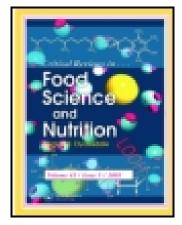
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Quinoa: Nutritional, Functional and Antinutritional Aspects

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QUINOA: NUTRITIONAL, FUNCTIONAL AND ANTINUTRITIONAL ASPECTS

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ABSTRACT

We have prepared a review of the physical-chemical composition, the functional and antinutritional properties of quinoa (*Chenopodium quinoa* Willd.). It is a plant of the Chenopodiaceae family, originally from the Andean regions, adaptable to different types of soil and climatic conditions. Its composition has attracted the attention of the scientific community for its high nutritional value, being rich in proteins, lipids, fibers, vitamins and minerals, with an extraordinary balance of essential amino acids. It is also gluten-free, a characteristic that enables its use by celiac patients. Despite all these attributes, quinoa is not widely used due to the high

cost of the imported grain and little knowledge of its benefits by most consumers. More studies are needed to increase knowledge about this õpseudocerealö, to demonstrate its functional and nutritional benefits and to study its antinutritional effects, since it presents high commercial value and excellent nutritional quality.

Keywords

Chenopodium quinoa Willd, nutritional value, functional properties, antinutritional factors, celiac disease.

Abbreviations

dm dry material, kDa unit of mass equal to 1000 daltons, DSC differential scan calorimetry, RVA rapid visco analyzer, SEM scanning electron microscopy, UTI unit trypsin inhibitor, ADI acceptable daily intake, WHO World Health Organization

1. INTRODUCTION

Quinoa (*Chenopodium quinoa* Willd.) belongs to the Chenopodiaceae family, the same of spinach and beets. The *Chenopodium* genus is found worldwide, with approximately 250 species identified. It is a granifer species native to South America and domesticated by the people inhabiting the Andes, mainly in Peru and Bolivia, for thousands of years. Rich in protein and with an extraordinary balance of essential amino acids, it was considered a sacred plant by those people (Spehar and Santos, 2002; Spehar, 2006; Spehar, 2007; Farro, 2008; Jancurová et al., 2009).

It is a plant that stands out for its good nutritional value and, above all, by the considerable resistance to weather climate and soil conditions. The edible parts involve leaves and grains, the latter being the most economically and scientifically explored (Spehar, 2006; Farro, 2008; Rock, 2008). Despite having cereal characteristics, as it does not belong to the Gramineae family and owns botanical aspects such as the presence of panicle-type inflorescence and exceptional nutritional balance of protein and lipids, high protein content, sulfur amino acids and lysine, it is designated as a õpseudocerealö and even an oleaginous õpseudoseedö (Farro, 2008; Vega-Gálvez et al, 2010; Repo-Carrasco-Valencia and Serna, 2011).

Quinoa contains more protein content and balanced distribution of essential amino acids than cereals, resembling the biological value of protein in milk. It overcomes cereals in the level of lipids, proteins, dietary fibers, vitamins B1, B2, B6, C, E and minerals, especially calcium, phosphorus, iron and zinc. In addition to presenting high nutritional quality, is also characterized by being gluten-free, a characteristic that enables greater offer and variety of more nutritious and suitable food products for patients with celiac disease. All this has contributed to the increased

interest and popularity of its use among people seeking alternative food with high nutritional value, particularly in developed countries, hence stimulating the production for export, mainly by the Andean countries (Spehar and Santos, 2002; Spehar, 2007; Farro, 2008; Almeida e Sá, 2009). Despite all these attributes, this feedstock is not widely used due to the high cost of importation and little knowledge of its benefits for the majority of the population and, therefore, its marketing is still very limited. So we realize the need for more studies to have a better understanding about this õpseudocerealö, to characterize its key components, to demonstrate its functional and nutritional benefits and to study its antinutritional effects, since it presents good commercial value and high nutritional quality.

2. GENERAL ASPECTS ON QUINOA

Quinoa is a food plant of the Chenopodiaceae family, *Chenopodium* genus, native to the Andean regions of Chile, Peru, Ecuador and Bolivia, and its cultivation dates back thousands of years, making this food, which comes from the Andean cradle, the oldest ever recorded (Spehar and Santos, 2002; Farro, 2008). The millennial experience with this crop allowed ancient populations to recognize the high nutritional value of this food, called by them the õgolden grainö, and considered a sacred food (Farro, 2008; Jacobsen et al, 2003.).

This seed has attracted attention as a new food source, because of the quality and nutritional value of its proteins. It is especially rich in lysine, making it a protein more complete than most vegetables, particularly having its amino acid composition close to the ideal protein equilibrium recommended by the FAO and similar to milk. It has a relatively high level of vitamins and minerals, and lipids on this seed have high quality as an edible vegetable oil (Chauhan et al.,

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1992; Ogungbenle, 2003; Comai et al., 2007; Spehar, 2007; Abugoch James, 2009; Vega-Gálvez et al., 2010).

The absence of gliadins (gluten-forming proteins present in wheat) and protein fractions corresponding to gliadin (found in oats, barley, rye and malt) makes quinoa appropriate for the preparation of food products popularly referred to as õgluten-freeö, important aspects that enable greater variety and supply of more nutritious food, suitable for patients with celiac disease (Almeida & Sá, 2009; Borges et al., 2010).

The gluten-induced autoimmune intestinal enteropathy, or celiac disease, is a type of food intolerance in genetically susceptible individuals, associated specifically to products containing gluten such as wheat, rye, barley, oats and triticale. It is characterized by chronic inflammation of the mucosa of the small intestine, which can result in partial or total intestinal villous atrophy. Studies worldwide have shown that the prevalence of this disease is considerably higher than previously supposed, ranging from 1:100 to 1:300 individuals in the healthy adult population of most part of the world (Borges et al., 2003; Castro et al., 2007; Bicudo, 2010).

The antinutritional factors present in the quinoa seed are saponins, phytic acid, oxalates, tannins and trypsin inhibitors. These substances are present in higher concentrations in the outer layers of the grain, among which saponin stands out. It is a natural detergent, soluble in water, with bitter taste, which can be easily removed by wet methods (washing with cold water) and dry methods (browning and abrasion) (Mastebroek et al., 2000; Comai et al., 2007; Spehar, 2007; Borges et al., 2010).

3. NUTRITIONAL CHARACTERISTICS OF QUINOA

The factors that make quinoa attractive for the production system are the characteristics of the plant and grain composition. In the Andean region, this grassy is an important source for both human and animal nourishment. The leaves and panicles are excellent sources of protein, fiber, minerals and vitamins, also providing good digestibility (Table 1), and the leaves can be consumed in cooking the same way as spinach and flower buttons like broccoli or cabbage-flower (Spehar, 2007).

The quinoa grain is a starchy raw material with high content of carbohydrates, consisting mainly of starch and a small percentage of sugars. It is a complete food with high nutritional value, mainly due to its high content of good quality protein. It also presents, in its composition, fiber, vitamins of complex B, vitamin E and C and minerals like calcium, magnesium, iron, potassium, phosphorus, manganese, zinc, copper and sodium. It contains higher levels of total protein, methionine and lysine when compared to traditional cereals such as rice, maize, barley and wheat, with fatty acids similar to those of soybean oil in its lipid composition (Chauhan et al., 1992; Ogungbenle, 2003; Spehar, 2007; Abugoch James, 2009; Vega-Gálvez et al., 2010). The percent composition of the quinoa grain is presented in Table 2.

