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ACCESSIBLE BIOACTIVE COMPOUNDS AND NUTRITIONAL PROFILE OF QUINOA (*Chenopodium quinoa* Willd)

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1. Introduction:

Quinoa (*Chenopodium quinoa* Willd) is small seed pseudo-cereal traditionally grown by Andeans for the food purpose. Quinoa belongs to Chenopodiaceae family and originated from Andean region in South America. South American countries like Bolivia, Ecuador, and Peru produces 80% of the total world production of quinoa (Hernandez-Ledesma, 2019). It is highly tolerant to cold, drought and has ability to survive in high salt condition. The last decade (2013), was declared as “International Year of Quinoa” by United Nations Food and Agricultural Organization (UNFAO) because of its high nutritional value (Tang and Tsao, 2017). The recent investigations have focused that the chemical constituents, bioactive compounds and their therapeutic properties is rapidly increase their recognition as functional food and nutraceuticals. Furthermore, quinoa species are also investigated as superior source of proteins, amino acids, and other micronutrients like minerals (Ca, P, Zn, and F) and vitamins (C, E, B₁, B₂, and B₆). Moreover, the phytochemicals found in quinoa species helpful in the reduction of cardio-vascular diseases including increased blood sugar level, cancer, allergies etc. (Nickel, et al., 2016). Other than seeds, the green plant parts of quinoa like leaves, stems, sprouts, are also contain good amount of nutritive elements, with health promotive properties like antidiabetic, anticancerous, antioxidant, antimicrobial and anti-obesity (Camaggio and Amicarelli, 2014). In addition, quinoa contains some anti-nutritional factors like phytic acid, tannins, saponins, and protease inhibitors. ON the basis of anti-nutritional factors, quinoa species are classified as sweet quinoa and bitter quinoa (Satheesh and Fanta, 2018).

2. Bioactive compounds in quinoa:

Quinoa is the excellent source of bioactive compounds and phytochemicals. Most of the bioactive compounds found in quinoa species are secondary plant products and they do not contribute in the growth and development. The major bioactive compounds found in quinoa species are phenolic compounds, flavonoids, carotenoids, and antioxidants. The bioactive compounds including, phenolic compounds, flavonoids, antioxidants and

carotenoids found in quinoa species varies from species to species. Various bioactive compounds found in quinoa grains and plant parts are given in the table – 1.

Table–1: Bioactive compounds found in various plant parts of quinoa

Grains and Plant parts	Bioactive compounds			
	Phenolic contents	Flavonoids	Carotenoids	Antioxidants
Leaves (mg GAE 100 g ⁻¹ DW)	131.80-544.00	10.38-304.10	23.02-66.96	29.90–55.40
Sprouts (mg QE 100 g ⁻¹ DW)	49.02-417.75	8.69–9.14	12.42-32.71	5.26–7.39
Grains (mg TE 100 g ⁻¹ DW)	39.29-198.23	11.40-223.80	8.11-15.58	13.61–59.61

**Source: Safiullah and Rafat (2022)*

2.1. Phenolic content: Phenolic compounds are major bioactive compounds found in the grains, leaves, stems and sprouts of quinoa species. The range of phenolic compound found in quinoa depends on the quinoa species. The increased total phenolic contents have been observed by several researchers during seed germination process than dry seed (Le, et al., 2021).

2.2. Flavonoids: Flavonoids are secondary metabolites found in the various plant parts of the quinoa. The flavonoids and their derivatives like rutin, quercetin, and kemferol have been reported from grains and other plant parts of quinoa. In several observations it has been reported that the quantity of rutin, quercetin, and kemferol increased in sprouted and germinated seed (Pasko, et al., 2008). The degree of flavonoids in quinoa varies from species to species. In various observations with respect to flavonoids, the yellow sprout quinoa has higher quantity than red sprouts.

2.3. Carotenoids: The entire green plant of quinoa is the excellent source of carotenoids. Most of the carotenoids are beta-carotene, lutein, and lycopene. The beta-carotene found in quinoa is the precursor of vitamin A. The range of carotenoids present in various plant organs of quinoa are varies from species to species (Chacaliaza-Rodriguez, et al., 2016). Regular consumption of carotenoids in the food plays an important role in the human health nutrition.

