Quinoa – a Review

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Abstract

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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. Pseudocereals (amaranth, buckwheat, and quinoa) are convenient for this purpose. Their high nutritious and dietary quality meets the demands of the food industry and consumers. Our collective dealt with quinoa, a commodity of Andean, because quinoa is a good source of essential amino acids such as lysine and methionine. Quinoa contains relatively high quantities of vitamins (thiamin, vitamin C) and minerals.

Keywords: quinoa; essential amino acids; nutrition quality

Quinoa (*Chenopodium quinoa* Willd.) is a pseudocereal native to the Andean regions of South America (Matiacevich *et al.* 2006).

Quinoa is one of the oldest crops of the American continent. Archeological findings in northern Chile have shown that quinoa was used prior to 3000 bc. in Ayacucho, Peru, evidence has been obtained that quinoa was cultivated there before 5000 bc. The quinoa plant was widely cultivated in the whole Andrean region, in Columbia, Equador, Peru, Bolivia, and Chile, before the Spanish conquest. However, the habits and traditional foods of natives were replaced with foreign crops such as wheat and barley. Therefore, quinoa was cultivated either in small plantations in rural areas for domestic consumption or as borders for other crops such as potatoes or maize. For this reason, it was classified as food for poor people (Valencia-Chamorro 2003).

Bolivia and Peru are the greatest exporters with 88% of the worldwide production (Vilche *et al.* 2003).

Quinoa belongs to the *Chenopodiaceae* family, genus *Chenopodium*. Its botanical name is *Chenopodium quinoa* Willd. (Valencia-Chamorro 2003).

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. For practical reasons, quinoa, like maize, has been classified as a race. Quinoa collected in Ecuador, Peru, and Bolivia has been classified into 17 races, however, more races may exist. Two types of inflorescence have been described (Valencia-Chamorro 2003):

(1) Glomerulates – small groups of flowers (glomeruli) originating from tertiary axes.
(2) Amaranthiformes have glomeruli originating mainly from secondary axes.

Quinoa grows in the altitudes from the sea level to the Andean highlands. Thus, one of the most useful classifications is that describing five ecotypes: sea-level, valley, subtropical, salar, and antiplanic (Table 1) (Valencia-Chamorro 2003).

The cultivation of quinoa is related to the crop rotation seen in potatoes. This is a usual practice

Table 1. General categories of quinoa (Valencia-Chamorro 2003)

Ecotypes	Location	Growth altitude (m)	Varieties	Characteristics
Sea-level	South of Chile	< 500	Chilean varieties	unbranched, long day plants, yellow, bitter seeds
Valley	Andean valley	2000–4000	Blanca de Junín, Rosada de Juní, Amarilla de Matangani, Dulce de Quitopamba, Dulce de Lazo	big plants, branched, short growth period
Subtropical	Subtropical area of Bolivia (Yungas)	2500–3000		plants with intense green color that tums orange as they mature, small seeds, white or orange
Salar	Bolivian Salares	3700–3800	Real	plants adapted to salty and alkalinic soils, bitter seeds, high saponin content
Antiplanic	Area around Lake Titicaca	3500–4000	Cheweca, Kancolla, Blanca de Julí	short plants with straight stems, short growth period, resistant to frost

that improves quinoa yield and preserves soil fertility. Moreover, the biological cycle of several pathogenic microorganisms is broken down (Valencia-Chamorro 2003).

Quinoa tolerates a wide range of acidic conditions of the soil, from pH 6.0 to 8.5. The plant is not affected from around −1°C. However, it tolerates high temperatures up to 35°C. Quinoa is frostresistant if the frost occurs before flowering, after that significant damage may occur. The flowers are sensitive to frost. Quinoa is drought-resistant. It is able to develop even in regions where the annual rainfall is in the range of 200–400 mm (Valencia-Chamorro 2003).

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 mechanised practices become difficult. Quinoa is planted in rows (row spacing range between 40–80 cm) where mechanised agriculture practices are used (Valencia-Chamorro 2003).

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 Ecuador. A density of 1.2 g/m^2 has been recommended in Puno for mechanical drilling (Valencia-Chamorro 2003).

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 by reached within 70–90 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 (Valencia-Chamorro 2003).

