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RESEARCH ARTICLE

Quinoa (*Chenopodium quinoa Willd*.): A Nutritional Healthy Grain

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Abstract

Quinoa (Chenopodium quinoa Willd.), which is considered a pseudo-cereal or pseudo-grain, it is highly nutritious due to its outstanding protein quality and wide range of minerals and vitamins. It has been recognized as a complete food due to its protein quality. It has remarkable nutritional properties; not only from its protein content (15%) but also from its great amino acid balance. The quinoa grain protein is rich in amino acids like lysine and methionine that are deficient in cereal proteins. The grain is used to make flour, soup, breakfast, cereal and alcohol, while the flour is utilized in making biscuits, bread and processed food. Quinoa starch having small grains and high viscosity can be exploited for various industrial applications. It is also been found to contain minor compounds like phytosterols and flavonoids with possible nutraceutical benefits. Quinoa starch has some functional (technological) properties like solubility, good water-holding capacity, gelation, emulsifying, and foaming that allow diversified uses. Besides, it has been considered an oil crop, with an interesting proportion of omega-6 and notable vitamin-E content. Quinoa starch has physico-chemical properties (such as viscosity, freeze stability) which give it functional properties with novel uses. Quinoa has a high nutritional value and has recently been used as a novel functional food because of all these properties. Quinoa's ability to produce high-protein grains under ecologically extreme conditions makes it important for the diversification of future agricultural systems, especially in high-altitude area of the Himalayas and North Indian Plains. The healthy lifestyle and appropriate nutrition are stressed nowadays. New foodstuffs are still investigated with the aim to improve the diet and conduce to a better health state of the population. Quinoa (pseudo-cereals) is convenient for this purpose for their high nutritious and dietary quality meets the demands of the food industry and consumers.

INTRODUCTION

Quinoa is considered as pseudo-cereals crop, it is a broad leaf plant with starchy dicotyledonous seed and therefore not a cereal. Quinoa is used like the cereal foods; it is also an important ingredient source for the functional food industry. Quinoa grains have an established excellent nutritional food quality and was also called ‘‘the mother grain’’ this seed was the major crop of the pre-Columbian cultures in Latin America. Later, after the arrival of the Spaniards, quinoa cultivation was almost eliminated and only remained in the farmer’s traditions.

Botanically, quinoa belongs to the class Dicotyledoneae, family Chenopodiaceae, genus Chenopodium, and species quinoa. The full name is *Chenopodium quinoa Willd.,* is a very interesting food due to its complete nutritional characteristics. Quinoa is grown in South America, it is also cultivated in the USA (Colorado and California), China, Europe, Canada, and India. It is also cultivated experimentally in Finland and the UK. Increasing amounts are being exported to the developed world like Europe and the USA. In Europe quinoa was introduced in England in the 1970s, and later research projects focused on its production for humans and/or as a fodder crop. Currently quinoa is produced in Bolivia, Peru, and Ecuador and Chile. Almost all quinoa seed (QS) is exported to Europe and the USA.

Figure 1: Photograph of quinoa chenopodium plants with varying fruit colors.

HISTORICAL BACKGROUND

Quinoa is one of the oldest crops in the Andean Region, with approximately 7000 years of cultivation history, great cultures like the Incas and Tiahuanacu had domesticated and conserved this ancient crop (Jacobsen,2003), archaeological findings in Peru and Argentina indicate presence of quinoa seeds around the beginning of the Christian era (Heisser and Nelson, 1974). Quinoa seeds were also found in indigenous graves of Tarapaca, Calama, Tiltel and Quillagua Bollaerd and Latcham, as cited by Cardenas (1944). Quinoa was widely cultivated by pre-Columbian cultures and its grains have been used in the diet of inhabitants of the valleys, and in drier areas (350 mm rain fall) with higher altitudes (above 3500 m) and colder temperatures (average 12ºC) such as the Altiplano. Although quinoa is a fully domesticated species, its seed still contain saponin, removal of toxic saponins is necessary before they can be consumed (Mujica, 1992; Heisser and Nelson, 1974). Spanish conquest of region and an introduction of cereals such as barley and wheat resulted marginalization and replacement of quinoa crop (Mujica, 1992; Jacobsen and Stolen, 1993). It went unnoticed among the urban population of the region for mainly economic and social reasons, still the crop never lost among the Andean people. It was also noted that during the 80's, European and the United States market were opened for food products. The expansion of these food consumer markets in the search for new foods linked to ancient cultures helped to transform quinoa from a subsistence crop to a product of export potential (Risi, 1997).

