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Quinoa - a treasure trove of nutrients

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Abstract

Sensitivity to gluten results in a wide spectrum of manifestations triggered by ingestion of the gluten-containing grains such as wheat, barley and rye. Celiac Disease, also known as gluten sensitivity enteropathy , is characterized by inflammation of the small –intestinal mucosa that results from a genetically based immunologic intolerance to ingested gluten. Rising demands for gluten free products parallels the increase in celiac disease .Humans have many options when it comes to fueling their bodies, but the benefits of some options are so nutritious that they are labeled as “Superfoods”. The new emerging super food quinoa (*chenopodium quinoa*) was the international food of the year 2013 and it is a staple food got originated in the Andean region of South America. It is a pseudo cereal rather than a true cereal, as it is not a member of the true grass family. It is a small seed which look like a cross between sesame seeds and millets. It has exceptionally high protein containing balanced set of essential amino acid such as methionine, cysteine and lysine as compared to wheat .Quinoa protein is free of gluten with a low Glycemic Index, and thus it is ideal for celiac patients. Quinoa contained good amount of total dietary fibre consisting of both insoluble fibre and soluble fibre, essential fatty acids such as linoleic and linolenic acid. The use of quinoa in diet can be considered beneficial in the prevention and treatment of risk factors related to celiac disease, cardiovascular diseases, gastrointestinal problems and reducing lipid peroxidation. Quinoa can be cooked as a cereal such as porridge, add it to salads, dessert and can be used as flour for preparation of gluten free bread and bakery products. Thus, variety of products can be developed from Quinoa alone or in combination with other food material and therefore, Quinoa is considered to be an excellent novel source of natural health promoting food and can be used for prevention of many diseases.

Keywords: *Chenopodium quinoa,* celiac disease, superfood, nutrients, product.

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Introduction

Sensitivity to gluten results in a wide spectrum of manifestations triggered by ingestion of the gluten-containing grains such as wheat, barley and rye (Catassi and Fasano 2008). Celiac disease, also known as gluten-sensitive enteropathy, is characterized by inflammation of the small-intestinal mucosa that results from a genetically based immunologic intolerance to ingested gluten. The inflammation occurring in celiac disease classically produces a malabsorption syndrome, with diarrhoea, steatorrhea, and loss of weight or failure to thrive. Deficiencies of the fat-soluble vitamins A, D, E, and K, iron, folic acid and calcium are also common. Due to these changes the improvement is usually observed by gluten withdrawal from the diet or inclusion of gluten free food products. Rising demands for gluten free products parallels the increase in celiac disease. Products made from corn, rice, soybean, tapioca, amaranth seeds and pseudo cereal such as quinoa can be included in diet.

Quinoa (Chenopodium quinoa)

It is a staple food of ancient civilizations and got originated in the Andean region of South America and is now finding its place under “Project Anantha” in which Quinoa was grown both at Hyderabad a year back and in Ananthapuramu district of Andhra Pradesh and was met with a runaway success and are also found in Himalayan region. It is a pseudo cereal rather than a true cereal, as it is not a member of the true grass family. It is a small seed which look like a cross between sesame seeds and millets. Quinoa is a multipurpose crop for agricultural diversification. The United Nations General Assembly declared 2013 as the "International Year of Quinoa" in recognition of ancestral practices of the Andean people, who have preserved quinoa as food for present and future generations, through knowledge and practices of living in harmony with nature. Three most widely cultivated varieties of quinoa are available: white, red, and black. It is rich in various nutrients and due to its wider acceptability it is also used for the development of various products and has numerous health benefits.

Chemistry: quality aspects

Leaves

Quinoa leaves contain ample amount of ash (3.3%), fibre (1.9%), nitrates (0.4%), vitamin E (2.9 mg-te/100 g) and Sodium (289 mg/100 g).

Study on fresh leaves revealed abundant moisture (83.92–89.11%), chlorophyll a (0.48–1.82 mg/g), chlorophyll b (0.25–0.07 mg/g) and much higher amount of leaf carotenoid (230.23–669.57 mg/kg) than that reported earlier.

