Quinoa: A Traditional Andean Crop with New Horizons

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Farmers in the Andes have conserved, adapted, and developed more than 70 food crops. Some of them, such as potatoes, maize, sweet potatoes, and beans, have been adopted as staple foods throughout the world. Many others that include pseudocereals, legumes, roots, tubers, vegetables, and fruits have not been widely used and may present new opportunities for the development of ingredients and new products with unique nutritional properties and flavor profiles. One of these products is quinoa (*Chenopodium quinoa* Wild), a relatively unknown millet-size grain that is usually referred to as one of the most important sources of nutrition of the past. Because of its nutritional properties and importance to the diet of the Incas, quinoa was considered the mother grain and revered as sacred. Thus, it was banned by the Spanish conquerors for its association with religious rituals, and its production was never developed or adopted except for use in traditional recipes. Currently, its consumption is not yet widespread, but there is renewed attention to this crop. Its versatility and attributes have sparked new interest, bringing it again to the forefront as a food charged with future potential.

Quinoa is the seed of the chenopod or goosefoot plant and has been extensively cultivated in the cold, high plateaus of the Andean valleys since approximately 3000 B.C.E. Like amaranth and buckwheat, it is considered a pseudocereal because it is the seed of a broadleaf plant rather than a grass. In addition to its nutritional value, quinoa is an interesting crop because it thrives in extreme conditions of drought, frost, and soil salinity, making it a perfect crop for mountainous areas. Currently, it continues to be grown in South American countries such as Colombia, Ecuador, Peru, Bolivia, Chile, and Argentina, where it is usually consumed as a traditional product. However, among health-conscious consumers in the United States and Europe, there is an expanding market, particularly for organically grown quinoa. Bolivia and Peru are the major producers, with a 46 and 42% share of world production, respectively, and the United States is the third producer, with only a 6.3% share (6). Bolivia controls approximately 90% of world exports of the product, mainly organic products from the variety commonly named "Real" going to European markets, where they have found very good acceptance.

One of the biggest limitations in the development of the market for quinoa and its products is the low productivity of the varieties grown using traditional methods, which increases costs and limits its availability. Current supplies are unable to satisfy the increasing demand for quinoa from national and international markets. Therefore, much research is being done to increase production and productivity, and, thanks to various international projects over the past 5 years, quinoa production in the Andean region has grown by 50%. According to the Food and Agriculture Organization of the United Nations (FAO) (4), with adequate soil preparation, fertilization, and disease and pest control, quinoa can yield more than 3–4 tons per hectare.

In recent years, quinoa introduced into international markets has brought prices in excess of $1.50/kg. This however, has not been an easy road. The exporting Andean countries have had to update their traditional process to include improved varieties, retention of organic status, and increased yields to achieve competitive productivity and access higher-value markets while complying with sanitary and phytosanitary measures. In addition to supplying a growing niche demand and producing high-quality ingredients to address novel needs, the market has made a great achievement in linking small producers with global markets through new ways of working that have a better impact in these poor communities.

Interest in this so-called "grain of the future" is based on its unique nutritional properties. In comparison with other cereal grains, it has a higher protein content with an attractive amino acid balance. This nutritious Andean crop boasts high amounts of lysine, an amino acid of which most cereals have low amounts. In addition, it is high in methionine and cystine, making it complement both cereals and legumes, which are deficient in these nutrients. In addition, it is rich in calcium, phosphorus, iron, fiber, and B vitamins. Table I shows its average nutritional composition compared with other common cereals, and Table II shows the average mineral content of quinoa. The FAO has compared quinoa in nutritional content with milk casein and considers it

Table I. Nutrient (g/100 g) and caloric (kcal/100 g) content of quinoa and other grains

Content	Quinoa	Whole Wheat	Rye (whole grain)	Barley (whole grain)	Brown Rice	Corn (whole grain)
Caloric value	350.00	309.00	269.00	299.00	353.00	338.00
Protein	13.81	11.50	8.70	10.60	7.4	9.2
Fat	5.01	2.00	1.70	2.10	2.2	3.8
Carbohydrates	59.74	59.40	53.50	57.70	74.6	65.2
Water	12.65	13.20	13.70	11.70	13.1	12.5
Fiber	5.20	10.60	13.15	9.80	4.0	9.2

[a] Source: Jacobsen and Sherwood (4).

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close to the FAO standard for human nutrition, making it a good option for formulation of diverse products for special diets such as vegan-friendly products. Quinoa is also rich in polyunsaturated fatty acids and is comparable in composition to maize oil, making it a good alternative for cardiovascular protection.

Quinoa can be consumed in several ways. Sometimes the plant is grown as a green vegetable, and the leaves are consumed fresh or cooked. However, the seed is the most commonly used form of quinoa. The seed has a bitter outer coat with high levels of saponins that must be removed by washing and milling before consumption to avoid a bitter final product. Saponins are antinutritional glycosides that cannot be digested and can sometimes cause intestinal damage or reduce intestinal absorption of nutrients. However, once removed from the edible portion, these compounds have other industrial applications. Quinoa has two types of saponins. One, extracted from white quinoa, can be used in the production of pharmaceutical steroids, and a more common type, prevalent in other colors of quinoa, can be used in soaps, detergents, beer, shampoos, cosmetics, and synthetic hormones. Because of their toxicity to various organisms, saponins also have potential applications as natural insecticides, antibiotics, and fungicides, in addition to other pharmacological properties. One property of interest is their ability to induce changes in intestinal permeability, which may aid patients in absorbing drugs. Removal of saponins does not harm the protein quality of the grain, which is left intact (5).

