The Nutritional Applications of Quinoa Seeds

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Abstract

As global population increases, food crops, which at a particular time appeared to be neglected or lesser known, begins to gain recognition. *Chenopodium quinoa* (Willd.) (quinoa) belongs to the family Amaranthaceae; it is regarded as a pseudocereal that is a natural to the Andean regions and is adaptable to diverse soil types and climatic conditions. Its high nutritional composition has stirred up enormous attention from the scientific community. Quinoa is very rich in dietary fiber, proteins, vitamins, unsaturated fats, and minerals, having an astonishing equilibrium of very essential amino acids, similarly branded as being a gluten-free grain, which permits its usage in the nutrition of celiac patients. Saponins, protease, and phytic acid inhibitors are among the utmost antinutrients found in quinoa seeds. Saponins happen to be the most dominant and are present in the exterior coating of the seeds, where they are responsible for the seed's characteristic bitter taste. However, several researchers have tried to develop methods of saponin removal in seeds without altering the nutrient composition of the seeds significantly; this includes washing the seeds in cold water. Research shows that consumption of quinoa gave positive results against the antibodies of wheat proteins, thus suggesting that people with wheat protein allergies could consume quinoa. As a product of significance with regard to its mineral composition and phytochemicals, it is pertinent that more research should be carried out to come up with appropriate methods of propagation, distribution, and preparation to help solve the issue of malnutrition worldwide, especially in Africa and Asia where the production of food is constantly being threatened by environmental stress and global climate change.

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Keywords

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3.1 Introduction

Chenopodium quinoa (Willd.) (quinoa) belongs to the family Amaranthaceae; it is regarded as a pseudocereal which is a natural to the Andean regions of Peru, Bolivia, Ecuador, and Chile and is adaptable to diverse soil types and climatic conditions. Its high nutritional composition has stirred up enormous attention from the scientific community. Quinoa is appropriately rich in dietary fiber, proteins, vitamins, unsaturated fats, and minerals, having an astonishing equilibrium of very essential amino acids, similarly branded as being a gluten-free grain, which permits its usage in the nutrition of celiac patients (Alvarez-Jubete et al. 2010a, b; Maradini-Filho et al. 2017). The cultivation of quinoa can be dated back to about 1000 years in the Andean region (Peru, Chile, Ecuador, and Bolivia) (Galvez Ranilla et al. 2009; Jancurová et al. 2009). In these regions, it is known by various local and common names, or it can simply or generally be referred to as "quinoa" (Vega-Gálvez et al. 2010). The Incas refers to quinoa as "a gift from the god" and "the mother of grains," which they use traditionally in treating various medical problems. Quinoa seeds can be consumed traditionally as cereal, cooked, roasted, sometimes supplemented to soups, and often fermented and made into beer or a local traditional drink by the Andes known as "chichi" (Vega-Gálvez et al. 2010; Bazile et al. 2014; Cooper 2015). Similar to spinach, quinoa leaves can be consumed in like manner (Oelke et al. 1992); young seedling sprouts are important components of salads (Schlick and Bubenheim 1996); quinoa whole plant stalks make up pig, poultry, and cattle feeds because of its excess nutritional value (Bhargava et al. 2006).

3.2 Nutritional Profile/Value of *Chenopodium quinoa* (Quinoa)

Quinoa possesses a very high level of protein which is very much comparable to those found in milk, and reports put its rate higher than values reportedly contained in other cereals, namely, maize, wheat, and rice; the National Aeronautics and Space Administration (NASA) deployed extensively the use of quinoa to meet the requirements for astronauts on missions in space because of the versatile nature of quinoa (Koziol 1992; Asao and Watanabe 2010; Cooper 2015).

Quinoa seeds are generally consumed in the same manner as other grains. It can be pulverized into flour and used to make bread, it is also cooked or supplemented in soups, and it can as well be fermented into drinks or beer. Note also that quinoa is a very decent source of minerals, proteins, dietary fiber, and polyunsaturated fats. Experts advise that although quinoa is endowed with all these nutrients, to achieve a decent inclusive nutrition, quinoa should be consumed as part of a balanced diet comprising several other food types. As regards the nutrition of quinoa, it is

equivalent with regard to energy to correspondingly other consumable foods like maize, wheat, or rice as presented in Table 3.1.