Pests and diseases

The major pests of the chenopod crop in the Himalayas are aphids (*Aphis* sp.) which attack the inflorescence, the inflorescence caterpillar (*Pachyzanda*), defoliating insects (*Epicanta*), and sucking insects (*Myzus persicae*). Several fungal diseases also attack chenopods in Himalayas – downy mildew (*Peronospora* sp.), damping off (*Sclerotium* sp.), leaf blight (*Cercospora* sp.), etc. (Partap & Galwey 1995).

The most important fungus disease is downy mildew (*Peronospora farinosa*), which requires high humidity and temperature as the ideal conditions to grow. The main symptom is chlorotic lesions on the upper surfaces of the leaves, with a white or purple mycelium on the lower surfaces (Valencia-Chamorro 2003).

The disease brown stalk rot is caused by *Phoma exigua* var. *fovaeta*. Low temperatures, high humidity, and wounds in the plant, such as those produced by hail, favour the growth of the pathogen. Dark brown lesions with a vitreous edge (5–15 cm) on the stem and inflorescences are the main symptoms (Valencia-Chamorro 2003).

Kcona Kcona (*Scrobipalpula* sp.) is probably the most serious pest of quinoa. When drought periods and high temperatures are present, the insect attacks intensely. The larvae destroy first leaves and inflorescence. Later on, when the plants are mature, the larvae destroy the panicle and grains (Valencia-Chamorro 2003).

Quinoa is not a true cereal grain: it is a pseudocereal, which is dicotyledonous. In contrast, cereals are monocotyledonous (Valencia-Chamorro 2003).

Quinoa, as a plant, grows 1–3 m high. The seeds can germinate very fast, i.e. in a few hours after having been exposed to moisture. The roots can reach the depth of up to 30 cm. The stem is cylindrical, 3.5 cm in diameter, it can be either straight or branched and its colour is variable. Depending on the variety, it changes from white, yellow, or light brown to red. Leaves are shaped like a goose foot. The flowers are incomplete, they do not have petals. Quinoa has both hermafrodite flowers, located at the distal end of a group, and female flowers located at the proximal end. Quinoa inflorescence is full of bunches (racemose), which emerge on the upper part and do not have branches. The arrangement of flowers in the raceme is considered to be the panicle. The lenght of the panicle varies from 15 cm to 70 cm. Flowers can be clustered in different forms – either amaranthiforme or glomerulate (Valencia-Chamorro 2003).

Quinoa is a fruit of the *Chenopodium* family. The fruit of quinoa is an achene (Valencia-Chamorro 2003). The quinoa seeds, which are small, round, and flattened, measure about 1.5 mm in diameter, and about 350 seeds weigh 1 g (Ruales & Nair 1993). 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 enclose the seed. Pericarp adheres to the seed; it contains saponins which transmit the bitter taste characteristic of quinoa. Episperm encloses the cylindrical seed as a thin layer. The embryo can make up to 60% of the seed weight. It forms a ring around the perisperm. The high protein content in quinoa, as compared to cereals, is explained by the high proportion of embryo (Valencia-Chamorro 2003).

Protein

In comparison to most cereals, quinoa seeds have a higher nutritional value (Matiacevich *et al.* 2006).

The protein content of quinoa seeds varies from 8% to 22%, which is higher on average than that in common cereals such as rice, wheat, and barley (Table 2). However, it presents less than 50% of the protein content found in most legumes. In quinoa, most of the protein is located in the embryo (Valencia-Chamorro 2003).

In pseudocereals, such as quinoa, albumins and globulins are the major protein fraction (44–77% of total protein), which is greater than that of prolamins (0.5–7.0%). Quinoa is considered to be a gluten-free grain because it contains very little or no prolamin. Quinoa provides a nutritional, economical, easy-to-prepare, flavourful food source which is of particular relevance for people with gluten intolerance, such as those with celiac disease (Valencia-Chamorro 2003).

Table 2. Chemical composition of quinoa and some cereals and legumes (g/100 g dry wt) (Valencia-Chamorro 2003)

	Quinoa	Barley	Maize	Rice	Wheat	Oat[b]	Rye[b]	Bean	Lupine	Soya
Protein	16.5	10.8	10.22	7.6	14.3	11.6	13.4	28.0	39.1	36.1
Fat	6.3	1.9	4.7	2.2	2.3	5.2	1.8	1.1	7.0	18.9
Fibre	3.8	4.4	2.3	6.4	2.8	10.4	2.6	5.0	14.6	5.6
Ash	3.8	2.2	11.7	3.4	2.2	2.9	2.1	4.7	4.0	5.3
Carbohydrates	69.0	80.7	81.1	80.4	78.4	69.8	80.1	61.2	35.3	34.1
kcal/100 g[a]	399	383	408	372	392	372	390	367	361	451

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

Quinoa has a good balance of the amino acids that make up the protein. It is exceptionally high in lysine (Table 3), an amino acid which is not overly abundant in the vegetable kingdom. It is also a good complement for legumes, which are often low in methionine and cystine (Valencia-Chamorro 2003).