POTENTIAL CONTRIBUTION OF QUINOA TO FOOD SECURITY AND SOVEREIGNTY

Availability, access, consumption and biological utilization are the four pillars of food security. In these context; aspects like exceptional nutritional quality, genetic variability, adaptability to adverse climate and soil conditions, and low production cost constitutes quinoa as a strategic crop with potential contributor to food security and sovereignty. Quinoa is a grain with intrinsic outstanding characteristics. Quinoa adapts to desert, hot and dry climates. This crop can grow with relative humidity from 40% to 88%, and survive with temperatures from -4°C to 38°C. It is resistant to low soil moisture, and can produce acceptable yields even with precipitations from 100 to 200 mm. Due to its ability to adapt to adverse climate and soil conditions where other crops are unable to grow, harvest can be obtained at altitudes from sea level to 4000 m (high Andean plateau, 'salares', 'Andean plateau', inter-Andean valleys, 'yungas', sea level). The cultivation of quinoa provides an alternative for countries with limited food production. Quinoa has potential agronomic importance because it can adapt to produce high yields under adverse conditions and contribute to food security in different regions worldwide (Wilson, 1985).

Quinoa is a complete food with high-nutritional value due mainly to its high content of good quality protein. Besides protein content, many studies have been made of their lipids, starch, minerals and saponins it also contains minerals and vitamins like vitamin B, vitamin C and vitamin E. In 1996, quinoa was catalogued by FAO as one of the most promising crops for the humanity, not only for its great properties and its multiple uses, and it is also considered an option to solve human nutrition problems (FAO, 2011).

Bolivia and Peru are the biggest exporters of quinoa with 88% of the worldwide production, followed by the United States of America with 6% (Brenes, et al., 2001). In Argentina production is usually used for domestic consumption as seed or flour.

PHYSICAL PROPERTIES OF QUINOA

The physical, gravimetric, frictional and aerodynamic properties of seeds are useful for designing different postharvest processes like cleaning, classification, transport, aeration, drying and storage. (Vilche, et al., 2003); determined these properties of quinoa seed samples having moisture contents varying from 4.6 % to 25.8 % (dry basis). At an average moisture content of 15% length of quinoa seed varied from 1.7 to 2 mm in 72 5% grains while 27.4 % seeds were of more than 2 mm size given in Table 1. Other properties are tabulated as below.

Table 1: Physical Properties of Quinoa Seeds.

Property		**Moisture 4.6% d.b.**	**Moisture 25 % d.b.**
Gravimetric	1000 Seed Mass	2.53 g	3.11 g
	True Density	928 kg m^{-3}	1188 kg m^{-3}
	Bulk Density	747 kg m^{-3}	667 kg m^{-3}
	Bed Porosity	0.19	0.44
Frictional	Angle of repose static	18^{0}	25^{0}
	coefficient of friction	0.14	0.27
Aerodynamic	Terminal Velocity	0.6 ms^{-1}	1.02 ms^{-1}

Source: Vilche et al., (2003)

CHEMICAL AND NUTRITIONAL PROPERTIES OF QUINOA

Table 2: Chemical composition of quinoa seeds

Comparison of other cereals				
Energy value	**Quinoa**	**Wheat**	**Rice**	**Maize**
Kcal/100g	350.00	309.00	353.00	338.00
Protein/100g	13.81	11.50	7.40	9.20
Fat/100g	5.01	2.00	2.20	3.80
Carbohydrates/100g	59.74	59.40	74.60	65.20
Calcium mg/100g	66.60	43.70	23.00	15.00
Phosphorus mg/100g	408.30	406.00	325.00	256.20
Magnesium mg/100g	204.20	147.00	157.20	120.00
Potassium mg/100g	1040.0	502.00	150.00	330.00
Iron mg/100g	10.90	3.30	2.60	-
Manganese mg/100g	2.47	3.40	1.10	0.48
Zinc mg/100g	7.47	4.10	-	2.50

The extensive literature is available on quinoa covering aspects like proximate composition of reserves, chemical characterization of proteins, fatty acid composition of the oils, mineral content and functional and nutritional values. Proximate composition of four different quinoa varieties cultivated in Andean region viz. Blanca de Juli, Kcancolla, La Molina 89 and Sajama of was determined by Valencia (2011) results of their analysis is presented in Table:3.

Table 3: Proximate composition of four quinoa varieties (% dry basis).