3.3 Protein/Amino Acid Composition of Quinoa

Proteins are considered as a key biological macromolecules which catalyzes several enzymatic reactions; it also serves as a structural element, an energy source, and a component in the synthesis of protein (Morrison and Laeger 2015; Lee et al. 2015). Quinoa is abundantly rich in proteins; this puts its worth among the finest sources of protein for human consumption. The biological protein value measures the quantity of protein absorbed from a food, which is then assimilated into human body proteins.

Quinoa protein content value is very high and ranges from about 13 to 17%, depending on the variety (Filho et al. 2015). Quinoa's biological value is very high, about 73%, comparable to that obtained in beef which is 74% and higher than those obtained in rice (56%), corn (36%), and wheat (49%) (Gordillo-Bastidas et al. 2016). According to the World Health Organization (WHO) and the Food and Agriculture Organization (FAO), the protein obtained from quinoa can meet 100% of the day-to-day recommended ingestion of essential amino acids for humans (Reyes-Montaño et al. 2006; Jyoti and Chanu 2018). It is a well-known fact that amino acids make up proteins; eight of such amino acids are regarded as very essential for both children and adults. Table 3.2 shows the essential amino acid composition of quinoa seeds compared with that of other seeds.

3.4 Lipids/Fatty Acid Composition of Quinoa

Aside from possessing a good and high portion of biological quality of protein, quinoa also has an appropriate and remarkable composition of lipids. Quinoa seeds have an oil composition that varies between 2 and 10%, comprising very vital fatty acids like α-linolenic and linoleic acids (Jyoti and Chanu 2018); quinoa correspondingly has extraordinary concentrations of natural antioxidants, including α- and γ-tocopherol (Maradini-Filho et al. 2017), in an comestible proportion similar or higher than that found in rice, wheat, and corn (Jyoti and Chanu 2018); this makes quinoa a crop that can be consumed for its rich and readily available lipids (Navruz-Varli and Sanlier 2016).

The utmost essential fractions established in quinoa include diglycerides and triglycerides, which account for about 20 and 50%, respectively, for the neutral lipids found in quinoa seeds (Przybylski et al. 1994; Blanca 2019). When considering the total polar lipids in quinoa seeds, lysophosphatidylethanolamine and phosphatidylcholine make up 57% of the entire polar lipids; this makes them the most abundant (Blanca 2019). The fatty acids present in quinoa seeds are principally polyunsaturated and monounsaturated, making up about 55 and 27%, respectively; however, 12% of the entire fatty acids in quinoa is represented by saturated acids as shown in Table 3.3 (Blanca 2019).

Table 3.1 Comparative nutritional profile of quinoa seeds with that of other cereals

Food	Energy (Kcal)	Carbohydrate (g/100 g)	Protein (g/100 g)	Lipids (g/100 g)	Fiber (g/100 g)	Unsaturated fatty acids (g/100 g)	Essential amino acids (number)
Quinoa	368	64.12	14.1	1.92	2.8–10	1.61	10/10
Rice	365	79.95	6.6	0.21	0.3	0.12	9/10
Wheat	340	71.97	13.7	0.66	4.23	0.35	10/10
Maize	365	74.26	9.4	1.5	2.4	0.98	9/10

Sources: Gordillo-Bastidas et al. (2016); USDA (2015, 2017); Jyoti and Chanu (2018)

Table 3.2 Essential amino acid composition of quinoa seeds likened to other cereals

g/100 g edible portion	Quinoa	Maize	Wheat	Rice
Phenylalanine	0.59	0.46	0.68	0.35
Tryptophan	0.17	0.07	0.18	0.08
Threonine	0.45	0.35	0.37	0.24
Tyrosine	0.27	0.38	0.36	0.22
Isoleucine	0.50	0.34	0.53	0.29
Valine	0.59	0.48	0.59	0.40
Leucine	0.84	1.16	0.93	0.55
Arginine	1.09	0.47	0.48	0.55
Lysine	0.77	0.27	0.30	0.34
Histidine	0.41	0.29	0.32	0.16
Methionine	0.31	0.20	0.22	0.16
Alanine	0.59	0.71	0.43	0.38
Cysteine	0.20	0.17	0.29	0.14
Aspartic acid	1.13	0.66	0.62	0.62
Glycine	0.69	0.39	0.50	0.30
Glutamic acid	1.87	1.77	4.74	1.29
Proline	0.77	0.82	1.46	0.31
Serine	0.57	0.45	0.65	0.35

Sources: USDA (2018); Blanca (2019)

