. Amino acid profiles show a balanced content of essential amino acids, when compared with reference patterns of other cereals from the World Health Organization [18]. The total fat content of quinoa was about 5.23%, which is almost two fold higher than that of 2.83% in buckwheat. Despite the high levels of unsaturated fatty acids, which are susceptible to oxidation, quinoa oil is quite stable due to the high level of vitamin E. Recently, a lot of nutritional facts and potential of these grains were summarized by Vega-Galvez *et al.* [19].

Table 1. Chemical characteristics of purified quinoa and buckwheat seeds; means ± standard deviation followed by different letters in each row show the least significant difference at p < 0.05 (a > b). The values were expressed on dry weight basis

Content, %	Quinoa	Buckwheat
Moisture	12.53±0.01^{a}	10.59±0.02^{b}
Protein	15.23±0.03^{a}	14.38±0,20^{b}
Fat	5.23±0.00^{a}	2.83±0.01^{b}
Crude fiber	5.87±0.07^{a}	1.14± 0.04^{b}
Ash	1.96±0.01^{b}	2.12±0.03^{a}
Starch	59.18±0,02^{b}	68.94±0.03^{a}
Ca	0.22±0.00^{a}	0.05±0.01^{b}
P	0.30±0.01^{a}	0.21±0.01^{b}
NaCl	0.17±0.00^{b}	0.28±0.01^{a}

Rheology

Differences in dough water absorption were small for dough supplemented with variable amounts of seeds. However, all supplemented dough absorbed much more water than wheat dough (Table 2). Softening typical for wheat dough after 15 minutes of kneading was registered for wheat but not for seed supplemented dough (Figure 1). On the contrary, due to subsequent absorption of water from the dough during kneading, hardening of the dough occurred. Differences in size, structural and mechanical characteristics of quinoa and buckwheat seeds significantly influenced the quantity of water absorbed during seed preparation and further during kneading. The result of these interactions was that the degree of hardening for dough supplemented with 30% of seeds where buckwheat comprised 20% was 227.5 BU. Although in 40% supplemented dough there was the same amount of

Table 2. Rheological parameters of respective doughs supplemented with quinoa and buckwheat seeds; means ± standard deviation followed by different letters in each row show the least significant difference at $p < 0.05$ ($a > b > c$). The values were expressed on dry weight basis; + denotes dough hardening

Parameter	Wheat dough	Dough with 20% quinoa + 10% buckwheat	Dough with 10% quinoa + 20% buckwheat	Dough with 20% quinoa + 20% buckwheat
Dough water absorption, %	50.0±0.4^{c}	63.8±0.5^{a}	61.25±0.25^{b}	62.8±0.6^{a}
Degree of softening, BU	70±0.0^{c}	152.3±17.5^{b}	227.5±7.5^{a}	+147.5±17.5^{b}
Bread specific volume, ml g^{-1}	4.6±0.09^{b}	5.35±0.13^{a}	4.78±0.10^{b}	4.6±0.05^{b}

buckwheat, 20% of quinoa had dominant effect on the degree of hardening leading it to 147.5 BU. The specific volume of supplemented breads was negligibly higher or the same as for control wheat bread.

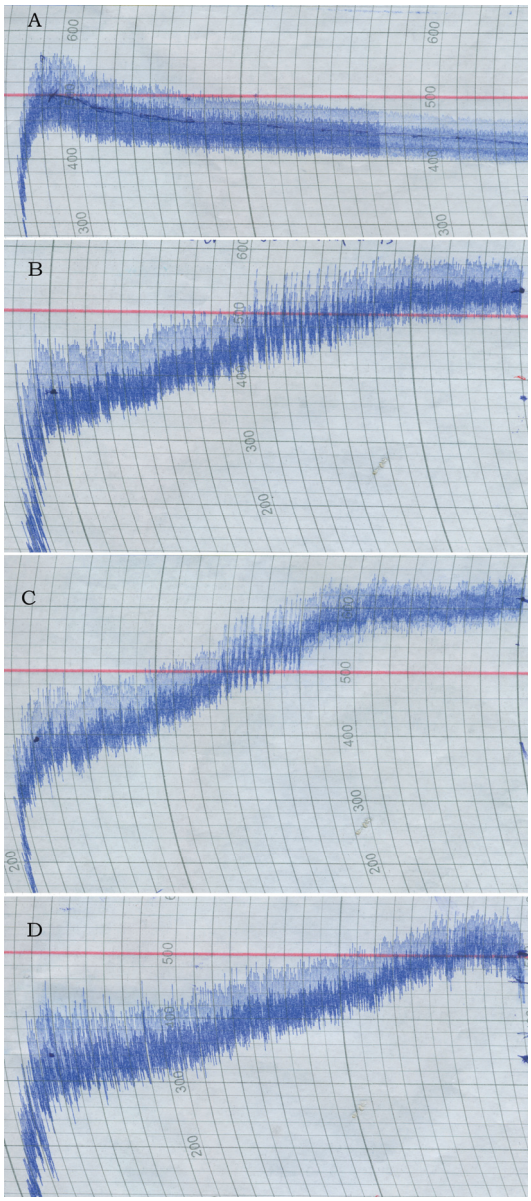

Figure 1. Farinograms of respective dough with quinoa and buckwheat seeds: A – wheat dough, B – dough + 20% quinoa + 10% buckwheat, C – dough + 10% quinoa + 20% buckwheat and D – dough + 20% quinoa + 20% buckwheat.