Cereals play an important role in human nutrition, contributing approximately to half the energy and protein intake of the population, with wheat, corn, rice, barley, oats, rye and sorghum being the most important worldwide. Comparing the nutritional components of these cereals with quinoa (Table 3), we can notice the richness of this nutrient, which contains higher values of protein, fat and ash content (USDA, 2011).

Quinoa is an excellent example of õfunctional foodö, and it can help reduce the risk of various diseases. Its functional properties may be related to the presence of fiber, minerals, vitamins, fatty acids, antioxidants and plant hormones that contribute to human nutrition, especially in the protection of cell membranes, with proven result in the improvement of neuronal function. These features provide to the grain big advantage over other plant foods for human nutrition and health maintenance (Vega-Gálvez et al., 2010; Repo-Carrasco-Valencia & Serna, 2011).

In the mid-70s, the National Academic Science (NAS) considered quinoa as one of 23 promising and recommended plants for studies, aiming to improve the nutrition and quality of life of the population on õdevelopingö countries (Farro, 2008). It is one of the most nutritious foods used in human food, chosen by the FAO as one of the crops destined to collaborate with food security in this century (Repo-Carrasco-Valencia & Serna, 2011).

3.1 Proteins

Proteins participate in the construction and maintenance of tissues, formation of enzymes, hormones and antibodies, power supply and regulation of metabolic processes. In addition to nitrogen, amino acids provide sulfur compounds to the body. In the form of lipoprotein, they are involved in the transport of triglycerides, cholesterol, phospholipids and fat-soluble vitamins (Ahmed et al., 2008).

For some populations of the world, including high quality protein in their diets is a problem, especially people who rarely consume animal protein and should get them from cereals, legumes and other grains. Even though the contribution of proteins by these foods is enhanced, insufficient concentrations of some essential amino acids can increase the prevalence of malnutrition (Mujica et al., 2001; Alves et al., 2008).

The protein content in quinoa grain ranges from 13.8% to 16.5% with an average 15% dm (Koziol, 1992). Compared to the cereal grains as shown in Table 3, the total protein content of quinoa is higher than for barley (11.0% dm), rice (8.8% dm), corn (10.5% dm), rye (dm 11.6%) and sorghum (12.4% dm), getting close to wheat (14.8% dm) (Koziol, 1992; Comai et al., 2007; Jancurová et al., 2009).

Albumins (2S) and globulins (11S) make up most of the storage proteins from quinoa grain (35 and 37%, respectively), while the prolamins are present in low concentrations, and this ratio is variable in the different species (Brinegar &Goudan, 1993; Brinegar et al., 1996; Abugoch James, 2009).

The globulin 11S called chenopodin is an oligomeric protein with a 320 kDa quaternary structure. It is composed of monomers or subunits, which consist of a basic polypeptide and an acid, with a molecular mass of 20-25 kDa and 30-40 kDa, respectively, united by disulfide bonds. Chenopodin has high content of glutamine-glutamic acid, asparagine-aspartic acid, arginine, serine, leucine, and glycine, but it is relatively low in sulfur amino acids, compared to the total composition of the quinoa seed protein (Brinegar & Goudan 1993; Abugoch James, 2009).

The protein fraction of type 2S presents a heterogeneous group of polypeptides with molecular mass of 8-9 kDa under reducing conditions. The amino acid composition of this protein was shown to be high in cysteine, arginine and histidine, which have important nutritional features, especially for children. Thus, the 2S fraction appears to contribute to the greater level of sulfur amino acids of quinoa, showing great potential as dietary supplementation, especially for

children, both in the form of enrichment or food supplementation with quinoa grains or derivatives (Brinegar et al., 1996; Abugoch James, 2009).

The nutritional quality of the protein is determined by the proportion of essential amino acids, namely those that cannot be synthesized by animals, and must therefore be supplied in the diet. If only one of these amino acids is limiting, the others will not be fully absorbed, resulting in loss of dietary protein and less growth. Nine amino acids are strictly essential for humans: phenylalanine, isoleucine, leucine, lysine, methionine, threonine, tryptophan, valine and histidine (essential in childhood) (Who, 2007), which are present in quinoa (Table 4), providing a protein value similar to casein from milk (Vega-Gálvez et al., 2010).

Thus, quinoa is one of the few plant foods that provide all essential amino acids for human life with values close to those set by the Food and Agriculture Organization (FAO), with an excellent aminoacidic balance, being rich in sulfur amino acids and lysine, and it can be considered as a high quality protein, unlike the protein content of cereals, which are especially deficient in lysine (Mujica et al., 2001; Alves et al., 2008).

The nutritional value of a food is determined mainly by its protein quality, which depends on the composition of essential amino acids, and the biological utilization of the amino acids (bioavailability) also depends on the digestibility of protein, the influence of present antinutritional factors and the ratio between tryptophan and neutral amino acids. The protein digestibility or the bioavailability (true digestibility) of amino acids in quinoa varies according to the variety and treatment that the grains receive, increasing considerably with cooking (Koziol, 1992; Comai et al., 2007; Alves et al., 2008; Abugoch James, 2009).

Comai et al. (2007) found that quinoa not only has a high protein content, but also an adequate amino acid composition, besides high concentration of tryptophan, usually the second limiting amino acid in cereals. Moreover, it presents a high rate of non-protein tryptophan, which is more easily absorbed and can contribute to increase the availability of this amino acid in the brain, thereby influencing the synthesis of the serotonin neurotransmitter.

3.2 Carbohydrates

Carbohydrates comprise one of the largest groups of organic compounds found in nature, and together with proteins, they form the major components of living organisms, being the most abundant and economical source of energy for humans. They can be classified according to their degree of polymerization in three main groups: mono, oligo and polysaccharides (Mahan & Escott-Stump, 2010).

Starch is the main carbohydrate component of quinoa and is present between 52% and 69% (dm). The total dietary fiber is close to the value found in cereals (7 to 9.7% dm), wherein the embryo contains higher levels than those in perisperm. The soluble fiber content is reported ranging from 1.3% to 6.1% (dm). Quinoa still presents approximately 3% simple sugars, mostly maltose, followed by D-galactose and D-ribose, plus low levels of fructose and glucose (Abugoch James, 2009).

Dietary fiber has a number of beneficial effects related with its indigestibility in the small intestine. Therefore, the reported high content of quinoa fibers can improve digestibility by facilitating the absorption process of the other nutrients present in quinoa in the large intestine (Ogungbenle, 2003). The intake of gluten-free dietary fiber is considered inadequate and, thus, experts recommend a higher intake of whole grains rich in fiber, unlike grains and refined

products in the diet of patients with celiac disease, relieving, at least partially, the deficit of fiber intake by that portion of the population (Alvarez-Jubete et al., 2010).

It was observed that the total and insoluble content of dietary fibers decreased during the extrusion process, being significant only for some varieties of quinoa. On the other hand, the soluble dietary fiber content increased during this process. Exposure to shear stress and high temperature causes disruption of chemical bonds, creating smaller and more soluble particles. There is, therefore, a transformation of some components of the insoluble fiber into soluble fiber during extrusion (Repo-Carrasco-Valencia and Serna, 2011).

Starch, the main biopolymer constituent of plants (beans, seeds, roots and tubers) typically occurs as granules of various shapes and sizes. Quinoa starch granules have a polygonal shape with diameter of 0.6 to 2.2 m, less than starch of most cereal grains, and may be found as single entities or forming aggregates of spherical or elliptical composite structures. The extremely small size can be beneficially exploited and used in blends with synthetic polymers in the preparation of biodegradable packaging. Its excellent freeze-thaw stability makes it an ideal thickener for sauces, condiments and soups due to its low gellation temperature and storage stability at low temperatures and in other applications where resistance to retrogradation is desired, and it may also be used to produce a creamy and smooth texture similar to fats (Lorenz, 1990; Tari et al., 2003; Abugoch James, 2009; Vega-Gálvez et al., 2010).