Table 3.3 Fatty acid composition of quinoa seeds likened to other cereals

g/100 g edible portion	Quinoa	Maize	Wheat	Rice	Sources
Linoleic/α-linolenic	5.8–13.8	–	14.5	nr	Beatriz and Suzana (2012); Bruni et al. (2001); Alvarez-Jubete et al. (2009).
Oleic acid	24.5–26.7	29.8	13.2	nr	
Linolenic acid	3.8–8.3	0.9	3.8	nr	
Eicosenoic acid	1.4	–	–	nr	
Myristic acid	0.1	0.2	–	nr	
9-Docosenoic acid	1.2–1.5	–	nd	nr	
Tetracosenoic acid	2.4–2.6	–	–	–	
Saturated	0.71	0.67	0.45	0.16	USDA (2018); Blanca (2019)
Monounsaturated	1.61	1.25	0.34	0.18	
Polyunsaturated	3.29	2.16	0.98	0.16	

nd not detected, *nr* not reported

3.5 Carbohydrate Composition of Quinoa

Reports have indicated that about 50–70% of biological energy obtained through diets are contributed by carbohydrates and its associated components (Beatriz and Suzana 2012). Based on the degree of polymerization, carbohydrates are classified into three major groups, namely, sugars (monosaccharides, disaccharides, polyols), oligosaccharides, and polysaccharides (starch and non-starch) (Copeland 2009; Beatriz and Suzana 2012).

Quinoa's carbohydrate composition is reported to be between 52 and 74% (dm) (Maradini-Filho 2017). This is still within the range of 58–64.2% of the dry weight also reported by Repo-Carrasco et al. (2003) and Blanca (2019). Quinoa seeds contain carbohydrate contents slightly lower than or similar to those found in maize, rice, and wheat (Table 3.1); however, its monosaccharide subunit composition can be preferably compared to similar quantity found in vegetables, fruits, and legumes (Maradini-Filho et al. 2017). Quinoa seed grains contain free disaccharides like sucrose (2.90 g/100 g dry weight) and maltose (1.40 g/100 g dry weight) and monosaccharides such as glucose (1.70 g/100 g dry weight) and fructose (0.20 g/100 g dry weight) (Repo-Carrasco et al. 2003; Blanca 2019). The starch quinoa is polygonal, which is much smaller in size in comparison to those found in other common cereals with a diameter of about 0.6–2.2 μm (Tari et al. 2003; Maradini-Filho et al. 2017; Maradini-Filho 2017). It can as well be used as thickeners in frozen food because of its rich contents of amylopectin, which gives it exceptional freeze-thaw stability (Tang et al. 2002; Maradini-Filho 2017).

3.6 Dietary Fiber Content of Quinoa

Quinoa has been reported to contain high dietary fiber. The percentage of plant food which is indigestible is referred to as "dietary fiber"; it aids proper digestion and prevents constipation. The dietary fiber composition of quinoa seeds is in close range with that found in other cereals; however, higher levels have been reported within embryos than the reported levels found within the perisperm (James 2009; Maradini-Filho et al. 2017; Maradini-Filho 2017). Lamothe et al. (2015), USDA (2018), and Blanca (2019) reported a scale of 7–10% of the total dietary fiber present in quinoa seeds. Repo-Carrasco-Valencia and Serna (2011) while studying about the four variations of quinoa reported a similar scale of dietary fiber in raw quinoa as 13.6–16.0 g/100 g dry weight. They also reported that most of the dietary fibers in the study were insoluble ranging from 12.0 to 14.4 g when matched to 1.4–1.6 g of soluble fiber per 100 g dry weight. Quinoa's dietary fiber contents just like its protein composition are usually higher than that of most of the other common grains but generally lower than that of legumes.

Quinoa is known to possess fiber content in high quantity, which aids in the relief of constipation. Improvement of food digestibility has been recounted as a function of the fiber content in quinoa, which is high and facilitates in the absorption of additional nutrients existent in quinoa (Ogungbenle 2003; Maradini-Filho et al.

2017; Maradini-Filho 2017). It also aids in the prevention of diseases of the heart as a consequence of its reduction effect on high blood pressure and diabetes (Shilpi et al. 2016). Shilpi et al. (2016) also reported that cholesterol is lowered by dietary fiber and glucose levels, ultimately leading to an abridged risk of the development of hemorrhoid and supporting weight loss.