The nutritional evaluation of quinoa protein has been reported in several studies. 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).

In fact, the protein content represents 14–20% (g/100 g dry basis, d.b.), being particularly rich in essential amino acids such as lysine and methionine, thus supplying high-quality protein. They also contain large amounts of carbohydrates, fat, vitamins, and minerals (Matiacevich *et al.* 2006). The protein is of an exceptionally high quality and is particularly rich in histidine and lysine. Preliminary studies on the protein fractionation have shown that the main proteins are albumin, globulin (called Chenopodin), and prolamin in a low percentage. Their proportions vary in different species. The digestibility of quinoa protein was found to be comparable to that of other high quality food proteins (Comai *et al.* 2007).

Quinoa has also a relatively high quantity of vitamins and minerals and quinoa seed lipids appear to be a high quality edible vegetable oil, similar in the fatty-acid composition to soybean oil (Comai *et al.* 2007).

The proximate composition of quinoa ranges from 10% to 18% of protein, from 4.5% to 8.75% of crude fat, from 54.1% to 64.2% of carbohydrates, from 2.4% to 3.65% of ash, and from 2.1% to 4.9% of crude fibre. The amino acid balance is better than that of wheat or maize, because the first limiting amino acid, lysine, is present in relatively higher amounts in quinoa seeds (Vilche *et al.* 2003). The main constituent of Chenopodium and Amaranthus is the small granule sized (< 1 micron) starch (Caussette *et al.* 1997). Starch accounts for 52–60% of the grain weight (Comai *et al.* 2007). The amylase content in quinoa starch is 7.1%. The relative crystallinity of starch granules in quinoa is 35.0% (Tari & Singhal 2002).

Carbohydrates

The major component in quinoa consists of carbohydrates, and varies from 67% to 74% of the dry matter. Starch makes about 52–60%. The starch compound is located in the perisperm of the seeds; starch can be present as simple units or as spherical aggregates. The amylose content is about 11%, which is lower than in cereals, for example rice (17%), wheat (22%), or barley (26%) (Valencia-Chamorro 2003).

The diameter of quinoa starch granules is smaller than those reported for maize (range 1–23 μm) or wheat (2–40 μm) (Valencia-Chamorro 2003).

Small-granule starches exhibit a higher gelatinisation temperature, for quinoa this temperature range

Table 3. Essential amino acids in quinoa and other foods (g/100 g protein) (Koziol 1992)

	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 – Food Agriculture Organization

is 57–64°C. Other carbohydrates are found in small amounts, such as monosaccharides (2 %) and disaccharides (2.3%), crude fiber (2.5–3.9%), and pentosans (2.9–3.6%) (Valencia-Chamorro 2003).

Fat, vitamins and minerals

Quinoa contains from 2% to 10% fat. Quinoa and soya oils exhibit similar fatty acid compositions; thus, quinoa is a rich source of essential fatty acids such as linolenic (18:2n-6: 52%) and linolenic (18:3n-6: 40%) (Valencia-Chamorro2003).

Lipids isolated from quinoa seed and seed fractions have been characterised by lipid classes and fatty acid composition. Quinoa seed lipids contained the largest amount of neutral lipids among all the seed fractions analysed. A very high content of free fatty acids was detected in the whole quinoa seed and hulls, accounting for 18.9% and 15.4% of total lipids, respectively. Triglycerides were the major fraction present and accounted for over 50% of neutral lipids. Diglycerides were present in the whole seed and contributed 20% to the neutral lipid fraction. Of the phospholipids examined, lysophosphatidyl ethanolamine was the most abundant and made up 45% of the total polar lipids. Phosphatidyl choline was the second most represented phospholipid component and contributed 12% of whole seed phospholipids. A considerable variation in phospholipids was evident between different fractions. The overall fatty acid composition of the whole quinoa seeds, however, was similar to that reported for other cereal grains, with linoleic, oleic, and palmitic acids as the major acids present (Przybylski *et al.* 1994).