According to Park et al. (2007) and Praznik et al. (1999), quinoa starch has an average molar of 11.3x10⁶ g mol⁻¹, mass lower than waxy maize starch (17.4x10⁶ g mol⁻¹) or rice (0.52-1.96x10⁸ g mol⁻¹) and larger than wheat starch (5.5x10⁶ g mol⁻¹). It is highly branched, with a minimum degree of polymerization of 4,600 glucose units, maximum of 161,000 and a weighted average

of 70,000 (Praznik et al., 1999). The length of the chain depends on the botanical source, ranging from 500 to 6,000 glucose units.

As mentioned by James Abugoch (2009) and Koziol (1992), the amylose content of quinoa starch ranges from 3% to 22%, which is lower than that present in wheat or maize, greater than some varieties of barley and similar to certain varieties of rice. According to Tang et al. (2002), this fraction has an average degree of polymerization of 920, much lower than that of barley, which is 1,660.

The content of amylopectin in quinoa starch, according Tari et al. (2003) is 77.5%. The fraction of amylopectin is high and comparable to that of some rice varieties. It has a length distribution similar to waxy starch amylopectin, averaging 317 branching and average polymerization degree of 6,700 glucose units per fraction. Quinoa amylopectin, as well as buckwheat and amaranth, contains a large number of short chains from 8 to 12 units and a small number of longer chains from 13 to 20 units in comparison with starches from other cereals (Tang et al., 2002; Abugoch James, 2009).

X-ray diffraction studies have been used to explain the structure and crystallinity of the starch granule. Depending upon its biological origin, proportion of amylose/amylopectin and branching length of amylopectin, the starch granules show three types of diffraction patterns associated with different crystalline polymorphic forms: type A (cereal grain), type B (tubers) and type C (crystals A and B coexisting on the same granule) (Qian and Kuhn, 1999, Lopez-Rubio et al., 2008).

The quinoa starch has a diffraction pattern of X-ray with reflections in 15.3°, 17°, 18°, 20° and 23.4°, characteristic of cereal starches (type A). The relative degree of crystallinity is between

35% and 43%. The relative crystallinity of this starch has been described as higher than that of barley starch, smaller than that of amaranth starch, and similar to that of waxy barley starch (Qian and Kuhn, 1999, Tang et al, 2002.; Abugoch James, 2009). The thermogram by differential scanning calorimetry (DSC) of quinoa starch shows two thermal transitions, one for starch gelatinization and one for the amylose-lipid complex. The gelatinization properties of starch are linked to a variety of factors including the size, proportion and type of crystalline organization, as well as the ultrastructure of the starch granule. The initial, peak and final temperatures of quinoa starch were 54.5, 62.6 and 71.3° C respectively (Tang et al., 2002). As quoted by Abugoch James (2009) and Tang et al. (2002), the first enthalpy change was 10.3 J g⁻¹, and the second 0.186 J g⁻¹.

The gelatinization of quinoa starch occurs at a relatively low temperature, having been reported between 62.6 and 67°C, less than amaranth starch and waxy barley, and somewhat greater for starch from wheat, rice and barley. It has high maximum viscosity, higher water absorption capacity and greater swelling power, compared to starch from wheat and barley. The lower pasting temperature and lower rate of the quinoa starch breakdown results in higher hot paste stability, i.e., increased shear resistance during heating. The determination of the quinoa starch viscosity in RVA (rapid visco analyzer) showed behavior similar to starch paste of cereals and roots. Quinoa starch has excellent stability even under freezing and retrogradation processes (Lorenz, 1990; Qian and Kuhn, 1999, Tang et al., 2002; Abugoch James, 2009).

Quinoa carbohydrates can be considered as nutraceuticals because they have beneficial hypoglycemic effects and induce reduction of free fatty acids. Studies in individuals with celiac disease showed that the glycemic index of quinoa was slightly lower than that in gluten-free

pastas and breads. Furthermore, quinoa induced levels of free fatty acids lower than gluten-free pasta, and triglyceride levels significantly lower as compared to gluten-free bread. Other nutraceutical effects of quinoa have been reported, but they still need further study (Berti et al., 2004).

3.3 Lipids

Quinoa has been considered an alternative oilseed crop, due to the quality and quantity of its lipid fraction. Quinoa has a fat content between 2.0 and 9.5%, being rich in essential fatty acids like linoleic and -linolenic, and contains high concentrations of antioxidants like and -tocopherol. It has an oil content of around 7% (dm), higher than corn (4.7% dm) and other cereals, and lower than soybeans (19.0% dm). A comparison of the fatty acid profile of the quinoa grain oil to that in maize and soybeans (Table 5) showed similar levels to linoleic (C18:2), oleic (C18:1) and linolenic (C18:3) fatty acids, corresponding to approximately 88% of total fatty acids of the seed (Koziol, 1990; Koziol, 1992;. Ando et al., 2002; Repo-Carrasco et al., 2003; Ryan et al., 2007; Borges et al., 2010).

As reported by Ando et al. (2002), the major saturated fatty acid found in quinoa was palmitic, which corresponded to about 10% of the total fatty acids present. The unsaturated fatty acids were oleic (19.7 to 29.5%), linoleic (49.0 to 56.4%) and linolenic (8.7 to 11.7%), which constituted 87.2 to 87, 8% of the total fatty acids present in quinoa oil, which is similar to soy oil composition. As indicated by the high iodine value (82.7%) observed by Repo-Carrasco et al. (2003), the fatty acids of quinoa oil are polyunsaturated. In recent decades, polyunsaturated fatty acids have gained importance due to the health benefits attributed to them, such as positive effects on cardiovascular disease, metabolism of prostaglandins, increased insulin sensitivity,

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immune system and cell membrane function (Repo-Carrasco et al., 2003; Ogungbenle, 2003; Abugoch James, 2009).

The concentrations of tocopherols found in quinoa oil were 797.2 ppm of -tocopherol and 721.4 ppm of -tocopherol (Repo-Carrasco et al., 2003). The observed level of -tocopherol was slightly higher than that present in corn oil, ensuring quinoa oil a long shelf life due to the antioxidant potential of the substance. Furthermore, the content of -tocopherol, such as vitamin E, is very important, because it acts as a natural antioxidant at the level of the cell membrane, protecting fatty acids against damage by free radicals (Ruales & Nair, 1993a; Ng et al., 2007, Ryan et al., 2007; Abugoch James, 2009).

According to Ng et al. (2007) lipids of quinoa flour were stable during 30 days due to the naturally present vitamin E. As this micronutrient represents a natural antioxidant in this grain, and as it is present in large quantities, the potential of quinoa as a new oilseed has been strengthened, especially in the development of new food applications, focusing on the antioxidant qualities naturally present in this raw material.

The lipid content of quinoa (2 to 9.5%) is considered low for oil extraction to be economically attractive, but in maize, this content ranges from 2 to 5% (Koziol, 1992). It is estimated that with improved methods of cultivation, one can produce from 80 to 400 kg oil/ha, in comparison with corn oil yields (20-50 kg/ha), soybean (350-425 kg/ha), sunflower (330-510 kg/ha) or peanut (260-480 kg/ha) (Koziol, 1990). Furthermore, the 55-63% concentrations of linoleic and linolenic fatty acids found in the lipids fraction contribute for this oil to be a potentially valuable source of essential fatty acids (Koziol, 1990; Koziol, 1992).