3.7 Mineral Contents of Quinoa

Quinoa seeds, on average, have a high and better concentration of mineral nutrients than the majority of our common cereals, which is very essential for balanced diet to be maintained (Thoufeek et al. 1998). Quinoa seeds have abundant potassium, calcium, and phosphorus; magnesium, zinc, and iron can also be obtained in good quantities (Thoufeek et al. 1998) (Table 3.4). Quinoa seeds are also very rich in micronutrients as well; differences in values of macro- and micronutrients found in the seeds may be influenced by the variety of seeds and farming practices employed and also environmental conditions (Alvarez-Jubete et al. 2009; Jyoti and Chanu 2018). Quinoa seeds have calcium and potassium contents that can contribute to about 10% and 18–22% of the requirements needed by infants and adults, respectively (Comai et al. 2007; Abugoch 2009; Beatriz and Suzana 2012; Blanca 2019).

The deficiency of iron happens to be a major nutritional issue. Iron plays a lot of beneficial roles in the body of humans; it improves brain function and aids in the transport of oxygen from one cell to another (Shilpi et al. 2016). More so, just like any other food plant, quinoa seeds comprise some non-nutritive constituents that reduce mineral content and uptake. The exterior layer of quinoa seeds has a certain content of saponins that is responsible for its bitter taste, which is eliminated during treatment. Oxalate is also found in high concentration in quinoa seeds; this antioxidant is accountable for the reduction of uptake or absorption of minerals like magnesium and calcium when it binds to them (Siener et al. 2006).

3.8 Vitamin Composition of Quinoa

The Committee on Dietary Allowances postulated certain vitamin requirements which quinoa seeds satisfy effortlessly (Thoufeek et al. 1998). Quinoa seeds possess a very good portion of thiamine, B vitamin riboflavin, vitamin C, pantothenic acid, vitamin E, and folic acid (Table 3.5), even though the quantity of vitamin E seems to decline after processing (Koziol 1992). Folic acid aids decent emotional and mental health as it plays a vital role in proper brain functioning (Shilpi et al. 2016); similarly, riboflavin provides and increases brain energy metabolism and that of the muscle cells (Shilpi et al. 2016).

Table 3.4 Macro- and micronutrient composition of quinoa seeds likened to other cereals

mg/100 g edible portion	Macronutrients				Micronutrients			
	Potassium	Magnesium	Phosphorus	Calcium	Copper	Zinc	Iron	Manganese
Quinoa	563.0	197.0	383.7	148.7	0.6	4.4	4.6	2.0
Maize	287.0	127.0	292.6	17.1	0.3	2.9	2.7	0.5
Wheat	431.0	144.0	467.7	50.3	0.6	4.7	3.5	3.0
Rice	86.0	35.0	137.8	6.9	0.1	0.6	0.8	1.1
Sources	USDA (2018); Blanca (2019)	USDA (2018); Blanca (2019)	Koziol (1992); Shilpi et al. (2016)	Koziol (1992); Shilpi et al. (2016)	USDA (2018); Blanca (2019)	Koziol (1992); Shilpi et al. (2016)	USDA (2018); Blanca (2019)	USDA (2018); Blanca (2019)

Table 3.5 Vitamin composition of quinoa seeds likened to other cereals

	Vitamin C (mg/100 g)	Thiamine (B_1) (μg/100 g)	Riboflavin (B_2) (μg/100 g)	Folic acid (mg/kg DW)	Vitamin A (μg/100 g)	β-carotene (μg/100 g)	Pantothenic acid (μg/100 g)	Vitamin E (μg/1 g)
Quinoa	1.4	0.36	0.32	0.078	1.0	8.0	0.77	37.49–59.82
Maize	nr	0.39	0.20	0.026	11.0	nr	nr	nr
Wheat	nr	0.42	0.12	0.078	0.0	nr	0.94	nr
Rice	nr	0.07	0.05	0.02	nr	nr	1.34	nr
Sources	Gordillo-Bastidas et al. (2016)	USDA (2018); Blanca (2019)	USDA (2018); Blanca (2019)	Koziol (1992); Shilpi et al. (2016)	USDA (2018); Blanca (2019)	USDA (2018); Blanca (2019)	USDA (2018); Blanca (2019)	Gordillo-Bastidas et al. (2016)

nr not reported

3.9 Antinutritional Contents of Quinoa

Among the key and most commonly found antinutrients in quinoa seeds are saponins, phytic acid, and protease inhibitors (Thoufeek et al. 1998). The saponins found in quinoa seeds give the seeds its characteristic bitter taste, which occasionally results in gastric irritation (Gordillo-Bastidas et al. 2016). Saponin contents in quinoa seeds due to their varied nature (ranging from 0.1 to 5%) may be classified, agreeing to its free saponin levels, as either sweet (<0.11%) or bitter (>0.11%) quinoa (Gordillo-Bastidas et al. 2016). Chauhan et al. (1992) presented in their results that 34% of the total saponins are sited in the hulls of quinoa seeds and can be removed by dehulling.