Chemical composition of the breads

According to the literature data, there is no relevant information about additions of the quinoa and buckwheat seed mixtures to wheat dough in order to produce breads with improved nutritional and sensory quality. Recently we reported that it was possible to include 20% of quinoa seeds, which was the highest level tested, in molded bread. The addition of 20% quinoa seeds had a positive effect on nutritional and sensory characteristics of bread [17]. The chemical characteristics of the investigated breads supplemented with quinoa and buckwheat seeds (g per 100 g of dry weight) and the wheat bread as control are presented in Table 3.

The quality of all seed supplemented breads was superior compared to wheat bread regarding almost all the investigated parameters. All supplemented breads were for 2–2.5% higher in protein than the control. There was no difference in protein content between the breads made with the addition of 30% seeds. Incorporation of 40% of seeds further increased protein content. Also, breads supplemented with quinoa seeds showed an increase in fat content for 1.5–2%. Furthermore, almost two-fold increase in crude fiber was registered in all examined cases. The incorporation of quinoa and buckwheat seeds up to 40% in wheat breads induced increases in Ca and P contents. On the contrary, starch was reduced by 3–4%.

Sensory analyses of the breads

Modification of technological procedure of seeds preparation removed the bitter taste and afforded the inclusion of high levels of seeds in molded bread leading to a product with pleasant taste and easy to chew.

As presented in Figure 2, high sensory scores were given to all the breads. In general, these groups of breads slightly differed in aroma and texture of crust and crumb. The supplemented breads had a yellow-reddish crust color, crispy in respect to brittleness. The middle of the breads was light colored with finely structured uniform pores within which quinoa and buckwheat seeds were embedded. The taste of the breads was pleasant, very specific, slightly bitter and fully acceptable even at the 40% supplementation level.

Table 3. Chemical characteristics (Content, %) of wheat breads supplemented with quinoa and buckwheat seeds; means ± standard deviation followed by different letters in each row show the least significant difference at $p < 0.05$ ($a > b > c$). The values were expressed on the dry weight basis

Component	Control wheat bread	Bread with 10% quinoa + 20% buckwheat	Bread with 20% quinoa + 10% buckwheat	Bread with 20% quinoa + 20% buckwheat
Moisture	10.76±0.01^{a}	10.66±0.03^{b}	10.47±0.01^{c}	10.47±0.01^{c}
Protein	13.06±0.09^{c}	15.05±0.17^{b}	15.05±0.07^{b}	15.47±0.05^{a}
Fat	0.25±0.03^{d}	1.75±0.17^{b}	1.37±0.11^{c}	2.12±0.05^{a}
Crude fiber	0.50±0.05^{c}	0.93±0.13^{a,b}	1.12±0.08^{a}	0.91±0.04^{b}
Ash	3.98±0.04^{a}	3.09±0.06^{d}	3.52±0.03^{b}	3.35±0.01^{c}
Starch	71.45±0.08^{a}	68.52±0.17^{b}	68.47±0.23^{b}	67.60±0.07^{c}
Ca	0.05±0.01^{c}	0.07±0.00^{b}	0.07±0.00^{b}	0.08±0.00^{a}
P	0.09±0.01^{c}	0.12±0.00^{b}	0.16±0.01^{a}	0.16±0.01^{a}
NaCl	3.42±0.00^{a}	2.20±0.01^{c}	2.47±0.01^{b}	2.40±0.01^{b}