2.4. Antioxidants: Quinoa is rich in antioxidant and potentially reduces the cell damage through reactive oxygen species (ROS). Particularly, the green plant organs of quinoa have sufficient amount of antioxidants. The maximum antioxidants have been reported from red quinoa species than yellow species (Pasko, et al., 2009). The germinated and sprouted quinoa grains have increased antioxidant capacity because of several biological and physiological changes during seed germination.

3. Nutritional compound:

Quinoa is globally known for its nutritive quality. They contain carbohydrates, saturated and unsaturated fats, dietary fibers, proteins, amino acids, vitamins, and minerals. The entire plants of quinoa including grains, leaves, stems and sprouts are excellent source of human and animal nutrition.

3.1. Proteins and amino acids: Quinoa is the excellent source of nutritive macromolecules like proteins and essential amino acids. In quinoa, proteins are found in leaves, grains and sprouts. The dried leaves of quinoa contain higher amount of protein in comparison to the grains whereas fresh leaves of quinoa contain low quantity of proteins due to presence of moisture in leaves. The major proteins in quinoa leaves are albumin and globulin, while prolamin is present in very low quantity (Chacaliaza-Rodriguez, et al., 2011). All essential amino acids responsible for human growth and metabolic functions are present in quinoa

leaves and other green parts. Histidine, leucine, isoleucine, methionine, lysine, phenylalanine, valine, tryptophan, threonine, are the essential amino acids found in the quinoa leaves, sprouts, and grains (Gesinski and Nowak, 2011). The proteins and amino acids found in quinoa are given in table – 2:

Table–2: Protein and amino acid profile of various plant parts of quinoa

Proteins	Plant parts (mg/100gm) of dry weight basis		
	Grains	Sprouts	Leaves
Crude proteins	9.1–15.7	6.1–12.3	28.2–37.0
Essential amino acids			
Valine	0.8–6.1	1.3	1.8
Phenylalanine	0.1–2.7	1.2	1.8
Tryptophan	0.6–1.9	-	1.2
Threonine	2.1–8.9	1.0	1.5
Lysine	2.4–7.5	1.3	1.9
Histidine	1.4–5.4	0.7	0.7
Methionine	0.3–9.1	0.2	0.6
Leucine	2.3–9.4	2.0	2.7
Isoleucine	0.8–7.4	1.1	1.6

**Source: Safiullah and Rafat (2022)*

3.2. Vitamins and Minerals: Vitamins and minerals are existed as micromolecules in quinoa leaves, stems, grains and sprouts. Quinoa green is the good source of vitamin A, C and E. Quinoa leaves contain higher amount vitamin C and A than grains, whereas little quantity of vitamin E is found in quinoa leaves and grains (Laus, et al., 2017). Furthermore, essential minerals like Ca, Cu, Fe, P, K, Mg, Na, and Zn have been reported from quinoa leaves, sprouts, grains, and leaves (Le, et al., 2021). The micromolecules (vitamins and minerals) found in various plant parts of quinoa is given in table – 3.

Table – 3: Micromolecule (vitamin and Mineral) of various plant parts of quinoa

Vitamins	Plant parts (mg/100gm of dry weight basis)		
	Grain	Sprout	Leaves
Vitamin A	-	-	20-85
Vitamin C	16	40-52	70-230
Vitamin E	-	0.9	2.9
Mineral nutrition			
Zinc	2.8–4.8	-	3.3–6.8
Potassium	696.7–1475.0	525.2	474.0–8769.0
Calcium	27.5–148.7	21.7	147.0–1535.0
Copper	1.0–9.5	0.2	1.0–1.1
Sodium	11.0–31.0	-	3.0–15.1
Magnesium	26.0–502.0	219.3	14.0–902.0
Iron	1.4–16.7	-	11.6–148.0
Phosphorus	140.0–530.0	-	39.0–405.6

**Source: Safiullah and Rafat (2022)*

3.3. Carbohydrates: Quinoa grains and other plant parts contain variety of carbohydrates. It contains both monosaccharides and polysaccharides. Glucose and fructose and the major mono saccharides whereas major polysaccharides found in leaves and grains of the quinoa are maltose, starch, xylose. Starch is the main carbohydrates comprise approximately 60% of the total carbohydrates on dry weight basis. On an estimate quinoa grain contain higher carbohydrates (48.5-69.8%) followed by green leaves (34.1%). Glucose and fructose are the

major components of monosaccharaides found in quinoa (Vega-Galvez, et al, 2010). Quinoa contain very low amount of glucose (19 mg/100 gm), and fructose (19.6 mg/100 gm). However, consumption of quinoa in daily food is good for human health because they contain low carbohydrates.