3.9.1 Saponins

Saponins are largely spread among plant kingdom as one of the numerous key secondary metabolites found in plant seeds, roots, leaves, stems, and fruits. They are synthesized in plants basically for protection of the plants against harmful microorganisms and pest (Singh and Kaur 2018).

The high concentration of saponins in seeds of quinoa is responsible for its characteristic bitter taste, which occasionally results in gastric irritation. The saponin levels in quinoa seeds range from 0.1 to 5%. Quinoa seeds are oftentimes classified according to taste based on free saponins found in the seeds; it can be regarded as bitter when its free saponin level is >0.11% or sweet when its free saponin level is <0.11% (Gordillo-Bastidas et al. 2016). However, several researchers have tried to develop methods of saponin removal in quinoa seeds without altering the seeds' nutrient composition significantly; the predominantly used of all includes washing the seeds in water (cold) (Maradini-Filho et al. 2017; Gordillo-Bastidas et al. 2016).

3.9.2 Phytic Acid

In most plant tissues, phytic acid, which is regarded as a saturated cyclic acid, happens to be the primary storing form of phosphorus. Food substances have high contents of phytic acids; the minerals are rendered unavailable for metabolic processes because the acid binds the minerals (Fardet 2010; Gupta et al. 2015). When the phytic acid composition of quinoa seeds is compared to that of other cereals, it is observed that quinoa seeds hold a very low quantity of phytic acid, which ranges between 10.5 and 13.5 mg compared to wheat (390 mg), rice (60 mg), and corn (720 mg) (Vega-Gálvez et al. 2010).

3.10 Quinoa Seeds as Gluten-Free Diets

In 2013, a survey was carried out, and it was reported that in the United States alone, about one third of its population are trying to either minimize or avoid the intake of gluten (Shilpi et al. 2016). Gluten occurs as a complex of the proteins gliadin and glutenin (Zevallos et al. 2014); it is an ample constituent of most food substances which includes grains (Tovoli et al. 2015; Gordillo-Bastidas et al. 2016).

The occurrence of celiac disease, which is a genetic autoimmune disorder, happens when excessive consumption of diets rich in gluten results in injury of the small intestine (Shilpi et al. 2016). Estimate has it that this disease affects 1 out of every 100 people all over the world (Shilpi et al. 2016). Thus, celiac disease patients as a matter of urgency are required to consume gluten-free diets (Shilpi et al. 2016).

Several researchers have given a thought to the use of quinoa seeds as a very appropriate component for diets that are free from gluten (Shilpi et al. 2016). Quinoa seed's high composition of minerals and vitamins makes it a suitable candidate for any gluten-free healthy diet (Pellegrini and Agostoni 2014; Peñas et al. 2014); quinoa seeds are also rated as products free from gluten by the *Codex Alimentarius* nomenclature based on its gluten content (<20 mg/kg) (Zevallos et al. 2014).

3.11 Quinoa Seeds' Glycemic Index (GI)

Glycemic index may be regarded as a degree of how levels of sugar in blood are raised by food or the measure of how fast carbohydrates raise the levels of sugar in blood, which is usually on a measure of 0–100 usually after 2 h of consumption (Gordillo-Bastidas et al. 2016; Shilpi et al. 2016); glycemic points are classified as low (<55), moderate (56–69), and high (>70) (Gordillo-Bastidas et al. 2016; Shilpi et al. 2016). A major advantage of low glycemic foods includes the improvement of glucose and also lipid levels, also essential in weight control. Low glycemic foods also lead to reduction in the resistance to insulin and lower the risk of diabetes, cardiovascular diseases, and also cancers (Atkinson et al. 2008; Maki and Phillips 2015).

Quinoa seeds' glycemic index ranges from 35 to 53, which depends on the method and duration of cooking. Atkinson et al. (2008) reported that quinoa seeds of about 150 g cooked and then refrigerated before being reheated for about 1.5 min in a microwave maintained a glycemic index of 53; thus, if quinoa is overcooked, it will maintain a very low glycemic index.