Component	Blanca de Juli	Kcancolla	La Molina 89	Sajama
Moisture	11.39	10.78	12.03	12.62
Ash	3.38	3.52	5.46	3.04
Protein	13.96	15.17	15.47	14.53
Crude fat	5.51	5.77	6.85	4.69
Crude fiber	2.00	3.07	3.38	1.92
Carbohydrates	75.15	72.47	68.84	75.82

All data are the means of 2 replicates. All contents g.100 g^{-1} dry weight except moisture g.100 g^{-1} fresh weight Source: Repo-Carrasco-Valencia; Serna (2011).

The proximate composition of instant flour produced from quinoa by extrusion cooking has shown the composition as: moisture 4.8%, protein 12.2%, lipids 5.6%, ash 2.3%, total carbohydrate 74.9%, and fibre 4.1%. (Ascheri, et al. 2002).

Quinoa flour is low in gluten due the low contents of prolamines and glutamines. It is usually used to enhance baking flours in the preparation of biscuits, noodles, and pastries, and for the preparation of baked foods to maintain the moisture and give an agreeable flavour (Vilche, et al. 2003). Nutrient content of quinoa and other staple foods is compared in Table 4.

Table 4: Nutritional composition of quinoa compared with other staple foods (%)

Components (%)	Quinoa	Meat	Eggs	Cheese	Cow Milk	Human Milk
Proteins	13.00	30.00	14.00	18.00	3.50	1.80
Fats	6.10	50.00	3.20	-	3.50	3.50
Carbohydrates	71.00	-	-	-	-	-
Sugar	-	-	-	-	4.70	7.50
Iron	5.20	2.20	3.20	-	2.50	-
Calories per 100 g	350.00	431.00	200.00	24.00	60.00	80.00

Sourse: Agrifood Report, 2009, MDRT-BOLIVIA

Besides nutritive components quinoa seed pericarp contains saponins, which are toxic and bitter tasting constituents, making it necessary to eliminate before eating or processing for the manufacture of food products. Biopolymers are also found in specific parts of the grains, starch occupy the cells of the perisperm, while lipid bodies, protein bodies with globoid crystals of phytin, and proplastids with deposits of phytoferritin are the storage components of the endosperm and embryo tissues, Valencia-Chamorro (2003).

PROTEINS CONTENTS IN QUINOA

The protein quantity and quality of quinoa are generally superior to those of cereal grains, while offering gluten-free property and high digestibility. Quinoa has a higher total protein content (12.9% to 16.5%) than barley (10.8% to 11.0%), oat (11.6%), rice (7.5% to 9.1%), and maize (10.2% to 13.4%), and a total protein content equal to that of wheat (14.3% to 15.4%) (Comai, et al., 2007; Abugoch James 2009, Peiretti, et al., 2013). The storage proteins of quinoa consist mostly of globulin and albumin, with little to no presence of prolamins, the major storage proteins in many cereal crops. Prolamins, such as gliadin from wheat, secalin from rye, and hordein from barley (collectively referred to as "glutens"), induce autoimmune responses in celiac patients (Zevallos, et al., 2012; Biesiekierski, et al., 2013). A recent *in vitro* study of 15 cultivars of quinoa demonstrated that only 2 cultivars showed any detectable levels of celiac-toxic prolamin epitopes (Zevallos, et al., 2012), while immune responses were not replicated by whole food consumption *in vivo*. These results suggest that quinoa is a safe gluten-free substitute for cereal grains (Zevallos, et al., 2014). Among quinoa total protein, 37% is constituted by chenopodin, a globulin 11S-type protein (Repo-Carrasco, et al., 2003) that has become a reference source of leucine, isoleucine, and phenylalanine and tyrosine by the FAO (Abugoch James, 2009).

The mean protein content reported in the literature for quinoa seed is 16.3% on dry basis (db). Protein content of quinoa seeds is higher than that of barley (11% db), rice (7.5% db), or corn (13.4% db), and is comparable to that of wheat (15.4% db) .Quinoa seed contain relatively less proteins when compared to legume seeds (Table 5). The nutritional value of quinoa protein is comparable to that of milk protein (Koziol, 1992; Ranhotra et al., 1993). The protein efficiency ratio (PER) in raw debittered quinoa is 78-93% that of casein. These figures increase when quinoa is cooked, and become 102-105% those of casein (Valencia-Chamorro, 2003).