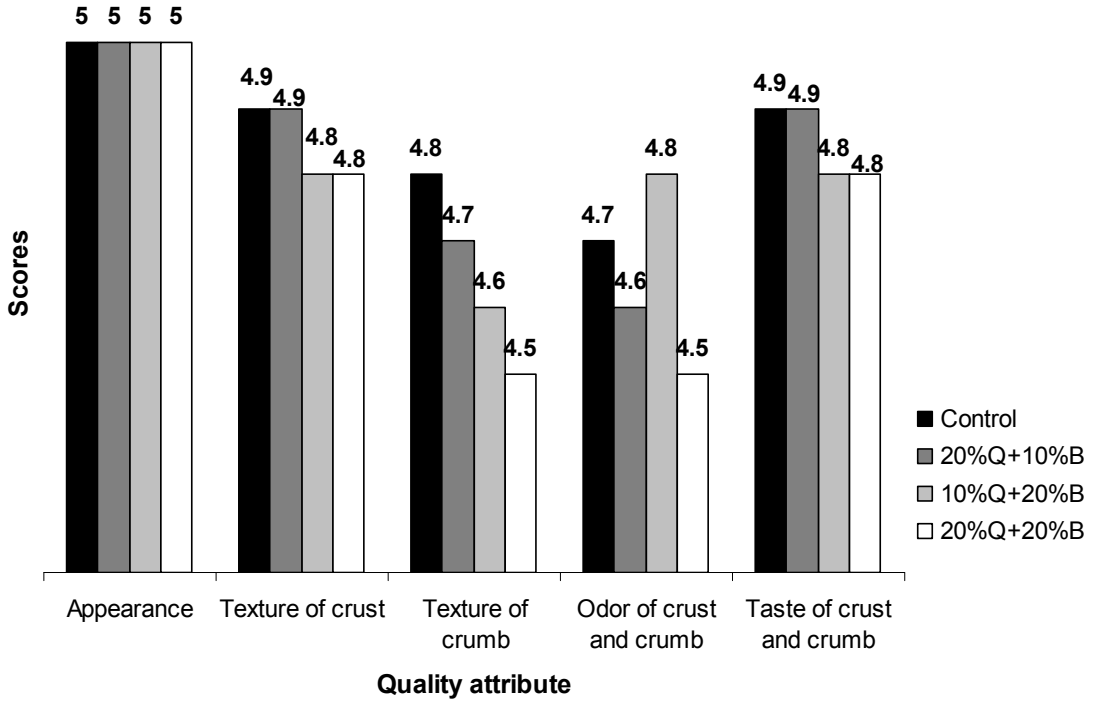

Figure 2. Sensory evaluation of selected attributes of bread.

CONCLUSION

Chemical composition revealed the potential of quinoa and buckwheat seeds as valuable ingredients in the production of molded bread of improved nutritional characteristics.

The results showed the possibility of development of a nutritionally valuable product with excellent sensory acceptance. The nutritional value of breads supplemented with 40% seed mixture was enhanced with 2.5% higher protein, 2% higher fat as well as two-fold higher fiber content. Additionally, it was fortified by higher Ca and P contents.

The addition of quinoa and buckwheat seeds influenced the rheological characteristics of dough. Sensory characteristics of evaluated breads were excellent even at 40% supplementation level. Modification of technological procedure of seed preparation afforded the inclusion of such high levels of seed in bread and could enable the development of a range of new baking products with enhanced nutritive value.

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IZVOD

PROIZVODNJA PŠENIČNOG HLEBA SA DODATKOM SEMENA KVINOJE I HELJDE

Mirjana A. Demin[1], Biljana V. Vucelić-Radović[1], Nebojša R. Banjac[1], Neli Nikolaevna Tipsina[2], Mirjana M. Milovanović[1]

[1]*Univerzitet u Beogradu, Poljoprivredni fakultet, Institut za prehrambenu tehnologiju i biohemiju, Beograd, Srbija*
[2]*Krasnoyarsk State Agrarian University, Krasnoyarsk, Russia*

(Naučni rad)

Kvinoja (*Chenopodium quinoa* Will.) jeste ratarska biljka poreklom iz andskih država Južne Amerike. Na području Srbije ova biljka dosad nije gajena. Agrotehnika kvinoje je zasnovana na principu organske poljoprivredne proizvodnje i primenjuje se u Danskoj i Makedoniji. Predmet proučavanja bila je danska sorta KVL 37, i domaća sorta heljde, koje su gajene na lokalitetu Stara Pazova. U ovom radu prikazan je hemijski sastav prečišćenih semena kvinoje i heljde koja su korišćena za proizvodnju hleba. Određene su nutritivne vrednosti pšeničnog hleba sa dodatkom semena pseudocerealija, kvinoje i heljde, u količini od 30 i 40% i upoređene su sa kontrolnim pšeničnim hlebom. Analizirane su tehnološke i pecivne osobine mešavina ovih semena i pšeničnog brašna, kao i mogućnost njihove primene u proizvodnji hleba u kalupu. Tehnološki proces je modifikovan uvođenjem hidrotermičkog tretmana semena. Hleb sa dodatkom 30% semena pseudocerealija je sadržao 2% više proteina, oko 0,5% više sirovih vlakana, dok je dodatak 40% semena hlebu povećao sadržaj proteina za 2,5% a vlakana za oko 0,4%. U pogledu sadržaja skroba, ulja i pepela nije bilo većih promena. Pokazano je da su se sve ispitivane mešavine pšeničnog brašna i semena pseudocerealija pokazale pogodnim za proizvodnju ukalupljenog hleba, povećane nutritivne vrednosti. Primenjeni tehnološki postupak je uticao na reološke osobine testa. Dobijeni hlebovi su imali dobru specifičnu zapreminu i odlične senzorne osobine.

Ključne reči: Kvinoja • Heljda • Hleb sa dodatkom semena • Tehnološki postupak