3.12 Cooking, Applications, and Utilization of Quinoa Seeds

Recently, quinoa seeds, alongside its products, are readily available at many grocery stores, health food stores, and supermarkets worldwide. Even though some packaged quinoa found in supermarkets are already rinsed, it is important to always rinse quinoa seeds before preparation to remove saponins, the antinutrients that are

existent in the exterior coating of the seed, as this will get rid of the bitter taste. The seeds of quinoa are processed via several methods, which include drum drying, extrusion, and autoclaving (Gordillo-Bastidas et al. 2016).

Quinoa has over a hundred recipes. Firstly, the seeds of quinoa may be ground into flour and used to make cakes and biscuits. Generally quinoa in most cases is a very good substitute for rice in some recipes because it is high in essential minerals and vitamins; more so, it provides about 16% iron value that is required daily. It has also been reported that in meatloaf recipes, quinoa is often used as a suitable substitute for bread crumbs, which will give the bread a nutlike flavor and texture (Shilpi et al. 2016).

In the food industry, there have been several applications and usage of quinoa in the preparation and manufacturing of several food products such as breads, pasta, beverages, beer, breakfast cereals, bars, soups, diet supplements, sauces, cookies, snacks, muffins, etc. because quinoa possesses a very good oil and water holding capacity, which makes it very suitable for the formulation of human food and drinks (Jyoti and Chanu 2018).

3.13 Allergenicity Associated with Quinoa Seeds

Asao and Watanabe (2010) reported that the consumption of quinoa gave positive results against the antibodies of wheat proteins, thus suggesting that people with wheat protein allergies could consume quinoa. In contrast, Astier et al. (2009) reported a single instance in France where a 52-year-old man showed anaphylaxis to quinoa. He developed a general reaction that included dysphonia, dysphagia, angioedema, and urticarial after eating quinoa with bread and fish. Only quinoa out of all the food samples he ingested revealed immunoglobulin E (IgE) reactivity in his serum (Astier et al. 2009).

3.14 Conclusion and Future Perspective

Quinoa grains have been of interest to the people of the Andean regions of Peru, Chile, Ecuador, and Bolivia since the early 1970, because proteins are found in abundance in quinoa primarily, which is very useful in countries where quality and appropriate amount of protein are lacking. It also has a very high value of dietary fiber and also in polyunsaturated fatty acids, which has been reported to have the potentials of treating cardiovascular disease, obesity, and hypercholesterolemia (Jyoti and Chanu 2018). Most cereals are lacking when it comes to certain essential amino acids, which are present in abundance in quinoa seeds. Also, the natural quinoa possesses some natural antioxidants which preclude degenerative disorders. Saponin happens to be the foremost antinutrient aside from phytic acid, which is associated with quinoa. This saponin is similarly accountable for the bitter tastes in quinoa, in which the bitterness and the saponin levels can be reduced either by boiling, soaking, or washing.

With regard to the significance of quinoa in relation to its mineral composition and phytochemicals, it is pertinent that more research should be carried out to come up with appropriate methods of propagation, distribution, and preparation to help decipher the difficult issues of malnutrition worldwide, especially in Africa and Asia where the production of food is constantly being threatened by environmental stress and global climate change. By doing so, health conditions of several populace worldwide living below and within the poverty mark will be enhanced.

References

Abugoch JLE (2009) Quinoa (Chenopodium quinoa Willd.): composition, chemistry, nutritional, and functional properties. Adv Food Nutr Res 58:1–31

Alvarez-Jubete L, Arendt EK, Gallagher E (2009) Nutritive value and chemical composition of pseudocereals as gluten-free ingredients. Int J Food Sci Nutr 60:240–257

Alvarez-Jubete L, Auty M, Arendt EK, Gallagher E (2010a) Baking properties and microstructure of pseudo-cereal flours in gluten-free bread formulations. Eur Food Res Technol 230:437–445

Alvarez-Jubete L, Wijngaard H, Arendt EK, Gallagher E (2010b) Polyphenol composition and in vitro antioxidant activity of amaranth, quinoa, buckwheat and wheat as affected by sprouting and baking. Food Chem 119:770–778

Asao M, Watanabe K (2010) Functional and bioactive properties of quinoa and amaranth. Food Sci Technol Res 16:163–168

Astier C, Moneret-Vautrin DA, Puillandre E, Bihain BE (2009) First case report of anaphylaxis to quinoa, a novel food in France. Allergy 64:819–820

Atkinson FS, Foster-Powell K, Brand Miller JC (2008) International tables of glycemic index and glycemic load values. Diabetes Care 31:2281–2283