Grain

Quinoa is referred as pseudo-oilseed crop due to exceptional balance between oil, protein and fats. Perisperm, embryo and endosperm are the three areas where reserve food is stored in quinoa seed. The nutritional value of quinoa grain has long been known to be superior to cereals and also gave similar value for starch content (52–60% of grain weight) and found varying size of starch granules (0.7 and 3.2m). Quinoa starch has the potential that can be used for specialized industrial applications due to its small granules and high viscosity. The ash content of quinoa (3.4%) is higher than that of rice (0.5%), wheat (1.8%) and other traditional cereals.

Quinoa is a treasure trove of nutrients. It has exceptionally high protein (16-18%) and more than 37% of the protein in quinoa comprises of essential amino acids like that of the milk protein, casein. Unlike wheat, rice and corn which are low in lysine, quinoa contain balanced set of essential amino acid such as methionine, cysteine and lysine and also making quinoa a good complement to legumes, which are limiting in these amino acids(Drzewiecki et al 2003). The protein quality of quinoa grain is superior to most cereal grains including wheat. Albumin and globulins are the major protein fraction (44–77% of total protein) while the percentage of prolamines is low (0.5–0.7%). Quinoa protein is low in prolamins (0.5-7.0%), which indicates that it is free of gluten and, therefore, non-allergenic. Quinoa has shown some hypoglycemic effects and has been used as an alternative to traditional ingredients in the production of cereal-based gluten-free products with a low Glycemic Index (Berti et al 2004).

Several studies have revealed that the oil content in quinoa ranges from 1.8 to 9.5%, with an average of 5.0–7.2% that is higher than that of maize (3–4%).Quinoa oil is rich in essential fatty acids, like linoleate and linolenate (koziol, 1992) and has a high concentration of natural antioxidants like α-tocopherol (5.3 mg/100 g) and β-tocopherol (2.6 mg/100 g) and appreciable amounts of thiamin (0.4 mg/100 g), folic acid (78.1 mg/100 g) and vitamin C (16.4 mg/100 g) (ruales and nair, 1992).

Quinoa contained total dietary fibre content of 13.4% in quinoa consisting of 11.0% insoluble fibre and 2.4% soluble fibre. Quinoa's fatty acids have been shown to maintain their quality because of quinoa's naturally high value of vitamin E, which acts as a natural antioxidant (Ng, S et al., 2007)

The riboflavin and carotene content as 0.39 mg/100 g and 0.39 mg/100 g respectively (Koziol 1992). In terms of 100 g edible portion, quinoa supplies 0.20 mg vitamin B6, 0.61 mg pantothenic acid, 23.5µg folic acid and 7.1µg biotin.

Quinoa grains contain large amounts of minerals like Ca, Fe, Zn, Cu and Mn (repo-carrasco et al., 2003).Calcium and iron are significantly higher than most commonly used cereals. It is also reported large amounts of iron (81 mg/kg) and calcium (874 mg/kg) in quinoa. It has about 0.26% of magnesium in comparison to 0.16% of wheat and 0.14% of corn (Ruales and nair, 1992).

Quinoa may also be germinated to boast its nutritional value. Germination activates its natural enzymes, improves its vitamin status and softens the grain. Quinoa has a short germination period of 2-4 hours as other grains require 12-14 hours germination process overnight.

Economic uses

Quinoa is highly nutritive and is being used to make flour, soup, breakfast and alcohol. It is sold either as whole grain that is cooked as rice or in combination dishes. It can be fermented to make beer, or used to feed livestock. Whole plant is also used as green fodder to feed cattle, pigs and poultry. Quinoa is being considered as a potential crop for NASA's controlled ecological life support system (celss), which aims to utilize plants to remove carbon dioxide from the atmosphere and generate food, oxygen and water for the crew of long-term space missions (schlick and bubenheim, 1993). Quinoa flour, in combination with wheat flour or corn meal, is used in making biscuits, bread and processed food. The seed flour has good gelation property, water-absorption capacity, emulsion capacity and stability.

It is evaluated the sugar content and chemical composition of seed flour of quinoa and stated that it has high proportion of d-xylose (120 mg/100 g), and maltose (101 mg/100 g), and a low content of glucose (19 mg/100 g) and fructose (19.6 mg/100 g). Thus, quinoa could be effectively utilized in the beverage industry for the preparation of malted drink formulations (Ogungbenle, 2003)

Saponins - antinutritional factors

Saponins are the principle antinutritional factors present in the seed coat of quinoa. The saponin content in seeds of sweet genotypes varies from 0.2 to 0.4 g/kg dry matter and in bitter genotypes from 4.7 to 11.3 g/kg dry matter (mastebroek et al., 2000).

