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QUINOA - A NEW HIGH QUALITY CROP IN SERBIA

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Quinoa is a pseudocereal plant native to the Andean regions of South America. Nowadays, quinoa has been recognized for its nutritional benefits all over the world. Amino acid and mineral composition revealed the potential of quinoa seeds as a valuable ingredient in the preparation of highly nutritious food products. Quinoa was successfully trialed in typical agro-climatic conditions of Serbia. In our experiment quinoa seeds had higher contents of most essential amino acids, especially lysine and methionine than wheat. The protein content of quinoa seeds was higher than in other cereals. Quinoa contains relatively high quantities of vitamins (thiamin, vitamin C). The pericarp of quinoa seeds contain saponins that impart a bitter taste and tend to foam in aqueous solutions. Further agronomic research, including phenology, morphology, physiological maturity and weeds control should be performed. Also, research is needed on the adaptability of different cultivars to new agro-climatic conditions. Quinoa is a crop of many potential uses. The seeds can be boiled like rice and used as a hot breakfast cereals, or used to thicken soups or as a porridge. The seeds can be popped like popcorn or ground and used as flour. Quinoa flour can be mixed with maize or wheat flour into bread,

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noodles, pasta and sweet biscuits. The study on the new form of quinoa presentation such as bread supplemented with quinoa seeds could enable the development of a range of new baking products with enhanced nutritive value. In all investigated cases, products are of excellent quality, with good physical, sensorial and nutritional qualities.

Key words: quinoa, essential amino acids, nutrition quality, seed supplemented breads

INTRODUCTION

Quinoa (*Chenopodium quinoa* Willd.) is a seed crop traditionally cultivated in the Andean region for several thousand years. Quinoa was cultivated in small plantations in rural areas for domestic consumption and it was frequently classified as food for poor people (JANCUROVA *et al.*, 2009). The seeds may be utilized for human food, in flour products and in animal feedstock because of its high nutritive value (Repo-Carrasco *et al.*, 2003). Due to its significant nutritive value and ability to adapt to a wide range of agro-ecological conditions, quinoa is becoming of increasing interest worldwide. Quinoa has been selected by FAO as one of the crops destined to offer food security in the 21st century (JACOBSEN, 2003).

BOTANICAL AND AGRONOMICAL CHARACTERISTICS

Quinoa is a pseudocereal (which is dicotyledonous whereas the cereals are monocotyledonous), belongs to the *Chenopodiaaceae* family, genus *Chenopodium*. Its botanical name is *Chenopodium quinoa* Willd. The classification of quinoa was first made from the colour of the plant and fruits. Subsequently, it was based on the morfological types of the plant. Despite the wide variation observed, quinoa is considered to be one single species. The species is an annual Amaranthacea that shows good adaptability to different environmental conditions (PULVENTO *et al.*, 2010).

Quinoa collected in Ecuador, Peru and Bolivia has been classified into 17 species but more species may exist. Two types of inflorescence have been described (glomerulates-small groups of flowers and amaranthiformers) and five ecotypes according to the altitudes (sea-level, valley, subtropical, salar and antiplanic). The cultivation of quinoa is related to the crop rotation seen in potatoes. This is a usual practice that improves quinoa yield and preserves soil fertility (JANCUROVA *et al.*, 2009).

In addition, the quinoa plants show tolerance to frost (-1ºC up to 35ºC), salinity and drought, and have the ability to grow on marginal soils (wide range of acid conditions from pH 6.0 to 8.5) (JANCUROVA *et al.*, 2009; JACOBSEN *et al.*, 2003).

Quinoa is frost resistant if the frost occurs before flowering, after that significant damage may occur. The flowers are sensitive to frost. Quinoa is a drought resistant plant. It is able to develop even in regions where the annual rainfall is in the range of 200-400 mm.

The planting season varies from August in the Andean highlands, extending through December and in some areas from January to March. Seeds may be spread but the weeds control and mechanized practices become difficult. Quinoa is planted in rows (row spacing range between 40-80 cm) where mechanized agriculture practices are used.