According to Ogungbenle (2003), the oil extracted from quinoa had saponification index of 192.0%. This value is lower than that of other lipids such as butter fat (220-241%) and coconut oil (200-250%), but it compares favorably with cottonseed oil (190-200%) and soybean (190-194%). The values of the acid and peroxide index (0.5% and 2.44%) indicate that the oil is not easily ripened when properly stored in the absence of atmospheric oxygen and other contaminants. As mentioned by Koziol (1992), quinoa oil contains 5.2% unsaponifiable matters, 1.8% phosphatides (lecithin) and 1.5% sterols. It presents specific density at 20°C of 0.8910 and refractive index at 25°C of 1.4637.

Squalene and phytosterols are components present in the unsaponifiable lipid fraction of the food, together with tocopherols. Squalene is produced by all higher organisms recognized for their beneficial properties for the human health, being an intermediate in the biosynthesis of cholesterol. According to Jahaniaval et al. (2000) and Ryan et al. (2007), squalene is present in quinoa between 33.9 to 58.4 mg 100 g⁻¹. It is the biochemical precursor to the whole family of steroids, and in addition to its efficient antioxidant activity, tocotrienols have other important functions, especially in maintaining a healthy cardiovascular system and a possible role in cancer protection (Abugoch James, 2009).

Phytosterols are natural components of plant cell membranes present abundantly in oils, seeds and grains. They have different biological effects such as anti-inflammatory, antioxidant, and anticarcinogenic action. As reported by Ryan et al. (2007), the levels of phytosterols present in quinoa were 63.7 mg 100 g⁻¹ of -sitosterol, 15.6 mg 100 g⁻¹ of campesterol and 3.2 mg 100 g⁻¹ of stigmasterol, which are the most abundant sterols in plants. These levels are higher than in pumpkin seeds, barley and corn, but lower than in lentils, chickpeas and sesame seeds. The

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recommended dose is 0.8-1.0 g of equivalent phytosterol per day, including natural sources, and they are important components in dietary reduction of low-density lipoprotein (LDL) assisting in maintaining a healthy heart (Ryan et al., 2007; Abugoch James, 2009).

3.4 Vitamins

Quinoa is also rich in micronutrients such as vitamins and minerals. Vitamins are compounds essential for the health of humans and animals. They cannot be synthesized by the human body, although some compounds belonging to the class of sterols and carotenoids can be processed in vitamins in the human body, which is why such substances are termed -pro-vitamins@ According to their solubility, they are divided into two groups: water-soluble and fat-soluble. Traditionally, they are among the most widely applied chemicals to improve the nutritional value of food products (Mahan & Escott-Stump, 2010; Vega-Gálvez et al., 2010).

Although there are few studies on the vitamin content in quinoa grain, several authors reported significant concentrations of pyridoxine (B6) and folic acid, whose values in 100 g can meet the needs of children and adults. The contents in 100g of riboflavin contribute with 80% of the daily needs of children and 40% of adults, as cited by Abugoch James (2009). The content of niacin does not meet daily needs, but it is an important source for the diet. The values of thiamine (B₁) are lower than those of oats or barley, but riboflavin (B₂), pyridoxine (B₆) and folic acid are higher than most cereals such as wheat, oats, barley, rye, rice and maize. Furthermore, quinoa is an excellent source of vitamin E, higher than wheat, as previously described (Ruales & Nair, 1993a; Abugoch James, 2009; Alvarez-Jubete et al., 2010).

Ruales & Nair (1993a) have reported considerable levels of thiamine (0.4 mg 100 g⁻¹), folic acid (78.1 mg 100 g⁻¹) and vitamin C (16.4 mg 100 g⁻¹). Koziol (1992) compared the levels of vitamins in quinoa with some grain, and reported that the grain contains substantially more riboflavin, -tocopherol, -carotene and ascorbic acid than rice, barley and wheat. Repo-Carrasco et al. (2003) also reported that quinoa is rich in vitamins A, B₂, and E. Table 6 shows the levels of vitamins in quinoa compared to other cereals.

The levels for ascorbic acid should be treated with caution, because this vitamin is highly susceptible to oxidation. Thus, 0-63.0 mg 100 g⁻¹ have been reported for quinoa. The vitamin concentration data can be misleading, since they represent values on a dry basis, and both sweet and bitter varieties of quinoa are usually washed, and the bitter ones are subjected to polishing (abrasive peeling) to remove saponins before being cooked, changing the levels of vitamins present in the raw grain (Koziol, 1992).

3.5 Minerals

Unlike carbohydrates, lipids and proteins, minerals are inorganic and cannot be produced by living beings. They have very important functions in the body. Low intake or reduction of bioavailability may generate imbalances in health and impairment of vital functions. Among the best known are calcium, phosphorus, iron, potassium, sulfur, sodium, magnesium, zinc, copper, selenium and chromium. These micronutrients must be ingested through a properly balanced diet to supply the daily needs, and special attention should be given to the correct food combinations, preparation techniques and nutrients in order to enhance their bioavailability (Cozolino, 2009; Vega-Gálvez et al., 2010).

The ash content of quinoa (3.4%) is greater than rice (0.5%), wheat (1.8%) and most other cereals. Thus, quinoa grain contain large quantities of minerals. The amount of calcium and iron are significantly higher than in the commonly used grain. It has about 0.26% magnesium, compared to 0.16% for wheat and 0.14% for corn. Since they are in bioavailable forms, calcium, magnesium and potassium are found in sufficient quantities in the quinoa grain for a balanced human diet (Repo-Carrasco et al., 2003; Bhargava et al., 2006; Vega-Gálvez et al., 2010). Several authors also reported large amounts of iron and calcium in quinoa (Table 7).

Vega-Gálvez et al. (2010) reported a large variation in the concentration of minerals in quinoa seeds. The difference in the values obtained by the various authors cited in Table 7 may be related to the fact that the samples were of different genotypes and regions with varying soil types and different mineral compositions and/or applied fertilizers.

Ogungbenle (2003) found that potassium is the most abundant mineral in quinoa grain, followed by magnesium and phosphorus, while iron showed the lowest value. The calcium content can be considered adequate for the child's development of bones and teeth. The figures suggest that quinoa could be used for different formulations in human consumption.

Ando et al. (2002) and Konish et al. (2004) analyzed the mineral content in the quinoa grain, getting higher levels of calcium, phosphorus, iron, potassium, magnesium and zinc among the minerals analyzed (Table 7). Some studies show that the quinoa grain shows significantly higher amounts for these minerals when compared to most cereals traditionally consumed in Brazil, as shown in Table 8 (Borges et al., 2003; Repo-Carrasco et al., 2003; Bhargava et al., 2006; NEPA, 2011).

As quoted by Alvarez-Jubete et al. (2010a), calcium, magnesium and iron are the main mineral deficiency in gluten-free products. The pseudocereals amaranth, quinoa and buckwheat are usually a good source of these and other important minerals for celiac disease patients. In particular, the high calcium content of these seeds has great relevance for celiac individuals due to the well-known prevalence of osteopenia and osteoporosis among patients recently diagnosed with this disease.

Quinoa contains more iron than ordinary cereals, however, its availability may be affected to some extent by saponins and phytic acid present in the seeds. As reported by Ruales & Nair (1993a), the amount of phytic acid after the washing process used for the removal of saponins remained high, about 8 mg g⁻¹. Excessive amounts of dietary phytate has a negative effect on the mineral balance because it binds with inorganic multivalent such as Fe³⁺, Zn²⁺, Ca²⁺ e Mg²⁺, making them less available for absorption in the intestinal tract. The procedure for cleaning and washing with water, used for removal of saponins, appears to influence the content of minerals. A significant reduction of 46% in the potassium content, 28% in iron, 27% in manganese and 8% in magnesium (Ruales & Nair, 1993a) was observed.