Quinoa is a good source of minerals. It contains more calcium, magnesium, iron, and zinc than common cereals, and the iron content is particularly high (Table 4). Polishing and washing quinoa seeds reduce the mineral content to some extent, 12–15% in the concentration of iron, zinc, and potassium, and cause 27% loss of copper and 3% loss of magnesium. Quinoa contains more riboflavin (B_2) and α-tocopherol than rice, barley, or wheat (Table 4). Quinoa seeds can be a source of vitamin E (Valencia-Chamorro 2003).

The Food and Agriculture Organization (FAO) observed that quinoa seeds have high quality proteins and higher levels of energy calcium, phosporus, iron, fibre, and B-vitamins than barley, oats, rice, corn, or wheat (Dini *et al.* 2005).

Quinoa is a good source of thiamin (0.4 mg/100 g), folic acid (78.1 mg/100 g), and vitamin C (16.4 mg/100 g). The seeds contain twice as much γ-tocopherol (5.3 mg/100 g) than α-tocopherol (2.6 mg/100 g) and larger amounts of calcium (874 mg/kg), phosphorus (5.3 g/kg), magnesium (2.6 mg/100 g), iron (81 mg/kg), zinc (36 mg/kg), potassium (12 g/kg), and copper (10 mg/kg) than most of the common cereal grains. The amounts of mercury, lead, and cadmium found in these samples are low in relation to the values of the tolerable intake of these elements. All values are expressed on a dry-weight basis with high amounts of oleic acid (24.8%) and linoleic acid (52.3%). The level of linolenic acid was 3.9%. The process of saponins removial 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 & Nair 1993).

The proximate composition, amino acid profile, and mineral content of instant flour produced from quinoa by extrusion cooking have been studied and compared with similar rice and corn flours. Proximate analysis of quinoa flour has showen the folloving composition: moisture 4.8%, protein

Table 4. Mineral composition (mg/kg dry wt) and vitamin concentrations (mg/100 g dry wt) in quinoa and some cereals (Koziol 1992)

Minerals	Quinoa	Wheat	Rice	Barley
Ca	1487	503	69	430
Mg	2496	1694	735	1291
K	9267	5783	1183	5028
P	3837	4677	1378	3873
Fe	132	38	7	32
Cu	51	7	2	3
Zn	44	47	6	35
Vitamins				
Thiamin (B_1)	0.38	0.55	0.47	0.49
Riboflavin (B_2)	0.39	0.16	0.10	0.20
Niacin (B_3)	1.06	5.88	5.98	5.44
Ascorbic acid (C)	4.00	0	0	0
α-Tocopherol	5.37	1.15	0.18	0.35
β-Carotene	0.39	0.02	NR	0.01

NR – not reported

12.2%, lipids 5.6%, ash 2.3%, total carbohydrate 74.9%, and fibre 4.1%. Quinoa flour has a higher protein content than corn or rice flours and has higher contents of certain amino acids such as lysine (710 mg/100 g vs. 141 and 194 mg/100 g in corn and rice flours, respectively) and aspartic acid (1160 vs. 400 and 758 mg/100 g). Quinoa flour is also rich in minerals, particularly K (546 vs. 119 and 99 mg/100 g), Fe (11.77 vs. 0.07 and 4.81 mg/100 g), Mg (160 vs. 21 and 54 mg/100 g), Ca (38.26 vs. 1.04 and 6.51 mg/ 100 g) and P (357 vs. 75 and 33.5 mg/100 g). It has been concluded that instant quinoa flour has high levels of many nutrients and so may find the application in foods, e.g infant foods and dietetics for sufferers from coeliac disease (Ascheri *et al.* 2002).

The effects of dietary polyphenols are of great current interest due to their antioxidative and potential anticarcinogenic activities. In particular, Nishibe and collective found mauritianin which may augment the immune resistance to cancer (Dini *et al.* 2005).

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).

Nutritional disadvantages

Saponins and phytic acid are the main disadvantageous factors in quinoa. Other inhibitors, trypsin inhibitor and tannins, are present in low levels (Valencia-Chamorro 2003).