The sowing density may vary according to the region. It has been reported to range from 0.4 to 0.6 g/m^2 in Bolivian Altiplano, from 0.5 to 2.3 g/m^2 in Puno and from 0.8 to 1.4 g/m^2 in Equador. Quinoa is harvested at physiological maturity. The grains become dry and hard, making it difficult to break them with a finger nail. Physiological maturity may be reached within 70 to 90 days after flowering. Depending on the variety, plants take between 5 and 8 months to mature. The yield of quinoa can be in the range of 45-500 g/m^2 depending on the variety and growing conditions (JANCUROVA *et al.*, 2009).

Quinoa plant grows 1-3 m high. The fruit of quinoa is in the form of the seeds which are small, round and flattened, measure about 1.5 mm in diameter and about 350 seeds weigh 1 g and can germinate very fast. They are covered by perigonium, which is of the same colour as the plant: white, yellow, gray, light brown, pink, black or red. It is easily removed when it is dried. Another two layers encolse the seed. Pericarp adherese to the seed, it contains the saponins which transmit the bitter taste characteristic of quinoa. Episperm encloses the cylindrical seed as a thin layer. The embrio can make up to 60% of the seed weight. It is forms a ring around the perisperm.

Quinoa has been tested in diverse climatic regions of USA, Canada, India, England, Denmark, Greece, Italy and other European countries (BHARGAVA *et al.*, 2007; JACOBSEN *et al.*, 1994; PULVENTO *et al.*, 2010). Although quinoa has been tested in FYR Macedonia with good yield (D. BOSEV, pers. com.), the potential of growing this crop in South East Europe has not been exploited.

Thus, the aims of some studies (STIKIĆ *et al.*, 2011; GLAMOČLIJA *et al.*, 2010; STIKIĆ *et al.*, 2011) were to test the possibility for growing and utilizing quinoa in Serbia by assessing potential yield under rain fed field conditions as well as chemical characteristics and quality of quinoa seeds. Also, chemical, technological and sensory aspects of supplementing wheat bread with quinoa seeds were studied. These characteristics are of special interest for quinoa to be accepted as a new crop by farmers and consumers, in climatic conditions typical for South Eastern Europe.

The characteristics of climate in Serbia, similarly to other countries in South Eastern European region (FYR Macedonia, Bosnia and Herzegovina, Bulgaria, Croatia, Montenegro), is continental, with very hot and dry summers and cold and rainy winters. The climatic characteristic for the year of 2009 when the quinoa experiment was conducted was a cold winter (December - February), a warm spring (March - May) and an extremely hot summer (June - August).

Results in the American and European Test of Quinoa showed that in Italy and Greece, Danish quinoa cultivar Q52 gave the best yield, with up to 2.280 and 3.960 t ha^{-1}, respectively (JACOBSEN, 2003). Furthermore, the yield of KVL 37 genotype could also be compared with the results of Schulte auf'm ERLEY *et al.* (2005) for quinoa grown in conditions without N fertilization. With an increase of N fertilization rate from 0 to 120 kg N ha^{-1}, seed yield was significantly increased from 1.790 to 3.495 t ha^{-1}. Our yield of around 1.750 t ha^{-1} was close to the one obtained in Germany without N fertilization by Schulte auf'm ERLEY *et al.* (2005).

The low precipitation and high temperature in July coincided with quinoa sensitive phases to drought (from flowering to seed filling). Drought in this period without supplemental irrigation might be the cause of lower yield of Puno compared to the yield in South Italy (1.9 - 3.28 t ha^{-1}) (PULVENTO *et al.*, 2010). Deficit irrigation strategy is another option to increase quinoa production. GEERTS *et al.* (2008) showed that irrigation applied during growth stages sensitive to drought can increase quinoa yields significantly and that deficit irrigation method can be used to stabilize yields in years of precipitation deficits. These results also showed that the milky seed phase was observed as being most sensitive to drought stress, followed by the flowering stage. The role of soil salinity was studied by RAZZAGHI *et al.* (2011). They demonstrated that increasing salinity decreased seed radiation use efficiency, seed yield, harvest index and number of seeds, and increased transpiration water use efficiency and radiation use efficiency of straw significantly.