However, as cited by Koziol (1992) and Ruales & Nair (1993a), feeding experiments with animals have shown that the availability of iron from diets based on quinoa was at least as good as the availability of iron from ferrous sulfate. However, the bioavailability of quinoa minerals in humans needs further evaluation.

The distribution of minerals in quinoa seeds was examined by Konishi et al. (2004), by using microanalysis of energy dispersive X-ray (EDX) in conjunction with scanning electron microscopy (SEM). Phosphorus, potassium and magnesium were located in the embryonic

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tissue. As the phytin cells are located in protein bodies of embryonic cells, it is suggested that P is assigned to phytic acid and that K and Mg are forming the phytates. Calcium and potassium were present in the pericarp, where the cell wall is densely developed, suggesting that these minerals are associated with pectin. Sulfur was found in embryonic tissues, being derived from sulfur of the amino acid residues of storage proteins concentrated in these tissues.

3.6 Antioxidants, flavonoids and phenolic compounds

Coronary heart disease is the leading cause of death in most developed countries and is growing rapidly in developing countries. Appropriate diets that include fruits, vegetables, whole grains and pseudocereals may contribute to cardiovascular protection. It has been shown that foods rich in dietary fiber are often an important source of vitamins, minerals, phytochemicals, natural antioxidants and other micronutrients. Among these foods, cereals and pseudocereals play an important role (Gorinstein et al., 2008).

Recently, much attention has been focused on natural antioxidants, which can play an important role in inhibiting free radicals and oxidation chain reactions within tissues, in particular for the protection of cell membranes, with proven success in neural functions, reducing the risk of several degenerative diseases associated to oxidative stress such as cancer, cardiovascular disease and osteoporosis (Nsimba et al., 2008; Alvarez-Jubete et al., 2010b; Vega-Gálvez et al., 2010).

Antioxidants are compounds that can retard or inhibit the oxidation of lipids or other molecules by inhibiting the initiation or propagation of oxidation chain reactions. When added to foods,

antioxidants minimize rancidity, retard the formation of toxic oxidation products, maintain nutritional quality and increase the shelf life (Vega-Gálvez et al., 2010).

Alvarez-Jubete et al. (2010a, 2010b) reported that among cereals and pseudocereals, buckwheat is one of the best sources of polyphenols, being quercetin, apigenin and luteolin the main flavonoids glycosides found. Quinoa seeds are also a rich source of flavonoids, which consist mainly of quercetin and kaempferol glycosides. The major phenolics found in amaranthus seeds are caffeic acid, *p*-hydroxybenzoic acid and ferulic acid (Alvarez-Jubete et al., 2010b).

Gorinstein et al. (2008) reported a tannin content of 0.05% bs for quinoa, whose value is comparable to that of amaranth. The content of phenolic acids have been reported as 251.5 g g⁻¹ ferulic acid, 1.1 g g⁻¹ *p*-coumaric acid and 6.31 g g⁻¹ caffeic acid on a dry basis. The authors also determined the content of polyphenols in the pericarp and buckwheat grains, and found that the content in the pericarp was significantly higher than in the grains. The methods used for the determination of the antioxidant capacity showed that buckwheat and quinoa presented the highest antioxidant activity among the studied cereals and pseudocereals.

Zhu et al. (2001) isolated six flavonols glycosilated from quinoa seeds. Two quercetin 3-glycosides showed the highest antioxidant activity than the four kaempferol 3-glucosides present, suggesting that quinoa could represent an important source of free radical inhibition.

Nsimba et al. (2008) found that among the five grain samples studied, the ethanol extract of the quinoa sample from Japan, grown at sea level, had the highest phenolic content (148.0 \pm 1.9 mg g⁻¹ of equivalent tannic acid), while the quinoa sample from Bolivia presented the lowest content (94.3 \pm 3.0 mg g⁻¹). Likewise, the Japanese quinoa sample showed the highest antioxidant capacity. The difference in the content of these phenolics between both quinoa ecotypes can be

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explained by different environmental conditions, farming techniques or genetic factor (Nsimba et al., 2008;. Miranda et al., 2011).

As observed by Nsimba et al. (2008), the low values of correlation between total phenolic content and antioxidant activity suggest that the highest antioxidant activity in the studied seeds can be from non-phenolic compounds. Despite the high proportion of total phenols, other non-phenolic compounds, such as ascorbic acid, phytic acid, tocopherols, sterols, carotenoids, saponins, ecdysteroids, among others, may be the most likely contributors to the antioxidant activity of the five samples.

Hirose et al. (2010) also found the highest antioxidant effect of quinoa seeds from Japan, compared with those in South America and other grains, except buckwheat. The results suggest that quinoa seeds cultivated in Japan have phenolic compounds, particularly quercetin glycosides in larger quantities, responsible for their high antioxidant capacity. These authors obtained a good correlation between the total phenolic contents of the grains analyzed and the ability to inhibit free radicals.

Pasko et al. (2009) showed that seeds and sprouts of amaranth and quinoa can be used as food, because they are good sources of total phenolics and anthocyanins, with relatively high antioxidant activity. The authors reported that quinoa showed antioxidant activity higher than amaranth using three different methodologies, and the data obtained showed good correlation, suggesting that the polyphenol contents can be a good indicator of in vitro antioxidant activity.

Repo-Carrasco-Valencia & Serna (2011) found that the content of total phenolic compounds and the inhibitory activity of free radicals increased during the extrusion process for the four varieties of studied quinoa. This increase of antioxidant activity in processed grains can be explained by

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the increase of soluble phenolic compounds released during thermal processing. There was a significant difference between the total polyphenol content on the varieties, and they concluded that quinoa could be considered a good source of dietary fiber, polyphenols and other antioxidants, and that the extrusion-cooking process can improve the nutritional value of the grain.

In another study by Alvarez-Jubete et al. (2010b), the composition of polyphenols and antioxidant properties of methanol extracts of quinoa, buckwheat, amaranth and wheat were analyzed, and how these properties were affected was evaluated after two types of processing: germination and baking. The content of total phenols between extracts of seeds was significantly higher in buckwheat followed by quinoa, wheat and amaranth. The antioxidant capacity, determined by three test methods, was also higher in the seed extract of buckwheat and quinoa. The total phenolic contents and the antioxidant activity generally increases with germination, and a decrease in levels was observed in the baking process. In general, sprouts and seeds of buckwheat and quinoa represent potential sources of phenolic compound to improve the nutritional properties of food products such as gluten-free breads.

According to Vega-Gálvez et al. (2010), the antioxidant activity of quinoa can be of particular interest to medical researchers and requires more attention regarding its use as a powerful natural antioxidant.

Experimental studies in animals or human cell cultures have demonstrated the role of plant polyphenols in preventing cardiovascular diseases. However, more studies in humans are needed to provide clear evidence of the actual bioactivity of flavonoids and their protective effects for

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health, as well as to assess the risks likely to result from the high consumption of polyphenols in food (Zhu et al., 2001; Gorinstein et al., 2008).

4. ANTINUTRITIONAL FACTORS

One of the main problems arising from the use of plants as a source of nutrients in the diet is the presence of some compounds derived from secondary plant metabolism. The term oantinutritional factoro has been used to describe this class of compounds present in a wide variety of plant foods, which, when consumed, reduce their nutritional value, interfering with their digestibility, absorption or utilization of nutrients, possibly causing harmful effects to health if ingested in high concentrations. Thus, it is essential to undertake studies of antinutritional factors of conventional and unconventional plant use, in order to determine which compounds interfere with their nutritional value (Lopes et al., 2009; Benevides et al., 2011).

