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Agronomical and nutritional evaluation of quinoa seeds (*Chenopodium quinoa* Willd.) as an ingredient in bread formulations

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ABSTRACT

Quinoa is an Andean seed crop of many potential uses. In 2009 a field trial was carried out to explore the potential for quinoa growing in climatic conditions of South Eastern Europe. Even under rainfed conditions, without fertilization, a seed yield as high as 1.721 t ha^{-1} was obtained. Seed quality was remarkably good, with protein content ranging from 15.16 to 17.41 % on a dry weight basis, depending on whether seeds were processed. Amino acid and mineral composition revealed the potential of quinoa seeds as a valuable ingredient in the preparation of highly nutritious foods. Quinoa seeds had higher contents of most essential amino acids, especially lysine, than wheat flour. Dehulled quinoa seeds, devoid of saponins, were included into wheat bread formulations, with up to 20%, which resulted in a positive effect on the rheological characteristics of dough. Furthermore, protein content in bread was increased by around 2%. Sensory characteristics of breads were excellent also at the 20% supplementation level. The study of bread supplemented with quinoa seeds could enable the development of a range of new baking products with enhanced nutritional value.

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1. Introduction

Quinoa (*Chenopodium quinoa* Willd.) is a seed crop traditionally cultivated in the Andean region for several thousand years. Quinoa is considered as a multipurpose agricultural crop. 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. During the last years in Bolivia the production of quinoa has increased strongly due to an increased market demand and price, which emphasize the need to grow the crop in other parts of the world (Jacobsen, 2011). Quinoa has been selected by FAO as one of the crops destined to offer food security in the 21st century (Jacobsen, 2003).

In addition, the quinoa plants show tolerance to frost, salinity and drought, and have the ability to grow on marginal soils (Jacobsen et al., 2003). 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 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).

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). The seed proteins are rich in amino acids like lysine, threonine and methionine that are deficient in cereals. 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).

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 bread-making and other baked products. In Denmark, bread for celiac

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people consisting of only quinoa as starch source is produced (S. E. Jacobsen, pers. comm.). The sensory evaluation of flavor, texture, and appearance showed the products to be moderately acceptable. A crunchy texture, a unique shape, and a nutty or wheaty flavor 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 color (Enriquez et al., 2003; Lorenz and Coulter, 1991). 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.

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 aim of this study was to test the possibility for growing and utilizing quinoa in Serbia by assessing potential yield under rainfed field conditions as well as chemical characteristics and quality of quinoa seeds and, by testing chemical, technological and sensory aspects of supplementing wheat bread with quinoa seeds. 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.

2. Materials and methods

2.1. Experimental site and set up

The experiment was carried out during the 2009 growing season in a field located 20 km north-west of Serbian capital, Belgrade. The experiment was organized as randomized complete block design with four replications. Plots size was 4 rows of 4 m, with an inter-row spacing of 0.5 m.

The soil of the field was classified as chernozem according to IUSS working group soil classification (IUSS, 2006). The topsoil (0–0.4 m) contained 4.32% sand, 67.14% silt, 26.13% clay and 2.49% of organic matter. Other soil characteristics were: bulk density of 1.27 gcm^{-3}, 7.6 pH, 0.22% N, 4.9% $CaCO_3$, volumetric soil water content of 38.5% at field capacity and of 15.72% at wilting point. The trial was conducted under rainfed conditions. Sowing rate of quinoa was 10 kg ha^{-1} at a final density of 400.000 plants ha^{-1}. Sowing depth was 5 cm. Sowing date was April 15th and growing period lasted 125 days. During the season, plants were treated against weeds. Harvest by hand on August 18th was done at physiological maturity, which was defined as the date when seeds from the main panicle become resistant when pressed (Bertero et al., 2004).

2.2. Materials

Quinoa (*C. quinoa* Willd.) variety used for investigation was Puno (KVL 37), provided by the University of Copenhagen. The variety has recently been registered as a new quinoa variety in Europe, bred from Chilean and Peruvian landraces and selected for earliness and adaptation to European conditions. Ten plants from the central rows in each replication were randomly chosen for seed yield quantity and quality. The seeds of 40 plants were bulked and weighed and the seed yield/plot was then converted to tonnes per hectare (t/ha).

Before any analyses, the raw and flaky quinoa seeds were manually dehulled to remove the pericarp. Manual dehulling was done in a mortar, and the hulls were separated carefully by sieving to avoid inclusion of other seed portions (Chauhan et al., 1992). In the next step, the remaining dehulled seeds were washed to extract saponins. Washing was carried out by adding cold water and by shaking vigorously for some seconds: this was repeated until the formation of foam was no longer observed (Risi and Galwey, 1984). The purified seeds were dried at 45 °C, conditioned in an airtight container. Commercial wheat flour (type T-500) containing 12.6% moisture, 0.51% ash, 11.04% protein and 25.5% moist gluten was used for breadmaking.

2.3. Estimated morphological parameters

Morphological parameters (plant height and number of lateral branches) were measured at harvest. At harvest, seeds per plant were also collected and the yield was calculated as a mean of fresh weight (FW) produced per plant.

2.4. Determination of mineral composition

For mineral analyses, the purified seeds were dried at 80 °C and dry material was ground using a laboratory mill (Cemotek Sample Mill Foss, Sweden). K, Mg, Fe, Cu, Zn and Mn were determined according to Jones and Steyn (1973). After dry ashing and digestion of samples with HCl, the concentration of Mg was measured by atomic absorption spectrometry (SensAA Dual Atomic Spectrometer, GBC Scientific equipment, Australia). Measurements of Fe, Cu, Zn and Mn contents were done after wet digestion of samples with HNO_3 and by the use of iCAP 6300 ICP Spectrometer (Thermo Fisher Scientific Inc, UK). After dry ashing of samples and digestion with HCl, the concentration of K was estimated by the flame-photometry method (Flapho-4 Flame Photometer, Carl Zeiss, Germany). Contents of Ca, P and Na were determined according to the standard AOAC methods (No. 944.03; 965.17 and 930.23, respectively, 1997).

2.5. Chemical analyses

The purified seeds were milled in Cemotek Sample Mill Foss, Sweden and the flour was further examined. Standard AOAC methods (AOAC, 1997), numbers 925.10, 923.03 and 920.87, were used to determine moisture, ash and protein (Kjeltec 2300 system) contents, respectively. The nitrogen to protein conversion factor of 6.25 was used for the calculation of crude protein content. Automatic extraction method AOAC number 920.39 (FOSS-TEKATOR SOXTEC AVANTI) was used for oil content. Fibertek 2010 System was used to determine crude fiber content, using the 962.09 AOAC method. According to Grosso et al. (2000), the total starch content was calculated by subtracting the sum of moisture, ash, crude fiber, oil and protein from 100%.

Wheat flour samples were analyzed by standard ICC (International Association for Cereal Science and Technology, 1996) methods for moisture, ash and crude protein contents; methods No. 109/1, 104/1 and 105/2, respectively. The specific nitrogen to protein conversion factor of 5.7 was used for the calculation of crude protein content in wheat flour. Chemical characteristics of the breads supplemented with the quinoa seeds are included. The breads (after drying in the storage conditions) were milled, using the Knifetec (Germany) model of mill. The same standard AOAC methods as described above were used for determining chemical composition of the wheat breads supplemented with quinoa seeds. All the measurments were done in triplicate.

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