It can be concluded that the genetic variability of quinoa is huge, with cultivars being adapted to growth from cold, highland climates to subtropical conditions, which makes it possible to select, adapt and breed cultivars for a wide range of environmental conditions (BERTERO *et al.*, 2004). Quinoa was successfully trialed in typical agro-climatic conditions of South Eastern Europe giving seed yield of around 1.750 t $ha^{-1}$of remarkable quality.

NUTRITIONAL VALUE AND BAKING QUALITY

High nutritional value of quinoa seeds is mainly due to the high protein content and wide range of minerals and vitamins (FLEMING and GALWEY, 1995). Additionally, the protein content of quinoa seeds varies from 8% to 22% which is higher on average that in the common cereals. It is known that albumins and globulins are the major protein fractions (44-77% of total protein). Quinoa has a good balance of the amino acid that make up the protein. The seed proteins are rich in amino acids like lysine, threonine and methionine that are deficient in cereals, as shown in Table 1.

Table 1. - Amino acid profile (g 100 g^{-1} protein). (Stikić et al., 2011)

Amino acid	Quinoa purified seeds	Wheat flour type T-500
Essential		
Thr	3.03 ± 0.07[a]	2.21 ± 0.03[b]
His	2.64 ± 0.04[a]	1.77 ± 0.02[b]
Tyr	3.63 ± 0.05[a]	3.54 ± 0.03[b]
Val	5.34 ± 0.04[a]	4.16 ± 0.02[b]
Met	2.16 ± 0.07[a]	1.50 ± 0.04[b]
Lys	3.91 ± 0.10[a]	1.68 ± 0.05[b]
Ile	5.00 ± 0.04[a]	9.90 ± 0.02[b]
Leu	8.29 ± 0.06[a]	2.65 ± 0.03[b]
Phe	4.69 ± 0.05[a]	12.38 ± 0.03[b]
Non-essential		
Asp+Glu	22.89 ± 0.16[a]	19.89 ± 0.09[b]
Ser	3.63 ± 0.03[a]	3.89 ± 0.01[b]
Gly	2.18 ± 0.06[a]	3.45 ± 0.02[b]
Ala + Pro	13.31 ± 0.09[a]	13.08 ± 0.08[b]
Arg	13.56 ± 0.11[a]	2.74 ± 0.07[b]

Means ± standard deviation with the different letter in the same row were significantly different at $p < 0.05$. The values are expressed on the dry weight basis.

The main component in quinoa consists of carbohydrates and varies from 67% to 74% of the dry matter. Starch makes about 52-60% and can be present as simple units or as spherical aggregates. Small granule starches exhibit a higher gelatinisation temperature (57-64ºC). Other carbohydrates are found in small amounts (2% monosaccharides, 2.3% disaccharides, 2.5-3.9% crude fiber and 2.9-3.6% pentosans) (JANCUROVA *et al.*, 2009).

Quinoa contains from 2% to 10% fat. The overall fatty acid composition of the whole quinoa seeds was similar to the other cereal grains with essential linoleic, oleic and palmitic acids as the major acids present (JANCUROVA *et al.*, 2009).

Quinoa contains more calcium, magnesium, iron and zinc that common cereals. Polishing and washing quinoa seeds reduce the mineral content to some extent: 12-15% in the concentration of iron, zinc and potassium, 27% loss of copper and 3% loss of magnesium (Table 2).