Table 5: Chemical composition of quinoa and some cereals and legumes (g/100 g dry wt) (Valencia-Chamorro 2003)

Components	Quinoa	Barley	Maize	Rice	Wheat	Bean	Lupine	Soya
Protein	16.5	10.8	10.22	7.6	14.3	28.0	39.1	36.1
Fat	6.3	1.9	4.7	2.2	2.3	1.1	7.0	18.9
Fibre	3.8	4.4	2.3	6.4	2.8	5.0	14.6	5.6
Ash	3.8	2.2	11.7	3.4	2.2	4.7	4.0	5.3
Carbohydrates	69.0	80.7	81.1	80.4	78.4	61.2	35.3	34.1
kcal/100 g[a]	399	383	408	372	392	367	361	451

Kcal/100 g: 4× (% protein + carbohydrates) + 9× (% fat); [b]Kent (1963), Koziol (1992)

Lysine is a limiting amino acid in most cereal grains. Amino acid composition of quinoa has been studied by Koziol (1992), essential amino acid balance in quinoa seed protein is excellent because of its higher lysine (5.1-6.4%) and methionine (0.4-1%) contents than cereals and legume proteins. Quinoa proteins (QP) have higher histidine content than maize, rice and wheat proteins. (Table 6).

Methionine plus cystine content of quinoa is also adequate for children (2-12 years old) and adults. According to the FAO/WHO suggested requirements for 10 year old children, quinoa protein has adequate levels of aromatic amino acids (phenylalanine and tyrosine) and similarly in histidine, isoleucine, threonine, phenylalanine, tyrosine, and valine contents. By comparison, lysine and leucine in QPs are limiting amino acids for 2-5 year old infants or children, while all the essential amino acids of this protein are sufficient according to FAO/WHO (Table 6).

Table 6: Essential amino acids in quinoa and other foods (g/100 g protein) (Koziol 1992)

Amino Acids	**Quinoa**	**Maize**	**Rice**	**Wheat**	**Bean**	**Milk**	**FAO[a]**
Histidine	3.2	2.6	2.1	2.0	3.1	2.7	2.6
Isoleucine	4.9	4.0	4.1	4.2	4.5	10.0	4.6
Leucine	6.6	12.5	8.2	6.8	8.1	6.5	9.3
Lysine	6.0	2.9	3.8	2.6	7.0	7.9	6.6
Methionine[b]	5.3	4.0	3.6	3.7	1.2	2.5	4.2
Phenylalanine[c]	6.9	8.6	10.5	8.2	5.4	1.4	7.2
Threonine	3.7	3.8	3.8	2.8	3.9	4.7	4.3
Tryptophan	0.9	0.7	1.1	1.2	1.1	1.4	1.7
Valline	4.5	5.0	6.1	4.4	5.0	7.0	5.5

[a]as reported by Koziol (1992); [b]methionine + cystine; [c] Phenylalanine + tyrosine; FAO

CARBOHYDRATES CONTENTS IN QUINOA

Carbohydrates are the major portions of quinoa seed dry matters; it comprises starch and dietary fibers as major components. Carbohydrates content in quinoa seeds vary from 67% to 74% of the dry matter; out of it starch makes up about 55-65%. In quinoa seeds primarily starch compound is located in perisperm as simple units or as spherical aggregates having very small grain size, less than 3 µm (Wolf et al., 1950; Atwell et al., 1983). When compared for its amylose content, quinoa starch contain 11% amylose which is less than other cereals like rice (17%), wheat (22%), or barley (26%).

According to Lamothe, et al., (2015), quinoa contains 10% total dietary fiber. Fiber is the carbohydrate fraction which is resistant to enzymatic digestion and absorption in the small intestine, and which usually undergoes full or partial fermentation in the large intestine. Dietary fiber is considered essential for optimal digestive health, and also imparts various functional benefits (Brownawell, et al., 2012).

Gelatinization temperature of quinoa starch is relatively low, 57-64°C (Atwell, et al., 1983). Quinoa starch exhibits higher viscosity than wheat starch, but it is not as high as corn starch. Like *waxy* corn starch quinoa starch has superior freeze-thaw stability to normal corn starch (Ahamed, et al., 1996). Other carbohydrates found are pentosans (2.9-3.6%), disaccharides (2.3%), crude fiber (2.5-3.9%), and monosaccharides (2%) (Valencia-Chamorro, 2003).

FAT CONTENTS IN QUINOA

Quinoa contains 2% to 9 % fat (Cardoza and Tapia, 1979), average oil content is around 6% USDA (2005) it can be considered as a pseudo-oil crop. These percentages are roughly similar to fat content of corn, but it is much less than soybean (20-25% oil). Quinoa, Corn and Soya oils exhibit similar fatty acid compositions (Koziol, 1991). As with soybean and most cereals, linoleic acid is the predominate fatty acid, similarly quinoa is a rich source of essential fatty acids like linolenic (18:2n-6: 52%) and linolenic (18:3n-6: 40%) (Valencia-Chamorro, 2003). The overall fatty acid composition of the whole quinoa seeds was similar to other cereal grains, with linoleic, oleic, and palmitic acids as the major acids present (Przybylski *et al*., 1994). Fatty acid composition in different grain is given in the table 7.