Trypsin inhibitor in eight varieties of quinoa (range 1.36–5.04 TIU/mg) was lower than in soybean (24.5 TIU/mg). Trypsin inhibitor is a thermolabile compound which is inactivated by heat treatment (Valencia-Chamorro 2003).

Polyphenols (tannins) are present in small amounts (0.53 g/100 g in the whole quinoa seeds) which are further reduced after scrubbing and washing with water (0.23 g/100 g) (Valencia-Chamorro 2003).

Saponins

Saponins are glycoside compounds which occur in two groups. According to the nature of the sapogenin moiety, they are conjugated with hexoses, pentoses, or uronic acids. The sapogenins are steroids (C27) or triterpenoids (C30) (Valencia-Chamorro 2003).

The pericarp of the quinoa seed contains saponins. Saponins are plant glycosides that impart a bitter taste and tend to foam in aqueous solutions. Until recently, saponins have been considered to be highly toxic, nevertheless, those present in foodstuffs are non-toxic and it has been suggested that they may be even beneficial in human diet. The digestibility of quinoa proteins is comparable to that of other high-quality food proteins and they do not exert any negative effect on the nutritive quality of the protein. However, saponins may impart a bitter taste; their separation from quinoa seed is easily accomplished by rinsing the seed in cold alkaline water or mechanical abrasion. Coulter and Lorenz have demonstrated that the protein quality of a saponin-free quinoa show a better growth response than white rice, maize or wheat (Vilche *et al.* 2003).

The amount of saponins present depends on the variety of quinoa. It is higher in bitter-flavour varieties than in sweet, or low-saponins, varieties. Quinoa contains saponins in the amount from 0.1% to 5% (Valencia-Chamorro 2003).

The reduction of plasma cholesterol and bile salt concentrations has been attributed to the presence of certain saponins in the diet. However, some saponins can form insoluble complexes with minerals, such as zinc and iron, which make the minerals unavailable for the absorption in the gut (Valencia-Chamorro 2003).

Phytic acid

Phytic acid (myoinositol 1,2,3,4,5,6-hexakis dihydrogen phosphate) is found in most cereals and legumes at concentrations of 1–3% dry matter. It is also found in some fruits and vegetables (Valencia-Chamorro 2003).

In cereals, phytic acid is located in the germ. In quinoa seeds, phytic acid is located in the external layers as well as in the endosperm. It has been reported that the mean (value) phytic acid concentration, was 1.18 g/100 g in five varieties of quinoa (Valencia-Chamorro 2003).

Oxalate

Oxalate is a toxic substance and an important health risk. A high dietary oxalate intake plays a key role in secondary hyperoxaluria, a major risk factor for calcium oxalate stone formation. A high dietary oxalate intake influences mineral and trace element absorption in humans and may lead to calcium oxalate stone formation due to the ability of oxalate to form insoluble complexes with divalent cations in the gastrointestinal tract. The soluble and total oxalate contents in the species of the *Polygonaceae*, *Amaranthaceae*, and *Chenopodiaceae* families were measured using an HPLC-enzyme-reactor method. *Polygonaceae*, *Amaranthaceae*, and *Chenopodiaceae* are included in most of the foods with excessively high oxalate concentrations. Amaranth is a species of the *Amaranthaceae* family, *Polygonaceae* include buckwheat, rhubarb, and sorrel, whereas beetroot, mangold, spinach, and quinoa are species of the *Chenopodiaceae* family. Obviously, oxalate is accumulated in these plant families in each plant tissue, i.e., in leaves, stems, hypocotyl-root and nuts. The highest oxalate content was found in leaves and stems. Soluble oxalate content ranged from 59 to 131 mg/100 g in roots and nuts, and from 258 to 1029 mg/100 g in leaves and stems. Total oxalate content ranged from 143 to 232 mg/100 g in roots and nuts, and from 874 to 1959 mg/100 g in leaves and stems (Siener *et al.* 2006).

USES

Quinoa can be eaten as a rice replacement, as a hot breakfast cereal, or can be boiled in water to make infant cereal food. The seeds can even be popped like popcorn. Seeds can be ground and used as flour, or sprouted. The sprouts need to get green before they can be added to salads (Valencia-Chamorro 2003).

Quinoa flour can be mixed with maize or wheat flour. Several levels of quinoa flour substitution have been reported, for instance, in bread (10–13% quinoa flour), noodles and pasta (30–40% quinoa flour), and sweet biscuits (60% quinoa flour) (Valencia-Chamorro 2003).