Table 2. - Chemical characteristics and mineral composition of the quinoa seeds. (Stikić et al., 2011)

Content (%)	Quinoa whole seeds	Quinoa dehulled seeds	Quinoa purified seeds
Moisture	10.87 ± 0.02[b]	10.08 ± 0.01[c]	11.43 ± 0.04[a]
Protein	17.41 ± 0.04[a]	15.69 ± 0.03[b]	15.16 ± 0.45[b]
Oil	4.79 ± 0.01[c]	5.20 ± 0.10[b]	5.79 ± 0.22[a]
Crude fiber	10.32 ± 0.01[a]	6.80 ± 0.46[b]	5.69 ± 0.1[c]
Ash	7.06 ± 0.05[a]	3.59 ± 0.02[b]	2.22 ± 0.03[c]
Starch	49.55 ± 0.04[b]	58.65 ± 0.40[a]	59.71± 0.60[a]
P (g kg^{-1})	2.40 ± 0.55[a]	2.30 ± 0.51[a]	2.80 ± 0.21[a]
Ca (g kg^{-1})	4.50 ± 0.24[a]	2.10 ± 0.21[b]	2.20 ± 0.16[b]
Na (g kg^{-1})	2.20 ± 0.18[a]	1.46 ± 0.21[b]	0.79 ± 0.22[c]
K (g kg^{-1})	9.52 ± 0.69[a]	8.09 ± 0.53[b]	4.86 ± 0.88[c]
Mg (g kg^{-1})	1.50 ± 0.15[a]	1.52 ± 0.20[a]	1.40 ± 0.17[a]
Fe (mg kg^{-1})	49.63 ± 4.90[a]	49.33 ± 3.95[a]	24.13 ± 2.30[b]
Cu (mg kg^{-1})	2.89 ± 0.78[a]	2.39 ± 0.91[a]	2.06 ± 0.89[a]
Zn (mg kg^{-1})	18.70 ± 0.81[a]	18.47 ± 0.87[a]	18.36 ± 0.96[a]
Mn (mg kg^{-1})	19.43 ± 0.61[a]	16.87 ± 0.71[b]	12.14 ± 0.67[c]

Means ± standard deviation with the different letter in the same row were significantly different at $p < 0.05$. The values are expressed on the dry weight basis.

Saponins and phytic acid are the main disadvantageous factors in quinoa. The pericarp of the quinoa seed contains saponins which may impart a bitter taste. Their separation is easily accomplished by rinsing the seed in cold alkaline water or mechanical abrasion. The amount of saponins present depends on the variety of quinoa (higher in the bitter-flavour varieties or low in low-saponins varieties). Quinoa contains saponins in the amount from 0.1 to 5% (JANCUROVA *et al.*, 2009).

Protein quality, starch properties and other nutrients of the quinoa seeds have been studied, but other aspects related to the technological applications have received less attention. Because of its low baking quality, which is due to the absence of gluten, quinoa flour can only partially substitute wheat flour in breadmaking and other baked products. In Denmark bread for celiac people consisting of only quinoa as starch source is produced (S. E. Jacobsen, pers.comm.). The sensory evaluation of flavour, texture, and appearance showed the products to be moderately acceptable. A crunchy texture, a unique shape, and a nutty or wheaty flavour in baking products are described (LINNEMANN and DIJKSTRA, 2002). Breadmaking ability of wheat flour mixed with quinoa seeds has not been studied yet. For the breadmaking process, 10 % substitution of wheat flour with quinoa flour has been reported to be acceptable based on dough stability, loaf volume, weight, structure, texture, taste and colour (LORENZ and COULTER, 1991; ENRIQUEZ *et al.*, 2003). The possibility of using quinoa flour inclusion in baked products up to 20-30% was mentioned. However, a bitter aftertaste at such high quinoa flour levels was reported. This is probably due to a deficient seed processing, leaving some of the hull. Good baking and sensory properties were obtained for mixtures with up to 10 % of quinoa flour. So far, the technology for incorporation of quinoa seeds into baking products has not been developed (STIKIĆ *et al.*, 2011).

PRODUCTS AND SENSORY PROPERTIES

The seed is used to make different food products including breads, biscuits, cookies, crepes, muffins, pancakes, and tortillas. More recently, attention has been given to quinoa for people with celiac disease (allergy to gluten), as an alternative to the cereals wheat, rye and barley, which all contain gluten (JACOBSEN, 2003) because it contains very little or no prolamin (0.5-7.0%) (JANCUROVA *et al.*, 2009).