Saponins in quinoa are basically glycosidic triterpenoids with glucose constituting about 80% of the weight. Saponin content is affected by soil-water deficit, high water deficit lowering the saponin content.

They are removed either by the wet method, i.e. Washing and rubbing in cold water, or by dry method, i.e. Toasting and subsequent rubbing of the grains to remove the outer layers. On commercial scale, saponins are removed by abrasive dehulling but in this method, some saponin remains attached to the perisperm.

- Saponins have immense industrial importance and are used in the preparation of soaps, detergents, shampoos, beer, fire extinguishers and photography, cosmetic and pharmaceutical industries.
- They have the ability to induce changes in intestinal permeability which aids in the absorption of particular drugs.
- Research has proved that quinoa saponins may have the potential to serve as adjuvants for mucosally administered vaccines.

- Seeing the pharmaceutical potential of saponins, efforts should be made towards the utilization of quinoa saponins for this purpose.

Health benefits

Quinoa plays a vital role in various diseases and has a large no. of health benefits.

Celiac disease

Celiac disease most common lifelong disorders worldwide with an estimated mean prevalence of 1% of the general population. The only acceptable treatment for celiac disease is the strict lifelong elimination of gluten from the diet (catassi and fasano 2008).

The prevalence of celiac disease among school children in Ludhiana district of Punjab, North India and final analysis was studied that the disease prevalence was one in 310 children (Sood et al 2006). Although this disease frequency of one in 310 is thought to be an under-assessment, it clearly shows that celiac disease is not rare in wheat-eating areas of North India.

Effect of Diet Supplemented (administration of quinoa seeds 310 g/kg fodder) with Quinoa Seeds on Oxidative Status in Plasma and Selected Tissues of High Fructose-Fed Rats study demonstrate that quinoa seeds can act as a moderate protective agent against potential of fructose-induced changes in rats by reducing lipid peroxidation and by enhancing the antioxidant capacity of blood (plasma) and heart, kidney, testis, lung and pancreas. Pasko et al (2010).

Gastro-Intestinal Effects

Gastrointestinal effects of eating quinoa in celiac patients was studied by the nineteen treated celiac patients had consumed 50g of quinoa every day for 6 weeks as part of their usual gluten free diet. Diet, serology, and gastrointestinal parameters were evaluated. Gastrointestinal parameters were normal. The ratio of villus height to crypt depth improved from slightly below normal values (2.8:1) to normal levels (3:1), the addition of quinoa to the gluten free diet of celiac patients was well tolerated and did not exacerbate the condition (zevallos et al.,2014).

Quinoa is a mild laxative, good for insomnia, combats dandruff and is a good hair tonic. Likewise, the cooking water from the cooked grain mixed with milk and almond oil is used to wash the ears where there is pain, noise and deafness**.** The broth, soup or warm grain of quinoa is a nutritive tonic, increases breast milk, is restorative and protects against tuberculosis. Quinoa soup immediately increases the milk supply of lactating women **.** It is a good sudorific is produced by cooking five tablespoons of quinoa seeds in two bottles of water. The same decoction, sweetened with honey or molasses, is a proven remedy against bronchial disorders, colds, cough and inflammation of the tonsils. The fresh leaves of quinoa 'chiwa', consumed either as a soup or dessert, are a remedy against scurvy and other illnesses or diseases caused by vitamin deficiency. It is a proven remedy against anthrax, herpes, urticaria, 'llejti' and other skin conditions (zalles and de lucca, 2006).

The oxidative stability of lipids in processed quinoa was investigated. Ground quinoa was subjected to accelerated aging for 30 days at 25, 35, 45, and 55 °C. Three samples were removed from each temperature treatment every 3 days. Free fatty acids, conjugated diene hydroperoxides, and hexanal were used as indicators of lipid oxidation. Storage time and temperature had significant effects ($p \leqslant 0.05$) on all three parameters, while the interaction between storage time and temperature was not significant for conjugated diene hydroperoxides produced. The results from these tests suggest that quinoa lipids are stable for the period of time studied. With vitamin E as a naturally antioxidant occurring abundantly in quinoa, the potential for quinoa to be a new oilseed could be enhanced (Chuen et al., 2007).