Table 7: Oil quality of quinoa and common cereal grains **(**values expressed as percent of total oil)

Fatty Acids	Quinoa	Wheat	Barley	Rice	Corn
Predominate acid	18:2	18:2	18:2	18:1	18:2
Saturated	13%	23%	26%	32%	16%
Monounsaturated	34%	22%	16%	37%	31%
Polyunsaturated	53%	55%	58%	31%	53%

Source: USDA, 2005

Lipids isolated from quinoa seed and seed fractions were characterized for lipid classes and fatty acid composition by Przybylski, when analyzed it was found that quinoa seed lipids contained the largest amount of neutral lipids among other seed fractions. Higher amounts of FFA were detected in the whole quinoa seed and hull 18.9% and 15.4% of total lipids respectively. 50 % of neutral lipids were triglycerides; diglycerides contributed 20% of the neutral lipid fractions and were present in the whole seed. Among the Phospholipids lysophosphatidyl ethanolamine was 45% and phosphatidyl choline was 12% of whole seed phospholipids. (Przybylski, *et al*., 1994).

MINERALS IN QUINOA

Quinoa is a good source of minerals; When compared with common staple foods like barley, oats, rice, corn, or wheat quinoa seeds contain high quality proteins, higher levels of energy, calcium, phosphorus, iron, fiber, and B-vitamins (Dini, *et al*., 2005). Comparative data of mineral content of quinoa seeds is presented in Table 8 (Koziol,1992).

Larger amounts of calcium (874 mg kg^{-1}), phosphorus (5.3 g kg^{-1}), magnesium (2.6 mg/100 g), iron (81 mg kg^{-1}), zinc (36 mgkg^{-1}), potassium (12 g kg^{-1}), and copper (10 mg kg^{-1}) than most of the common cereal grains were also reported by Ruales and Nair (1993). Polishing and washing of seeds reduce mineral content to some extent, reduction of 12-15% in iron, zinc, and potassium, 27% in copper and 3% in magnesium were reported.

Table 8: Mineral composition (mg kg^{-1} dry wt) in quinoa and some cereals (Koziol 1992)

Minerals	Quinoa	Wheat	Rice	Barley
Calcium	1487	503	69	430
Magnesium	2496	1694	735	1291
Potassium	9267	5783	1183	5028
Phosphorus	3837	4677	1378	3873
Irone	132	38	7	32
Copper	51	7	2	3
Zinc	44	47	6	35

VITAMINS CONTENTS IN QUINOA

Range of fat soluble vitamins like vitamin A, vitamin E and water soluble vitamins as thiamin, riboflavin, niacin and ascorbic acid was quantified by Ruales et al., (1992) and it is expressed in Table 9. Quinoa is considered as a good source of vitamins like thiamin (0.4 mg/100 g), folic acid (78.1 mg/100 g), and vitamin C (16.4 mg/100 g). The process of saponins removal from the seeds reduces the vitamin and mineral contents to some extent. The loss is significant ($P < 0.001$) in the case of potassium and considerable also in the case of iron and manganese ($P < 0.01$) (Ruales and Nair,1993).

Table 9: Vitamin content of quinoa grain (mg/100g dry matter)

S.No.	**Vitamins**	**Range**
1.	Vitamin A(carotenes)	0.12-0.53
2.	Vitamin E	4.60-5.90
3.	Thiamine	0.05-0.60
4.	Riboflavin	0.20-0.46
5.	Niacin	0.16-1.60
6.	Ascorbic Acid	0.00-8.50

Ruales et al., 1992, cited by Ayala et al., 2004

FUNCTIONAL PROPERTIES OF QUINOA

Antioxidant Property: Antioxidant potential of seeds and sprouts of selected pseudo cereals amaranth and quinoa was done by the methods like Ferric Reducing Ability of Plasma (FRAP) assay, radical scavenging activity (ABTS) and radical scavenging activity (DPPH). Total polyphenols and anthocyanins were also determined. In this study it was focused on the nutritional value of sprout as a good source of antioxidants present in the quinoa. Total Antioxidant capacity (TAC) values for quinoa seeds are as FRAP 4.97 in mmol $Fe2 + kg^{-1}$ DW, ABTS 27.19 in mmol trolox kg^{-1} DW, DPPH 38.84 in mmol trolox kg^{-1} DW, Total Anthocyanins 120.4 – ANT mg CGE 100 g^{-1} DW, total polyphenols -3.75 TP mg GAE g^{-1} DW. (Paweł, et al., 2009).