Traditionally, quinoa is harvested and transported to a processing facility, where the grain produced by small farmers is collected and immediately sieved to remove impurities. The grains are then washed to remove saponin. This can be done with alkaline water washing or mechanically via abrasion. The mechanical dehulling process involves "pearling" the grain to remove the pericarp as bran. The degree of abrasion needed is determined by the quinoa cultivar. In South America, a system involving flotation is used. The seed is wetted to remove dirt, saponin, and foreign matter. The grain is then dried using forced air (5).

The final dehulled grain is either packed as whole grains, processed further to obtain flour, or flaked to obtain other products. Quinoa is suitable for making flour for baked goods, breakfast cereals, beer, soups, pastas, desserts, and even livestock feed. The seeds can be boiled, added to soups, or even fermented. The cooked seeds have a nutlike flavor and remain separate, fluffy, and chewy. New quinoa-based food products include beverages (quinoa milk), bread, soft drinks, sprouts, protein concentrates, and natural colorants from colored cultivars.

Further processing can yield protein, oil, germ, fiber, and starch. The quality of quinoa starch granules (small, 1–2 µm, and uniform) makes quinoa starch suitable for many applications, and it has been used to develop fat-replacing ingredients and nondairy creamers, among other applications.

Table II. Mineral composition of quinoa[a]

Minerals	Quinoa (mg/g on dry basis)
Phosphorous	387
Potassium	697
Calcium	127
Magnesium	270
Sodium	11.5
Iron	12
Copper	3.7
Manganese	7.5
Zinc	4.8

[a] Source: Ayala (1).

Table III. Functional properties of quinoa flour (%)[a]

Component	Content (standard deviation)
Least gelatin concentration	16.0% w/v
Water absorption capacity	147.00 (0.05)
Oil absorption capacity	46.00 (0.02)
Emulsion capacity	104.00 (0.01)
Emulsion stability	45.00 (0.06)
Foaming capacity	9.00 (0.04)

[a] Source: Ogungbenle (7).

One of the great future applications for this product is as a gluten-free alternative. Recent studies suggest that, in the United States, more than 2 million people are afflicted with celiac disease, commonly known as gluten intolerance or wheat allergy. However, this number may be a gross underestimation of the actual number of cases. Celiac disease is difficult to diagnose since symptoms are general and vary from mild weakness, bone pain, and chronic diarrhea to abdominal bloating and progressive weight loss. Thus, there may be many more "silent" cases. People with celiac disease are not the only ones who should avoid gluten because it has been found that people with autism and disorders in the autistic spectrum may also be sensitive to gluten as well as casein. Currently, the only effective treatment is strict adherence to a diet completely devoid of gluten throughout life. Avoidance of the offending proteins results in mucosal recovery. However, following a gluten-free diet may be extremely challenging because gluten may be present in thickening and binding ingredients in many products that consumers may not normally think about, such as soups, meat products, breakfast cereals and cereal bars, sauces, pie fillings, desserts, and candies. According to data presented by David Browne, Director of Content Services SPINS, a San Francisco-based information firm, at the FDA public hearing on gluten-free labeling held August 19, 2005, in Washington, DC (3):

> Based on total research of all items identified as gluten-free by SPINS, in the United States there are now more than 2,000 products with gluten-free label claims with over $600 million USD in sales. Year over year, sales have increased $77.8 million USD for gluten-free products representing a growth rate of 14.6% in the United States alone. The share of total category sales for gluten-free products is increasing incrementally in nearly all key categories. Sales of gluten-free products are outpacing growth of the categories as a whole in nearly all key segments. Consumers historically have gone to natural health food stores for gluten-free food product options; however sales in conventional supermarkets now exceed those in natural stores by nearly 2 to 1.

Quinoa can be considered an alternative for healthy food production for special dietary use (diabetes and celiac disease) since it is not only considered to be free of gluten but also has a positive effect on satiety. The use of quinoa is of great nutritional interest because of its peculiar composition and the minor components that give it unique functional potential (2). Quinoa flour has functional properties (Table III) that can be used to replace other products as a food extender for binder formulation of viscous and colloidal foods as well as low-acid and acid beverages (7).

Although quinoa, the grain of the Incas, is a relative newcomer on the international market, it shows great potential for future specialty markets. Its nutritional properties, delicate nutty flavor, and versatile nature make it a perfect ingredient for novel sweet and savory formulations. In addition, processed quinoa by-products offer various functional properties that are attractive to formulators of foods and beverages. Although market growth is still dependent on increased production and productivity that will increase availability, this ancient grain has amazing potential to solve food security issues in the Andean communities and increase viable production opportunities for these communities while supplying the world with good, wholesome ingredients from Latin America.

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