The addition of quinoa integral flour increases the nutritional value of wheat flour (LORENZ and COULTER, 1991). Nutritional characteristics of breads supplemented with quinoa seeds have not been reported. Due to inducing a bitter taste, current limit for incorporation of quinoa into wheat flour is 15 % for baked products (LORENZ and COULTER, 1991).

Our experiments were done on breads supplemented with quinoa purified seeds. The chemical composition of the different breads made from wheat flour with incorporation of dehulled quinoa seeds, devoid of saponins, are presented in Table 3.

In our investigation incorporation of 15 % quinoa seeds into wheat flour type T-500, improved lysine content to 19.91 % and, methionine and histidine contents by around 7 %. Incorporation of 20 % quinoa seeds into wheat flour, improved lysine content by 26.5 %, methionine content by 8.8 % and histidine by 9.8 %.

There was important difference in protein content for breads made with the addition of 10-15 % quinoa seeds. Incorporation of 20 % of quinoa seeds further increased protein content by around 2 %. Also, breads supplemented with quinoa seeds showed increase in both oil and crude fiber contents for nearly 1 % in all examined cases. These results are very close to the examination of wheat-quinoa flour blends by ENRIQUEZ *et al.* (2003). Although it is slightly lower in supplemented breads, there are no significant differences in the ash content.

Table 3. - Chemical characteristics and mineral composition of wheat breads produced with the addition of purified quinoa seeds. (Stikić et al., 2011)

Content (%)	Wheat bread	Bread + 10% quinoa seeds	Bread + 15% quinoa seeds	Bread + 20% quinoa seeds
Moisture	13.29 ± 0.02[a]	12.84± 0.0[c]	13.02 ± 0.02[b]	12.60 ± 0.05[d]
Protein	11.89 ± 0.01[c]	13.49 ± 0.01[b]	13.58 ± 0.08[b]	13.83 ± 0.04[a]
Oil	0.98 ± 0.08[b]	1.36 ± 0.01[a]	1.51 ± 0.10[a]	1.90 ± 0.07[a]
Crude fiber	0.60 ± 0.08[b]	1.53 ± 0.03[a]	1.59 ± 0.13[a]	1.71 ± 0.13[a]
Ash	2.98 ± 0.02[a]	2.82 ± 0.04[a]	2.85 ± 0.01[a]	2.60 ± 0.01[a]
Starch	70.25 ± 0.15[a]	67.96 ± 0.05[b]	67.44 ± 0.31[c]	67.36 ± 0.27[c]
P (g kg^{-1})	1.00 ± 0.13[a]	1.00 ± 0.05[a]	1.10 ± 0.10[a]	1.10 ± 0.13[a]
Ca (g kg^{-1})	0.60 ± 0.10[a]	0.60 ± 0.10[a]	0.70 ± 0.10[a]	0.60 ± 0.20[a]
Na (g kg^{-1})	0.10 ± 0.02[a]	0.10 ± 0.01[a]	0.09 ± 0.01[a]	0.07 ± 0.01[a]
K (g kg^{-1})	2.46 ± 0.21[b]	3.21 ± 0.24[a]	2.88 ± 0.15[a]	2.88 ± 0.13[a]
Mg (g kg^{-1})	0.26 ± 0.01[c]	0.35 ± 0.05[b]	0.41 ± 0.03[ab]	0.45 ± 0.03[ab]
Fe (mg kg^{-1})	12.60 ± 0.10[b]	14.11 ± 0.99[a]	16.00 ± 1.00[a]	17.70 ± 0.61[a]
Cu(mg kg^{-1})	1.65 ± 0.26[a]	0.99 ± 0.84[a]	1.40 ± 0.10[a]	1.92 ± 0.27[a]
Zn (mg kg^{-1})	9.43 ± 0.76[a]	8.00 ± 1.00[a]	9.15 ± 0.83[a]	10.00 ± 0.89[a]
Mn (mg kg^{-1})	7.22 ± 0.85[a]	6.99 ± 0.99[a]	8.37 ± 0.78[a]	8.11 ± 0.84[a]

Means ± standard deviation with the different letter in the same row were significantly different at $p < 0.05$. The values are expressed on the dry weight basis.