Values for sprouts were also measured and found significantly higher indicating quinoa seeds and sprouts show relatively high antioxidant activity. Quinoa seems to be the better substitute for traditional cereals than amaranth. The results investigation have shown that sprouts have a significantly higher antioxidant activity than seeds, which may be a result of difference in the content of polyphenols, anthocyanins and other compounds and The sprouts of amaranth and quinoa are ‘‘new” vegetables, which can be used in the nutrition of vegans and vegetarians and as a common diet too (Paweł, et al., 2009).

Antimicrobial Property: Six different varieties of quinoa seeds (Ancovinto, Cancosa, Cahuil, Faro, Regalona and Villarrica) from three distinct geographical zones of Chile (two from each zone) were examined for their antimicrobial properties. Dry ethanol extract of seed was dissolved in water (30.0 mg of extract/mL of distilled

water) and used to test inhibition zone against two microorganisms, *Staphylococcus aureus* (ATCC 25923) (Gram-positive) and *Escherichia coli* (ATCC 25922) (Gram-negative), using the disk diffusion assay technique. Extracts of all quinoa samples showed antimicrobial activity in the range of 8.3-14.8 mm inhibition zone for *E. coli* and 8.5-15.0 mm inhibition zone for *S. aureus*. Cancosa seeds had the highest antimicrobial action. (Miranda, et al., 2014).
Pearson's coefficient correlations between Total Phenolic Content (TPC), Total Flavonoid Content (TFC), Total Saponin Content (TSC) and inhibition zone of all six varieties was done. The relationship between TFC and antimicrobial activities against *E. coli* and *S. aureus* was found moderate ($r = 0.60$ and 0.43, respectively) but positively significant ($p < 0.05$) for *E. coli*, indicating that flavonoid compounds might contribute to the antimicrobial activities against *E. coli* and *S. aureus.* (Miranda, et al., 2014).

USE OF QUINOA IN FOOD

Quinoa is a highly nutritious food; the nutritional value of this crop has been compared to that of dried whole milk by the Food and Agriculture Organization (FAO) of the United Nations. Quinoa is used to make flour, soup, breakfast cereal, and alcohol. Most quinoa sold in the United States has been sold as whole grain that is cooked separately as rice or in combination dishes such as pilaf. Quinoa flour works well as a starch extender when combined with wheat flour or grain, or corn meal, in making biscuits, bread, and processed food.

Kancolla is a sweet variety of quinoa, used as a food, principally in the same way as wheat and rice. Bitter varieties of quinoa need de-hulling prior to food use so as to remove bitter principles and anti-nutritional factors. Boiled seeds of quinoa can be eaten as a rice replacement, or used to thicken soup or as porridge or as a hot breakfast cereal. Green turned sprouted quinoa seeds can be added to salads. Like popcorns quinoa seed pops can also be made. Seeds can also be ground and used as flour to mix in bread flour at the level of 10 -13 %, noodles and pasta at the level of 30-40% and biscuits up to 60 %. (Valencia-Chamorro, 2003).

Quinoa seeds have been identified for making soups and desserts, pastries, drinks and dry snacks. Following is a brief description of traditional preparations that are made from quinoa in South America.

1. **Quinoa soup:** Not very thick cooked quinoa with meat or dried meat, tubers and vegetables.
2. **Lawa**: A semi thick "Mazamorra" (porridge like preparation) with raw flour, water with lime and animal fat.
3. **P'esque:** Quinoa grain cooked with water, without salt, served with either milk or grated cheese according to the availability of these additions.
4. **Kispiña:** Steamed buns of different shapes and sizes.
5. **Tacti o tactacho:** Fried buns, a kind of doughnut made with flour and llama fat.
6. **Mucuna:** Steam cooked balls made from quinoa flour with seasoning in the centre similar to tamales or humitas.
7. **Phiri:** Roasted and slightly dampened rough quinoa flour.
8. **Phisara:** Lightly roasted and cooked quinoa grain.
9. **Q'usa:** Quinoa chicha, a macerated cold drink.
10. **El Ullphu, Ullphi:** Cold drink prepared with roasted quinoa flour diluted in water with sugar added to taste.
11. **Kaswira de quinua:** Flattened bread fried in oil, made with katahui (lime) and white quinoa.
12. **Kaswira de ajara:** Flattened bread fried in oil, made with katahui (lime) and black quinoa or Ajara
13. **K'api kispiña**: Steamed bun, made with quinoa ground in a K `ona and cooked in a clay pot, common in the feast of all Saints.
14. **Turucha quispiña o Polonca:** Large steamed breads, made with katahui and quinoa lightly ground (chama) in a K `ona ,and cooked in a clay pot.
15. **Mululsito quispiña:** Steamed bread, made with katahui and quinoa flour, cooked in a clay pot, smaller than Kispiñas.
16. **Quichi quispiña:** Steamed and fried bread, made with katahui and quinoa flour, fried in a pan.