Cardiovascular Disease

The effects of quinoa on the biochemical and anthropometric profile and blood pressure in humans, parameters for measuring risk of cardiovascular diseases was studied.(farinazzi *et al.,* 2012) twenty-two 18 to 45-year-old persons were treated daily for 30 days with quinoa in the form of a cereal bar. Blood samples were collected before and after 30 days to determine glycemic and biochemical profile of the group. Results indicated that quinoa had beneficial effects since the levels of total cholesterol, triglycerides, and LDL showed reduction. It was concluded that the use of quinoa in diet can be considered beneficial in the prevention and treatment of risk factors related to cardiovascular diseases.

Product development

The pseudocereal proved to be a suitable substrate for dough aeration using yeast, since considerably more glucose and a higher activity of α-glucosidase were found in comparison to rice and corn flour. Quinoa white flour enhanced the specific volume by 33%.Moreover, the crumb featured homogeneous and finely distributed gas bubbles and the taste was not compromised. Thus, it was possible to improve the quality of gluten-free bread by using quinoa white flour, which might be a relief for celiac patients.

Quinoa may also be germinated to boast its nutritional value. Germination activates its natural enzymes, improves its vitamin status and softens the grain. Quinoa has a short germination period of 2-4 hours as other grains require 12-14 hours germination process overnight. Quinoa can be cooked as a cereal such as porridge, used as an alternative to rice or poha, add it to salads, dessert or even can be used to thicken the soups. It can be used as flour for preparation of gluten free bread and bakery products.

Calcium, magnesium and iron are minerals that are deficient in gluten-free products and in the gluten-free diet (Hopman et al 2006). The pseudocereals amaranth, quinoa and buckwheat are generally a good source of these and other important minerals (Alvarez et al 2009).

Cake quality was acceptable with 5% and 10% of quinoa flour. Cake grain became more open and the texture less silky as the level of quinoa substitution increased. Cake taste improved with either 5% or 10% quinoa flour in the blend. Flavor improved up to 20% quinoa flour in the blend. Cookie spread and cookie appearance was improved with a quinoa/low-spread flour blend by using 2% lecithin. (lorenz k, 2002).

The study was conducted in which oat and quinoa malts were produced and incorporated in rice and potato based gluten free formulation. Germination of oat led to a drastic increase of α-amylase activity from 0.3 to 48 U/g, and minor increases in

proteolytic and lipolytic activities. Little change was observed in quinoa except a decrease in proteolytic activity from 9.6 to 6.9 U/g. Oat malt addition decreased batter viscosities at both proofing temperature and during heating. These changes led to a decrease in bread density from 0.59 to 0.5 g/ml and the formation of a more open crumb, but overdosing of oat malt deteriorated the product as a result of excessive amylolysis during baking. Quinoa malt had no significant effect on the baking properties due to low α-amylase activity. Despite showing a very different impact on the bread quality, both malts influenced the electrophoretic patterns of rice flour protein similarly. This suggests that malt induced proteolysis does not influence the technological properties of a complex gluten free formulation. Makinen et al (2013).

Research was conducted in which Quinoa flour was subjected to a variety of thermal processes. Both unprocessed and processed quinoa samples were subjected to successive extractions in methanol and ethyl acetate solvents. Quinoa flour subjected to processing via roasting and extrusion resulted in a significant impact on the chemical profile when compared to unprocessed quinoa flour. Steam pre-conditioning had minimal effects on the chemical profile of quinoa flour. This research suggests that thermal processing of quinoa flour can result in degradation of saponin molecules. Saponin decomposition may influence sensory or pharmacological properties (Brady 2007).

The performance of quinoa-wheat flour blends (5/95, 10/90, 20/80, 30/70) in breads, cakes and cookies was evaluated. Breads baked with 5% and 10% quinoa flour were of good quality. Loaf volume decreased, crumb grain became more open and the texture slightly harsh at higher usage levels of quinoa flour. Cake quality was acceptable with 5% and 10% of quinoa flour. Cake taste improved with either 5% or 10% quinoa flour in the blend. Cookie spread and top grain scores decreased with increasing levels of quinoa flour blended with high-spread cookie flour. Flavor improved up to 20% quinoa flour in the blend. Cookie spread and cookie appearance was improved with a quinoa/low-spread flour blend by using 2% lecithin (Lorenz and Coulter, 1991)