Bazile D, Bertero D, Nieto C (2014) Estado del arte de la quinua en el mundo en 2013: FAO (Santiago de Chile) y CIRAD (Montpellier, Francia). Perspectiv as Nutracéuticas de la Quinua: Propiedades Biológicas y aplicaciones funcionales. FAO, pp 341–357

Beatriz V-Y, Suzana CL (2012) Applications of quinoa (*Chenopodium Quinoa* Willd.) and Amaranth (*Amaranthus spp.)* and their influence in the nutritional value of cereal based foods. Food Public Health 2:265–275

Bhargava A, Shukla S, Ohri D (2006) *Chenopodium quinoa*—an Indian perspective. Ind Crop Prod 23:73–87

Blanca H-L (2019) Quinoa (*Chenopodium quinoa* Willd.) as a source of nutrients and bioactive compounds: a review. Bioactive Compds Health Dis 2:27–47

Bruni R, Medici A, Guerrini A, Scalia S, Poli F, Muzzoli M, Sacchetti G (2001) Wild *Amaranthus caudatus* seed oil, a nutraceutical resource from Ecuadorian flora. J Agric Food Chem 49:5455–5460

Chauhan GS, Eskin NAM, Tkachuk R (1992) Nutrients and antinutrients in quinoa seed. Cereal Chem 69:85–88

Comai S, Bertazzo A, Bailoni L, Zancato M, Costa C, Allegri G (2007) The content of proteic and nonproteic (free and protein-bound) tryptophan in quinoa and cereal flours. Food Chem 100:1350–1355

Cooper R (2015) Re-discovering ancient wheat varieties as functional foods. J Tradit Complement Med 5:138–143

Copeland L (2009) Structural characterization of wheat starch granules differing in amylase content and functional characteristics. Carbohydr Polym 75:705–711

Fardet A (2010) New hypotheses for the health-protective mechanisms of whole-grain cereals: what is beyond fibre? Nutr Res Rev 23:65–134

Filho AM, Pirozi MR, Borges JT, Pinheiro HM, Chaves JB, Coimbra JS (2015) Quinoa: nutritional, functional and antinutritional aspects. Crit Rev Food Sci Nutr. https://doi.org/10.1080/10408398.2014.1001811

Galvez Ranilla L, Apostolidis E, Genoveses MI, Lajolo FM, Shetty K (2009) Evaluation of indigenous grains from the Peruvian Andean region for antidiabetes and antihypertension potential using in vitro methods. J Med Food 12:704–713

Gordillo-Bastidas E, Diaz-Rizzolo DA, Roura E, Massanes T, Gomis R (2016) Quinoa (*Chenopodium quinoa* Willd), from nutritional value to potential health benefits: an integrated review. J Nutr Food Sci 6:497

Gupta RK, Gangoliya SS, Singh NK (2015) Reduction of phytic acid and enhancement of bioavailable micronutrients in food grains. J Food Sci Technol 52:676–684

James LAE (2009) Quinoa (*Chenopodium quinoa* Willd.): composition, chemistry, nutritional and functional properties. Adv Food Nutr Res 58:1–31

Jancurová M, Minarovicova L, Dandar A (2009) Quinoa—a review. Czech J Food Sci 27:71–79

Jyoti G, Chanu H (2018) Quinoa (*Chenopodium quinoa* Willd.)—the forgotten golden grain. Int J Food Nutr Sci 7:1–9

Koziol MJ (1992) Chemical composition and nutritional evaluation of quinoa (*Chenopodium quinoa* Willd.). J Food Compos Anal 5:35–68

Lamothe LM, Srichuwong S, Reuhs BL, Hamaker BR (2015) Quinoa (*Chenopodium quinoa* W.) and amaranth (*Amaranthus caudatus* L.) provide dietary fibres high in pectic substances and xyloglucans. Food Chem 167:490–496

Lee D, Hwang W, Artan M, Jeong DE, Lee SJ (2015) Effects of nutritional components on aging. Aging Cell 14:8–16

Maki KC, Phillips AK (2015) Dietary substitutions for refined carbohydrate that show promise for reducing risk of type 2 diabetes in men and women. J Nutr 145:159–163

Maradini-Filho AM (2017) Quinoa: nutritional aspects. J Nutraceuticals Food Sci 2:1

Maradini-Filho AM, Pirozi MR, Borges JTS, Santana HMP, Chaves JBP et al (2017) Quinoa: nutritional, functional and anti-nutritional aspects. Crit Rev Food Sci Nutr 57:1618–1630