17. **Juchacha:** Andean soup based on ground quinoa and katahui, accompanied by roasted barley flour.
18. **Chiwa:** Young leaves of quinoa called Lliccha in Quechua and Chiwa in Aymara, are used as a vegetable in the preparation of soups and salads. The leaves are rich in vitamins and minerals, especially calcium, phosphorus and iron.

INDUSTRIAL USES OF QUINOA

Quinoa can be combined with legumes such as broad beans, kidney beans and tarwi to improve dietary quality, especially of school breakfasts for infants and children. There are also processed and semi-processed foods on the market but these are generally more expensive and unaffordable for most of the population.

Such processed or semi processed products include "cereals" which are ready-to-eat and generally consumed at breakfast. These include puffed, granular, flaked, shredded and hot cereals to which a hot liquid is added before consumption. There are also reconstituted baby foods.

Virtually all flour industry products can be made from quinoa whole grains and flour. Trials in the Andean region and elsewhere have indicated the feasibility of adding 10, 15, 20 and as much as 40% of quinoa flour to bread, up to 40% in noodles, up to 60% in sponge cake and up to 70% in biscuits. The main advantage of using quinoa as a food supplement in the flour industry is that it helps meet growing international demand for gluten-free products.
There is currently a need for high quality foods with high protein content. Protein is concentrated in the embryo of the quinoa seed containing up to 45% protein. The embryo can be separated from the rest of the seed and in concentrated form can then be applied directly to children's food, for example helping undernourished children to make a rapid nutritional recovery, or it can be added to a variety of dishes for adults needing nutritional assistance such as pregnant women.

ANIMAL FEED

The whole plant is used as green forage. Harvest residue is also used to feed cattle, sheep, pigs, horses and poultry.

MEDICINAL USE

The high nutritional value, medicinal properties, and gluten free quality of quinoa may benefit several at-risk consumer populations, including children, the elderly, high-performance athletes, lactose intolerant consumers, osteoporosis-prone women, and people with anemia, diabetes, dyslipidemia, obesity, or celiac disease (Bhargava, et al., 2006; Vega-Galvez, et al., 2010). Though the number of animal and human clinical trials on quinoa's therapeutic potential is limited, several studies indicate various benefits associated with quinoa consumption.

Quinoa leaves, stems and grains are used for medicinal purposes: healing wounds, reducing swelling, soothing pain (toothache) and disinfecting the urinary tract. They are also used in bone setting, internal bleeding and as insect repellents.

A study was conducted by Britney et al., (2015) on innovation in health value and functional food development of quinoa. In a 4 clinical research it has been demonstrated that quinoa supplementation exerts significant, positive effects on metabolic, cardiovascular and gastrointestinal health in humans. However, it was found that vast challenges and opportunities remain within the scientific, agricultural and development sectors to optimize quinoa's role in the promotion of global human health and nutrition.

OTHER INDUSTRIAL USES

Quinoa can produce a range of by-products for food, cosmetic, pharmaceutical and other uses as are in the figure 2.