Various types of antinutritional factors have been identified in different vegetables. In the quinoa seed, the identified antinutritional factors are saponins, phytic acid, tannins, nitrates, oxalates and trypsin inhibitors. These substances are present in higher concentrations in the outer layers of the grain. However, studies on the possible antinutrients in quinoa are scarce, and little is known about its antinutritional and/or toxic effects that might compromise its nutritional quality, in order to incorporate it effectively in the human diet (Santos, 2006; Lopes et al., 2009; Borges et al., 2010).

Despite the presence of antinutritional factors in the quinoa grain, these substances can be inactivated or reduced to safe health levels when appropriate techniques for industrial processing or household preparation of this food are used (Borges et al., 2010).

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4.1 Saponins

The quinoa grain has a natural bitter coating called saponin, generally present in the outer layers of the grain (episperm), which protects it from birds and insects. These substances found in plants, particularly of the Leguminosae family, are triterpenoid glycosides without well-defined chemical formula; however, in general, we can suggest the following basic chemical formula: $C_nH_{2n-8}O_{10}$ (n×5). Four main structures of sapogenins were identified in quinoa: oleanolic acid, hederagenin, phytolaccagenic acid and 30-*O*-methyl-espergulagenate. The major present carbohydrates are: glucose, arabinose and galactose (Dini et al., 2001, Zhu et al., 2002, Souza et al., 2004; Farro, 2008).

They are soluble in methanol or water and have toxic properties by causing hemolysis of red blood cells. This toxicity depends on the saponin type and on the sensitivity of the recipient organism. However, although they are extremely toxic to cold-blooded animals, their oral toxicity in mammals is low, not exerting any negative effect on the nutritional quality of the protein. Some saponins form complexes with iron and zinc reducing their absorption, but there is no evidence of the formation of complexes with vitamins A, E and D₃ (Gonzáles et al., 1989; Koziol, 1990; Koziol, 1992; Ruales & Nair, 1993b; Dini et al., 2001; Farro, 2008; Jancurová et al., 2009).

Although some are considered toxic, their insecticide, fungicide and antibiotic properties are recognized. They present pharmacological potential by modifying the permeability of the small intestine, which may aid in absorption of specific drugs and reduce the plasma or serum cholesterol by fecal secretion of bile acid and neutral steroids. In the pharmaceutical industry, they are used as precursors for the synthesis of steroids, hormones, contraceptives, anti-

inflammatories, expectorants and diuretics. Due to their surfactant and emulsifier effects, they are also known as foaming agents in water and used in soaps, detergents, shampoos, toothpastes and hair lotions (Dini et al., 2001; Farro, 2008; Veja-Gálvez et al., 2010).

The presence of saponins is not limited to seeds and can also be found in other parts of the plant, whose function is to protect against the adverse conditions of the outside environment. The content of total saponins in the leaves may be increased during the development of the plant, but it is less than that found in the seeds, whose content may vary from 0.2 to 0.4 g kg⁻¹ of dry matter in sweet genotypes and from 4.7 to 11.3 g kg⁻¹ in bitter genotypes. Hederagenin was the main sapogenin observed in the leaves and oleanolic acid in the seeds. The content of saponins is greater in the pericarp, accounting for 86% of the total present in the grain, showing that peeling can remove most of this substance. The amount of saponins in the quinoa grain is much smaller compared to that found in soybeans and other legumes (Chauhan et al., 1992; Mastebroek et al., 2000; Ando et al., 2002; Abugoch James, 2009).

Due to its characteristic bitter taste, the amount of this substance is usually reduced or removed from the outside of the grain in order to provide better sensory quality and consumer acceptance. Removal is accomplished through a process of selection of sweet varieties or through wet methods (strong washing in cold alkaline water), dry methods (heat treatment, extrusion, roasting or mechanical abrasion) or a combination of both methods (Koziol, 1990, Dini et al., 2001; Brady et al., 2007; Comai et al., 2007, Spehar, 2007; Farro, 2008; Jancurová et al., 2009).

The wet method is the most used household level, and it and can also be used on a commercial scale. However, it has economic and ecological inconvenience due to the large consumption of

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water and the need for drying the grains after washing, besides the contamination of water with saponins waste (Rütte, 1990).

On a commercial scale, the dry method by abrasive peeling is used to remove saponins. However, a disadvantage of this method is the loss of nutrients such as protein, vitamins and minerals, together with the bran. For this reason, the use of the wet method combined with polishing is suggested, which ensures obtaining derivatives of quinoa with effectively reduced saponin contents, minimizing nutrient loss (Chauhan et al., 1992; Lindeboom, 2005; Borges et al., 2010).

4.2 Phytic acid

Due to its high negative charge, phytic acid has been regarded as a component of antinutritional action, capable of chelating bivalent minerals such as calcium, iron, magnesium, zinc and copper, as well as starch, protein and enzyme, compromising the bioavailability of these components. It is mainly found in the peel of most cereals and legumes, in concentrations of 1% to 3% dry matter, constituting the main phosphate reserve of these seeds. It can also be found in some fruits and vegetables (Ruales & Nair, 1993b; Oliveira et al., 2003; Jancurová et al., 2009). Phytic acid is not present only in the outer layers of the quinoa grain, such as in wheat and rye, but it is also distributed uniformly in the endosperm. According to Chauhan et al. (1992), the phytate content was higher in bran than in flour or peel and accounted for 38-41% of total phytate from whole seeds. Values from 10.5 to 13.1 mg g⁻¹ of phytic acid from five different varieties of quinoa were reported by Koziol (1992), values close to those found in barley grains (9.7 to 11.6 mg g⁻¹), corn (from 8.9 to 9.9 mg g⁻¹), rice (8.9 mg g⁻¹) and wheat (6.2 to 13.5 mg g⁻¹)

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¹). While the amount of phytic acid in quinoa is higher than in grains, no adverse effects were observed in the incorporation of calcium in the bones, nor in iron absorption (Koziol, 1992).

The process of removing saponins from quinoa seeds by brushing and rinsing allowed a significant reduction of approximately 30% in the amount of phytic acid. The concentration of phytic acid in non-processed quinoa seed was 10.4 mg g⁻¹, while in processed seeds it was 7.8 mg g⁻¹ compared with values obtained in whole flour grain, such as rye (7.7 mg g⁻¹), wheat (8.7 mg g⁻¹), lentils (8.4 mg g⁻¹) and faba bean (8.0 mg g⁻¹) (Ruales & Nair, 1993b).

The content of phytic acid can be significantly reduced by processes such as steeping, germination and fermentation. The degradation efficiency is higher in processes that promote the activation of phytase, such as fermentation and cooking (Ruales & Nair, 1993b; Oliveira et al., 2003; Khattab & Arntfield, 2009).

As described by Ruales & Nair (1993b), a study in rats showed that the iron bioavailability in washed and polished quinoa is at least equal to the bioavailability of ferrous sulfate. Thus, animal experiments indicate good bioavailability of iron, despite the high content of phytate in quinoa seeds. However, studies in humans are needed to clarify these results.

4.3 Tannins

Tannins are included in the group of polyphenols, natural substances that are more numerous and widely distributed in the plant kingdom. They present as an undesirable biological effect, the ability to form complexes with proteins and other macromolecules, such as starch, for example, reducing the nutritional value of foods. The complexation with proteins is reversible, depending on the pH of the environment, and it may involve hydrophobic bonds and hydrogen bridges (Santos, 2006).