Morrison CD, Laeger T (2015) Protein-dependent regulation of feeding and metabolism. Trends Endocrinol Metab 26:256–262

Navruz-Varli S, Sanlier N (2016) Nutritional and health benefits of quinoa (*Chenopodium quinoa* Willd.). J Cereal Sci 69:371–376

Oelke EA, Putnam DH, Teynor TM, Oplinger ES (1992) Alternative field crops manual. University of Wisconsin Cooperative Extension Service, University of Minnesota Extension Service, Centre for Alternative Plant and Animal Products

Ogungbenle NH (2003) Nutritional evaluation and functional properties of quinoa (*Chenopodium quinoa*) flour. Int J Food Sci Nutr 54:153–158

Pellegrini N, Agostoni C (2014) Nutritional aspects of gluten-free products. J Sci Food Agric 95:1–6

Peñas E, Uberti F, di Lorenzo C, Ballabio C, Brandolini A et al (2014) Biochemical and immunochemical evidences supporting the inclusion of quinoa (*Chenopodium quinoa* Willd.) as a gluten-free ingredient. Plant Foods Hum Nutr 69:297–303

Przybylski R, Chauhan G, Eskin N (1994) Characterization of quinoa (*Chenopodium quinoa*) lipid. Food Chem 51:187–192

Repo-Carrasco R, Espinoza C, Jacobsen SE (2003) Nutritional value and use of the Andean crops quinoa (*Chenopodium quinoa*) and kañiwa (*Chenopodium pallidicaule*). Food Rev Int 19:179–189

Repo-Carrasco-Valencia R, Serna LA (2011) Quinoa (*Chenopodium quinoa* Willd.) as a source of dietary fiber and other functional components. Cienc Tecnol Aliment 19:225–230

Reyes-Montaño EA, Ávila-Torres DP, Guevara-Pulido JO (2006) Componente nutricional de diferentes variedades de quinua de la región Andina. AVANCES Invest Ing 5:86–97

Schlick G, Bubenheim DL (1996) Quinoa: candidate crop for NASA's controlled ecological life support systems. In: Janick J (ed) Progress in new crops. ASHS 254 Press, pp 632–640

Shilpi S, Rashmi S, Kunwar VS (2016) Quinoa (*Chenopodium quinoa* Willd), functional superfood for today's world: a review. World Sci News 58:84–96

Siener R, Honow R, Seidler A, Voss S, Hesse A (2006) Oxalate contents of species of the Polygonaceae, Amaranthaceae and Chenopodiaceae families. Food Chem 98:220–224

Singh B, Kaur A (2018) Control of insect pests in crop plants and stored food grains using plant saponins: a review. J Food Sci Technol 87:93–101

Tang H, Watanabe K, Mitsunaga T (2002) Characterization of storage starches from quinoa, barley and adzuki seeds. Carbohydr Polym 49:13–22

Tari TA, Annapure US, Singhal RS, Kulkarni PR (2003) Starch-based spherical aggregates: screening of small granule sized starches for entrapment of a model flavouring compound, vanillin. Carbohydr Polym 53:45–51

Thoufeek A, Rekha S, Singhal, Pushpa R, Kulkarni K, Mohinder P (1998) A lesser-known grain, *Chenopodium quinoa*: review of the chemical composition of its edible parts. Food Nutr Bull 19:61–69

Tovoli F, Masi C, Guidetti E, Negrini G, Paterini P et al (2015) Clinical and diagnostic aspects of gluten related disorders. World J Clin Cases 3:275–284

USDA (2015) National Nutrient database for Standard Reference Release 27. National Agricultural Library. Basic Report 20137 (consulted on March 2015)

USDA (2017) National Nutrient Database for Standard Reference Release 28 Slightly Revised May, 2016 [cited January 11, 2017]. https://ndb.nal.usda.gov/ndb/search/list

USDA (2018) United States Department of Agriculture. National Nutrient Database for Standard Reference Release

Vega-Gálvez A, Miranda M, Vergara J, Uribe E, Puente L et al (2010) Nutrition facts and functional potential of quinoa (*Chenopodium quinoa* Willd.), an ancient Andean grain: a review. J Sci Food Agric 90:2541–2547

Zevallos VF, Herencia LI, Chang F, Donnelly S, Ellis HJ et al (2014) Gastrointestinal effects of eating quinoa (*Chenopodium quinoa* Wild.) in celiac patients. Am J Gastroenterol 109:270–278