The starch that was isolated from lysine-rich high protein *Chenopodium quinoa* grains for physicochemical and functional properties. In contrast to corn starch which showed a two-stage swelling, *C. quinoa* showed a single-stage swelling in the temperature range of 65–95 °C. However, *C. quinoa* starch had a lower solubility and lower viscosity than corn starch at same concentration. The unique property of *C. quinoa* starch was its unusual freeze-thaw stability, a fact difficult to explain. The opaque nature of *C. quinoa* starch paste suggests applications in emulsion food products such as salad dressings (Ahamed et al., 1996)

The rheological properties of doughs prepared from wheat flour with buckwheat and quinoa flour addition (2.5 mass %, 5.0 mass %, 7.5 mass %, and 10 mass %) was investigated using a farinograph and compared with those of standard dough (without addition of pseudocereals). The following characteristics were determined: water absorption capacity, water consumption, dough growth time, level of dough softening, dough stability, mechanical resistance, and dough elasticity. Dough stability showed a linear decrease with the increasing content of pseudocereals. Doughs containing quinoa flour were more stable than those with buckwheat flour addition. Dough growth time was reduced with increasing amounts of buckwheat flour but it was not affected in the case of quinoa flour addition. From the comparison of the studied characteristics it can be concluded that an addition of lower amounts of quinoa (up to 5.0 mass %) to wheat flour will not significantly impair rheological properties of the dough but provides for enhanced nutritional value of the prepared bakery products (Jancurova 2009).

Experts recommend that the bulk of carbohydrate-containing foods consumed have a low glycemic index (GI), i.e. slowly digested carbohydrates (FAO/WHO 1997). Good glycemic control is particularly important in Celiac Disease (CD), as there appears to be a higher incidence of type I diabetes among CD patients. The limited data available on the GI of gluten-free foods suggests the need for an improvement in the formulation of these food products. Quinoa has shown some hypoglycemic effects in vivo and has been recommended as an alternative to traditional ingredients in the production of cereal-based gluten-free products with a low GI (Berti et al 2004).

Quinoa in Indian perspective

India, located between 8◦ and 38◦n and 68◦ and 93.5◦e, exhibits enormous diversity for agro-climatic regions and edapho-climatic conditions. An increasing population in this region of the world demands not only an increase in food grain production but also a shift towards environmentally sound sustainable agriculture.

In India, a large portion of the population has little access to protein-rich diet, since rice and wheat are the principal food crops.

Quinoa's highly proteinaceous grain can help to make diets more balanced in this region. Making quinoa popular in india would require dissemination of information about the crop among the farmers as well as the consumers, proper marketing and efficient post-harvest technologies. Quinoa has the potential to shed its underutilized status and become an important industrial and food crop of the 21st century.

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Supplementary Material

Quinoa, uncooked, per 100 g

Nutritional value per 100 g (3.5 oz)	
Energy	1,539 kJ (368 kcal)
Carbohydrates	64 g
Dietary fibre	7 g
Fat	6 g
Saturated	0.7 g
Monounsaturated	1.6 g
Polyunsaturated	3.3 g
Protein	14 g
Vitamins	
Vitamin A equiv.	1 µg
Thiamine (B1)	0.36 mg
Riboflavin (B2)	0.32 mg
Niacin (B3)	1.52 mg
Pantothenic acid (B5)	0.77 mg
Vitamin B6	0.49 mg
Folate (B9)	184 µg
Choline	70.2 mg
Vitamin C	0 mg
Vitamin E	2.44 mg
Trace metals	
Calcium	47 mg
Iron	4.6 mg
Magnesium	197 mg
Phosphorus	457 mg
Potassium	563 mg
Zinc	3.1 mg
Water	13 g

Units : µg=micrograms, mg=milligrams; IU = International units
Percentages are roughly approximated using US recommendations for adults. Source: USDA Nutrient Database

Essential amino acids in quinoa and other foods (g/100 g protein) (Koziol 1992)

	Quinoa	Maize	rice	wheat
Histidine	3.2	2.6	2.1	2
Isoleucine	4.9	4	4.1	4.2
Leucine	6.6	12.5	8.2	6.8
Lysine	6	2.9	3.8	2.6
Methionine	5.3	4	3.6	3.7
Phenylalanine	6.9	8.6	10.5	8.2
Threonine	3.7	3.8	3.8	2.8
Tryptophan	0.9	0.7	1.1	1.2
Valline	4.5	5	6.1	4.4