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Other harmful effects are assigned to tannins such as undesirable color to foods due to enzymatic browning reactions and decreased palatability due to astringency, besides other antinutritional effects such as damage to the intestinal mucosa and interference with iron absorption, glucose and vitamin B_{12} (Santos, 2006).

Tannins are present in small amounts in quinoa seeds (0.53%), considerably lower than in rice grains (1.3%), and further reduced after cleaning and rinsing with water. The tannins were higher in peeling (0.92%) compared with bran or flour. However, in the peeled grain, the bran still contained 46-50% of the total tannin of seeds (Chauhan et al., 1992; Jancurová et al., 2009).

Results suggest that the adequate use of washing and preparation steps (cooking) of quinoa grain may reduce the harmful effects of tannins, thus improving the digestibility (Borges et al. 2010).

4.4 Trypsin Inhibitor

Protease inhibitors are proteins widely distributed in nature, which form very stable complexes with proteolytic enzymes. The presence of trypsin inhibitor in the intestinal tract reduces the action of trypsin, which is responsible for the digestion of proteins, leading to increased enzyme production by the pancreas with resultant hypertrophy of this organ and reduction in growth. In human nutrition, such antinutritional factors have little consequence because they are thermolabile and are usually destroyed in the normal conditions of domestic or industrial food preparation (Khattab & Arntfield, 2009; Lopes et al., 2009).

Khattab & Arntfield (2009) obtained a total reduction of this component when submitting different legumes, including beans and peas to washing and soaking in water for a period of 18-22 hours, followed by heat treatments such as boiling, roasting, autoclaving and microwave. This

fact demonstrates that inactivation of this antinutrient in quinoa can be obtained by techniques generally employed in domestic food preparation (Borges et al., 2010).

The concentration of protease inhibitors in quinoa seeds is <50 p.p.m. Quinoa contains small amounts of trypsin inhibitors, much lower than those found in commonly consumed grains, and therefore they do not represent major concerns (Vega-Gálvez et al., 2010). As quoted by Jancurová et al. (2009) and Ruales & Nair (1993b), the contents of this antinutrient in eight varieties of quinoa ranged from 1.36 to 5.04 UTI mg⁻¹, much lower than in soybean (24.5 to 41.5 UTI mg⁻¹), beans (12.9 to 42.8 UTI mg⁻¹) and lentils (17.8 UTI mg⁻¹). Lopes et al. (2009) obtained a level of 2.11 UTI mg⁻¹ for the wholemeal ÷BRS Piabiruøquinoa.

According to Ando et al. (2002), phytates and trypsin inhibitors were higher in embryo of quinoa seeds. The embryo contained 60% of the total phytate and 89% of the trypsin inhibitory activity compared to the whole grain.

4.5 Nitrates

Nitrates are present in all plants and are essential sources of nitrogen for their normal growth. Some plants accumulate this substance in roots and shoots when absorption exceeds their metabolic needs. High levels are found in leaves, especially in mesophyll, but petioles and stems are the locations of maximum accumulation. Moreover, reproductive organs, fruits and seeds are supplied with amino acids via phloem, having, thus, low levels of nitrate. The nitrate present in vegetable may have its origin in used fertilizers or may be formed on the substrate by nitrification or mineralization (Beninni et al., 2002; Santos, 2006).

In the human body, nitrates interfere with the vitamin A metabolism and in the functions of the thyroid gland, and they can be reduced to nitrite and, after absorbed, yield cyanosis due to the

formation of metmyoglobin, or yet react with secondary and tertiary amines, forming potentially carcinogenic N-nitrous compound (Beninni et al., 2002; Santos, 2006; Lopes et al., 2009.).

The levels of nitrate (NO₃) found by Lopes et al. (2009) in quinoa wholemeal ±BRS Piabiruø (63.26 mg 100 g⁻¹) were twice lower than those reported in vegetables such as spinach, lettuce, radishes and beets, whose values are presented above 100 mg 100 g⁻¹ of the fresh produce, proving that quinoa offers no disadvantage to diet and health.

According to Benevides et al. (2011) the acceptable daily intake (ADI) recommended by the World Health Organization (WHO) of nitrate ions and nitrite is 3.7 and 0.06 mg kg⁻¹ of the body weight, respectively. Therefore, for a 60kg adult, the intake of nitrate should not exceed 222 mg day⁻¹ and nitrite 3.6 mg day⁻¹, which corresponds to the consumption of 351 g of quinoa wholemeal -BRS Piabiruø Thus, according to Lopes et al. (2009), the amount of normally consumed flour would not endanger the consumerøs safety.

4.6 Oxalates

Oxalate is a toxic substance and represents a major health risk. It is often found in vegetables such as spinach, beets, chard, rhubarb, tomatoes, nuts and cocoa. It cannot be metabolized by humans and is excreted in the urine. High intake of oxalate in the diet influences the absorption of minerals and trace elements, playing a key role in hyperoxaluria, a risk factor for the formation of calcium oxalate stones in the kidneys, due to the ability of the oxalate to form insoluble complexes with divalent cations in the gastrointestinal tract (Santos, 2006; Jancurová et al., 2009; Lopes et al., 2009).

The oxalic acid has been responsible for a significant number of harmful effects to humans and animals, with highlight to the decreased bioavailability of minerals, gastrointestinal irritation,

muscle contraction or tetany accompanied by other nervous symptoms, decreased ability to clot blood, possible injury to the excretory organs, among others, due to deposition of cell substance with high concentrations of crystalline calcium oxalate (Lopes et al., 2009).

The species belonging to the *Polygonaceae*, *Amaranthaceae* and *Chenopodiaceae* families are included in most vegetables with excessive concentrations of oxalate. Obviously, oxalate accumulates in these plant families, in all plant tissues, namely leaves, stems, roots and hypocotyls seeds. As quoted by Jancurová et al. (2009), the highest oxalate content was found in leaves and stems. The levels of soluble oxalate ranged 59-131 mg 100 g⁻¹ in roots and seeds and 258-1029 mg 100 g⁻¹ in leaves and stems. The total oxalate content ranged 143-232 mg 100 g⁻¹ in roots and seeds and 874-1959 mg 100 g⁻¹ in leaves and stems (Jancurová et al., 2009).

The quinoa wholemeal -BRS Piabiruø studied by Lopes et al. (2009) presented lower levels of oxalic acid (380 mg 100 g⁻¹) in relation to other foods of the same family, such as spinach (822 mg 100 g⁻¹) and close to beet (328 mg 100 g⁻¹). According to the authors, it is estimated that a normal diet should contain 50-200 mg day⁻¹ of oxalates. High levels of oxalate foods have been identified in the *Chenopodiacceae* and *Polygonacceae* families, such as spinach, rhubarb and beets. However, the levels of oxalic acid in some species of these families, such as quinoa, are scarce in the literature.

5. FINAL COMMENTS

Quinoa is a very interesting food because of its nutritional characteristics. Has been recognized as a complete food due to its protein quality, mainly, by its excellent amino acid balance. It is rich in the essential amino acid lysine, making it a more complete protein than many vegetables.

Quinoa is gluten-free, so it can be consumed by people who have celiac disease as well as by those who are allergic to wheat. The oil fraction of the seeds is of high quality and highly nutritional value. It is also rich in iron and magnesium and provides fiber, vitamin E, copper, phosphorus, potassium and zinc as well as some B vitamins.

Besides being an important source of minerals and vitamins, quinoa has also been found to contain compounds like polyphenols, phytosterols, and flavonoids with possible nutraceutical benefits. Quinoa starch has physicochemical properties, such as viscosity and freeze stability, which give it functional properties with novel uses.