Our next study (MILOVANOVIĆ *et al.*, 2011) has shown that the wheat flour supplemented at 40% level with quinoa, buckwheat and pumpkin seed kernels (15%, 15% ad 10%, respectively) produced composite bread with increased protein, crude fiber and oils contents that was nutritionally superior to wheat flour bread, as control. Also, because the wheat flours in baking industry are deficient in essential amino acids, such as lysine and methionine and as well as some elements, in particular calcium and iron, the fortification the wheat flour with the quinoa, buckwheat and pumpkin seed kernels, might improve their dietary properties. Applied technological procedure using well blended combination of supplements resulted in larger specific volume (5, 2 ml/g) of the bread and excellent sensory properties of aroma-odor and taste.

The supplementation of wheat flour with quinoa, buckwheat and flax seeds (15%, 15% and 10%, respectively) can effectively enhance the protein quality for 0.5% of the moulded bread. Additionally, the crude fiber content two fold times is increased, and also seven fold times in oils content were determined. Beside the high levels of unsaturated fatty acids, flax seeds are used in food industry as complement in the production of bread and cakes. The significant protein and crude fiber content and well-balanced amino acids profiles, especially in quinoa seeds, make the supplemented seeds very attractive in combination for the breadmaking properties (DEMIN *et al.*, 2011; DEMIN *et al.* 2012).

Sensory characteristics of evaluated breads were excellent. The supplemented breads had good loaf volume a yellow-reddish crust color, crispy in respect to brittleness. The middle of the bread was light colored with finely structured uniform pores, within which quinoa seeds were embedded. It is important to note that a characteristic, very pleasant aroma of quinoa (flavour and taste) was observed in all the breads supplemented with quinoa seeds. Taste of the breads was pleasant, very specific, slightly bitter and fully acceptable even at the highest level tested.

The studies on the new form of quinoa presentation such as bread supplemented with quinoa seeds could enable the development of a range of new baking products with enhanced nutritive value.

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KVINOJA - NOVA VISOKOVREDNA KULTURA U SRBIJI

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I z v o d

Kvinoja je pseudocerealija poreklom sa Anda, iz regiona Južne Amerike. Danas je kvinoja prepoznatljiva širom sveta po svojim hranljivim vrednostima. Amino kiselinski i mineralni sastav semena kvinje doprinose njenom velikom potencijalu, i ona se smatra dragocenim sastojkom u pripremi visoko hranljivih namirnica. U odnosu na pšenicu seme kvinoje ima viši sadržaj većine esencijalnih aminokiselina, posebno lizina i metionina. Sadržaj proteina u semenu kvinoje je veći u odnosu na ostalia žita. Kvinoja sadrži relativno velike količine vitamina (tiamina i vitamina C). Perikarp semena kvinoje sadrži saponine, koji daju gorak ukus i u vodenim rastvorima stvaraju penu. Potrebno je obaviti dalja agronomska istraživanja, uključujući određivanje fenoloških i morfoloških svojstava, fiziološke zrelosti i ispitati kontrolu korova. Dalja istraživanja su potrebna i za utvrđivanje prilagodljivosti različitih sorti u novim agro-klimatskim uslovima. Preliminarna ispitivanja gajenja kvinoje u tipičnim agro-klimatskim uslovima Srbije su dala dobre rezultate. Mogućnost upotrebe semena kvinoje je raznovrsna. Kuvano seme može se koristiti kao topao doručak od žita ili kao kaša. Seme se može kokati kao kokice ili mleti i koristi dalje kao brašno. Brašno od kvinoje može se mešati sa kukuruznim ili pšeničnim brašnom i koristiti za izradu hleba, nudli, testenina i slatkih biskvita. Studije o novom obliku upotrebe kvinoje kao što su hlebovi sa dodatkom semenom kvinoje mogu da omoguće razvoj niza novih pekarskih proizvoda sa poboljšanom hranljivom vrednošću. Svi ispitivani proizvodi su bili odličnog kvaliteta, sa dobrim fizičkim, senzornim i nutritivnim osobinama semena kvinoje.

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