In all cases, products of excellent quality are obtained Quinoa flour can be also drum-dried and extruded, providing products with good physical, sensorial, and nutritional qualities. Solid-state fermentation of quinoa with Rhizopus oligosporus Saito provides a good-quality tempeh (Valencia-Chamorro 2003).

The seeds are used boiled like rice or used to thicken soup or as porridge. Quinoa flour was made into noodles. Such a use is, however, complicated due to the bitter taste of seeds because of their saponin content which forms a soapy solution in water. Although much research has been done into the amino acid composition, there is only very limited information on the free and protein-bound tryptophan contents in quinoa and in cereals. The purpose of this research was to determine this nonproteic tryptophan in the flour of a Bolivian quinoa sample in comparison to the flours of common cereals (Comai *et al.* 2007).

Studies on the stability of vanillin entrapped within the spherical aggregates obtained from amaranth (*Amaranthus planiculatus* L.), quinoa (*Chenopodium quinoa* L.), rice (*Oryza sativa* L.) and colocasia (*Colocasia esculenta* L.) in the presence of Arabic gum, carboxymethyl cellulose (CMC), and carrageenan at 0.1–1.0% as bonding agents, were carried out using spray drying of 20% starch dispersions at 120°C. Vanillin was used at 5% based on starch (bos) (Tari *et al.* 2003). The recovery/retention of vanillin at 5% and 10% bos were found to be similar, though slightly high in the case of the latter. The extent of vanillin entrapment with various starches decreased in the order amaranth > colocasia > chenopodium > rice (Ahamed *et al.* 1996).

Quinoa seed, previously desaponified, was assayed for the activities of amylase, celulase, polygalacturonase, invertase, phenolase, alkaline and acid phosphatases, catalase, peroxidase, superoxide dismutase, protease, and lipoxygenase. Polygalacturonase, invertase, and lipoxygenase activities were not detected. All other enzymes were found to be active in quinoa seed extracts. Protease activity was found with haemoglobin as the substrate, but not with casein (Caussette *et al.* 1997).

Kancolla is a sweet variety of quinoa, used as a food plant, principally in the same way as wheat and rice. Quinoa is known as a pseudocereal, recently rediscovered by agricultural researchers of industialised societies. It is a highly nutritious food and the main edible part is the seeds (Dini *et al.* 2004). Kancolla is known as a pseudo-cereal, recently rediscovered by agricultural researchers of industrialised societies and selected for its tolerance to heat, cold, and resistance to disease. In this study, we have surveyed the betaines in kancolla seeds, because these compounds are widely accumulated in stressed plants. Particularly, we have evaluated the presence of glycine betaine, trigonelline, and their derivatives. In mammals, glycine betaine acts as an osmolyte in the inner medulla of the kidney, preserving osmotic equilibrium, maintaining at the same time the tertiary structure of macromolecules. In humans, glycine betaine can be readily absorbed through dietary intake or endogenously synthesised in the liver through choline catabolism. The concentration of glycine betaine in human plasma is highly regulated, although its concentrations are lower in patients with renal disease, and its urinary excretion is elevated in patients with diabetes mellitus (Dini *et al.* 2006). Glycine betaine intake can lower plasma homocysteine levels in patients suffering from homocystinuria, and in chronic renal failure patients with hyperhomocysteinemia, as well as in healthy subjects (Tang *et al.* 2002).

They contains bitter-tasting constituents (chiefly water-souble saponins) located in the outer layers of the seed coat. Because of this, they need to be washed or milled to remove the seed coat. The increased demand for quinoa has led the researchers to producing several cultivars, selected and bred for their tolerance to heat and cold, resistance to disease, and for other desirable characteristics (sweet taste). Perhaps the oldest and most widespread of the new varieties is Kancolla. Their occurence is interesting for nutritional properties and for chemotaxonomical purposes. A broad range of phenolic compounds occur in the food products, especially those coming from the plant material, in which they contribute to the organoleptic properties, i.e. astringency, beer hazes, specific (dis)colouration, and off-flavour. The effects of the dietary phenolic compounds are of a great current interest due to their antioxidative, cardiovascular protective, antiallergic, anti-inflammatory, antiviral, and anticarcinogenic activities (Dini *et al.* 2004).

FUTURE PERSPECTIVES

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 emphasised, 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 diferent 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 emphasised, 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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