Although quinoa grains show some antinutritional factors, these are easily removed during the manufacturing process or by the use of appropriate handling techniques and home preparation, usually applied to most grains used as food. Despite studies have demonstrated the effectiveness of the heat treatment in reducing the antinutritional factors, this process has some disadvantages such as loss of essential nutrients such as vitamins, minerals and amino acids, among others.

Therefore, Quinoa has a high nutritional value and has recently been used as a novel functional food because of all these properties becoming a very promising alternative cultivar.

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Table 1. Crude protein, lipid, fiber and digestibility of quinoa components, 84 days after emergence.

Component	Crude protein	Lipids	Fiber	Digestibility
Panicle	23.45	5.03	27.84	87.32
Leave	18.54	4.53	27.84	74.95
Stem	3.84	1.08	72.99	37.34

Source: Spehar (2007)

Table 2. Approximate composition in genotypes of quinoa grain (g 100 g⁻¹ dm).

References										
Component	Kozio€	Dini et	Wright et	Ogungbenle	USDA					
		al.	al.							
	(1992)	(1992)	(2002)	(2003)	(2011)					
Protein	16.5	13.7	16.7	15.2	16.3					
Lipids	6.3	14.5	5.5	7.1	7.0					
Ashes	3.8	3.5	3.2	1.4	2.7					
Carbohydrates	69.0	65.7	74.7	65.6	74.0					
Fiber	3.8	2.6	10.5	10.7	7.0					

Table 3. Approximate average composition of the quinoa grains compared to cereals (g 100 g⁻¹ dm).

Component	Quinoa ^c	Rice ^c	Barley ^c	Wheat ^c	Corn ^c	Rye ^c	Sorghum ^c
Lipids	7.0	3.2	1.3	2.8	5.3	1.8	3.6
Protein	16.3	8.8	11.0	14.8	10.5	11.6	12.4
Ashes	2.7	1.7	1.2	1.8	1.3	1.8	1.7
Dietary fiber	7.0	3.5	15.6	10.7	7.3	15.1	6.3
^a Carbohydrates	74.0	86.3	86.5	80.6	82.9	84.8	82.3
^b Kcal 100 g ⁻¹	424.2	409.2	401.7	406.8	421.3	401.8	411.2

^aCarbohydrates calculated by difference = [100 \u00f3 (% lipids + % protein + % ashes)]

^bKcal 100 g⁻¹ dm: 4x(% protein + % carbohydrate) + 9x(% fat)

^cUsda (2011)

Table 4. Composition of essential amino acids in quinoa, cereals, legumes, meat and milk, in relation to the FAO standard (g amino acid 100 g^{-1} protein).

Amino acid	Quinoa	Rice	Corn	Wheat	Bean	Meat	Milk	Standard
								(FAO)
Phenylalanine	4.0	5.0	4.7	4.8	5.4	4.1	1.4	6.0
Isoleucine	4.9	4.1	4.0	4.2	4.5	5.2	10.0	4.0
Leucine	6.6	8.2	12.5	6.8	8.1	8.2	6.5	7.0
Lysine	6.0	3.8	2.9	2.6	7.0	8.7	7.9	5.5
Methionine	2.3	2.2	2.0	1.4	1.2	2.5	2.5	3.5
Threonine	3.7	3.8	3.8	2.8	3.9	4.4	4.7	4.0
Tryptophan	0.9	1.1	0.7	1.2	1.1	1.2	1.4	1.0
Valine	4.5	6.1	5.0	4.4	5.0	5.5	7.0	5.0

Source: Spehar (2007).

Table 5. Composition of lipids fatty acids present in quinoa seeds, soybeans and corn.

Fatty Acids	Quinoa ^a	Soy ^b	Corn ^b						
Saturated									
Mirystic C14:0	0.1 ó 2.4	traces	traces						
Palmitic C16:0	9.2 ó 11.1	10.7	10.7						
Stearic C18:0	0.6 ó 1.1	3.6	2.8						
Monounsaturated	<u>I</u>	<u> </u>							
Myristoleic C14:1	1.0	ó	ó						
Palmitoleic C16:1	0.2 ó 1.2	0.2	traces						
Oleic C18:1	22.8 6 29.5	22.0	26.1						
Polyunsaturated (PUFA)									
Linoleic C18:2 (n - 6)	48.1 ó 52.3	56.0	57.7						
Linolenic C18:3 (<i>n</i> - 3)	4.6 ó 8.0	7.0	2.2						

Sources: ^aMasson and Mella (1985), cited by Abugoch James (2009).

^bUsda (2011).

Table 6. Concentrations of vitamins in quinoa grains and other cereals (mg 100 g⁻¹).

Vitamin	Quinoaª	Quinoab	Quinoa ^c	Rice ^c	Oat ^c	Wheat ^c
	(bs)	(bs)	(bu)	(bu)	(bu)	(bu)
Thiamine (B ₁)	0.38	0.40	0.36	0.40	0.76	0.50
Riboflavin (B ₂)	0.39	0.20	0.32	0.09	1.39	0.16
Niacin	1.06	ni	1.52	5.09	0.96	4.96
Pyridoxine (B ₆)	ni	ni	0.49	0.51	0.12	0.41
Pantothenic acid	ni	ni	0.77	1.49	1.35	0.60
Ascorbic acid (C)	4.00	16.40	ni	nd	nd	nd
Total folates (g 100 g ⁻¹)	ni	78.10	184.00	20.00	56.00	44.00
-tocopherol (E)	5.37	2.60	2.44	1.20	ni	0.71
-tocopherol	ni	0.20	0.08	nd	ni	0.23
-tocopherol	ni	5.30	4.55	nd	ni	1.91
-tocopherol	ni	0.30	0.35	nd	ni	nd
-Carotene (g 100 g ⁻¹)	0.39	ni	8.00	nd	ni	5.00
Vitamin A (μg RE 100 g ⁻¹)	ni	200	1.00	nd	nd	nd
Vitamin A (UI)	ni	ni	14	nd	nd	9

Sources: aKoziol (1992); bRuales & Nair (1993a); cUsda (2011).

ni = not informed.

nd = not detected.

Table 7. Mineral composition of quinoa (mg kg⁻¹ dm).

	Minerals									
References	Ca	P	Mg	Fe	Zn	K	Cu			
Kozio€(1992)	1487	3837	2496	132	44	9267	51			
Repo-Carrasco et al.	940	1400	2700	168	48	nd	37			
(2003)										
Ruales & Nair (1993a)	874	5350	2620	81	36	12000	10			
Bhargava et al. (2006)	1274	3869	nd	20	48	6967	nd			
Konishi et al. (2004)	863	4110	5020	150	40	7320	nd			
Ando et al. (2002)	1213	3595	4526	95	8	8257	7			
Chauhan et al. (1992)	1100	3600	5000	92	8	9000	9.5			
Ogungbenle (2003)	860	220	2320	26	38	7140	75			
González et al. (1989)	1020	1400	nd	105	nd	8225	nd			

nd = not determined

Table 8. Content of minerals in cereals and quinoa grains (mg/100 g dm).

Mineral	wheat	barley	oat	rye	triticale	rice	quinoa
Ca	48	52	94	49	37	15	94
Mg	152	145	138	138	147	118	270
Na	4	49	28	10	9	30	11.5
P	387	356	385	428	487	260	140
Fe	4.6	4.6	6.2	4.4	6.5	2.8	16.8
Cu	0.6	0.7	0.5	0.7	0.8	0.4	3.7
Zn	3.3	3.1	3.0	2.0	3.3	1.8	4.8

Source: Repo-Carrasco et al., 2003.