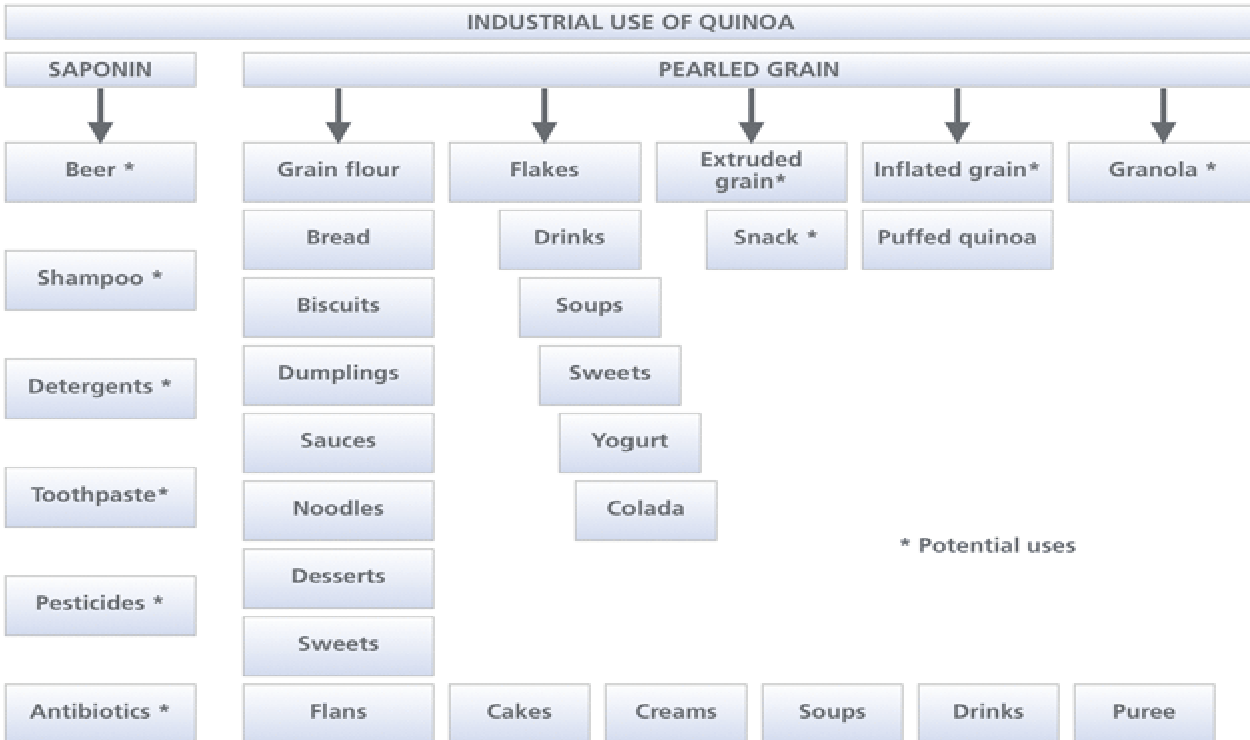

Figure 2: Flow chart of industrial use of quinoa

Quinoa starch has excellent stability in freeze-thaw conditions and in retrogradation. Quinoa starch could provide an interesting alternative to chemically modified starches. The starch has special potential for industrial use because of the small size of the starch grain, for example in aerosol production, pulps, self copy paper, dessert foods, excipients in the plastics industry, talcs and anti off-set powders.

The saponins from bitter quinoa can be used in the pharmaceutical industry which is interested because the saponins can induce changes in intestinal permeability which can be useful for the absorption of specific medicines and in the effects of hypocholesterolemia. Saponin can also be used as an antibiotic and to control fungi, among other pharmacological attributes.

Because saponin has differing toxicity depending on the organism, a study was carried out on its use as a strong natural insecticide with adverse effects on humans or large animals, highlighting its potential for use in integrated pest management programmes. The use of quinoa saponin as a bio-insecticide was successfully demonstrated in Bolivia.

FUTURE ASPECTS OF QUINOA

The nutritional excellence of quinoa has been known since ancient times in the Inca Empire. Nowadays, quinoa has been recognised for its nutritional benefits all over the world, and for its protein, mineral, and vitamin contents. The importance that quinoa could play in the nutritional behaviour has been emphasized, not only in the developing countries but also in the developed world. In the Andean countries, quinoa crops could play an important role in their economies in the future, giving a new export market, as well as in national subsistence. Moreover, quinoa could be a strategic crop used to complement the diet in rural/marginal regions where energy protein malnutrition affects most of the population of the developing countries. Quinoa, as the “mother grain”, represents an exotic and healthy rediscovery in the developed world (Valencia-Chamorro 2003). Germplasm collection should continue in the countries of the Andean region. Agronomic research, including the plant density, potential cultivation, phenology, morphology, physiological maturity, yield, and weeds control, should be performed. Further research is needed of the adaptability of different cultivars to “new homes of quinoa“ in the USA and Europe. The use of mechanisd agriculture may facilitate mechanical harvesting of the grain, reducing at the same time the postharvest losses (Valencia-Chamorro, 2003). The improvement of the methods for saponins removal without any significant modification of the nutritive value is encouraged. The selection of sweet genotypes with very low saponin content in the seeds, large grain, and high yield are the main breeding goals. Sweet genotypes could be selected early in the plant development in order to speed up the selection process. Further research is needed to find markers for the indirect selection of sweet genotypes. The need for intensive cultivation of quinoa should be emphasized, as it could meet the quality and quantity requirements by the food industry. Besides, aggressive promoting campaigns should be carried out to encourage greater consumption of the grain. Finally, quinoa is promoted as an extremely healthy food- a supergrain of the future (gluten free). It is a food of the twenty first century (Valencia-Chamorro, 2003).

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