3.4. Fats and fatty acids: Quinoa leaves, buds, stems, grains and sprouts are the good source of fats and fatty acids. Both saturated and unsaturated fatty acids are found in the quinoa. The major saturated fatty acids found in quinoa are palmitic acid, stearic acid, and oleic acid were linoleic acid and linolenic acids from unsaturated fatty acid group (Tang, et al, 2015). The level of fatty acids varies from various crop stages. At early vegetative stage of the crop, α -linoleic acid found abundantly (47%) followed by linoleic acid (16%). Furthermore, the higher amount of omega -3 and omega-6 fatty acids has been reported in green quinoa at early and mid-vegetative stage of the plants (Simopoulos, 2016). The fatty acid profiles of at various crop stage of the quinoa are given in table – 4.

Table – 4: Fatty acid profile of the quinoa at various crop stages

Quinoa plant parts at various crop stage	Fatty acid profile (%)				
	Unsaturated fatty acid		Saturated fatty acid		
	Linoleic	Linolenic	Palmitic	Stearic	Oleic
Grain	46.69	6.10	9.60	0.84	23.10
Bud	16.14	39.9	11.64	1.68	7.64
Early vegetative stage	15.97	47.4	12.07	1.51	7.49
Kale	11.8	54.1	11.84	3.95	2.14
Spinach	18.63	37.37	20.65	1.71	9.48

***Source:** Safiullah and Rafat (2022)

3.5. Dietary Fibers: Quinoa is the good source of dietary fibers. In various plant parts of quinoa both soluble and insoluble fibers are found in sufficient amount. The major source of fiber in quinoa is leaves, grains and sprouts. Quinoa green leaves contain 6.9 – 7.8% of the fibers, sprouts 4.6 -23.6% and grains 14.1% of the total fibers (Lamothe, et al., 2015).

4. Anti-nutritional factors

Quinoa grains, leaves and sprouts contain certain compounds that react with nutrients and interfere with their proper digestion and absorption is considered as anti-nutritional factor. Major anti-nutritional factors available in quinoa grains, leaves and sprouts are tannins, saponins, oxalates, and phytic acid.

4.1. Saponins and tannins: Saponins are secondary plant products found in leaves, stems, sprouts, and outer layer of the grain which provide bitter taste. The unfavorable climatic conditions like, water deficit, high temperature, soil salinity decreases the quantity of saponins in quinoa (Navarro del Hierro, et al., 2018). The sweet quinoa species has lower saponins content than bitter species. Some health promoting properties like anticancer, anti-obesity, neutralizing free radicals have been reported due to presence of saponins in quinoa. Tannins are another anti-nutritional factor mostly found in the quinoa grain (Saad-Allah and Youssef, 2018). The tannins found in the quinoa grain are polyphenolic in nature and have potential to interact with beneficial macromolecules and proteins and decreasing the nutritional value of the foods.

4.2. Phytic acid and oxalates: The dietary phytates found in the quinoa grains chelating agents and bind with the minerals like Fe, Zn, Mn, and Mg to form complex molecules. These complex molecules reduce the absorption rate of these essential minerals. On other hand, presences of phytic acid in the food simultaneously promote the phosphorus storage. Oxalates found in quinoa grains, toots, leaves and stems are reported as anti-nutritional factor

that can bind with mineral irons like Me, Ca and Fe and reduce the availability of these beneficial minerals (Sood, et al., 2012).

5. Conclusion

The entire quinoa plants including grains, leaves, sprouts, and stems are good source of health promotive components and nutrients. In addition, bioactive compounds available with quinoa have antimicrobial, anticancer, antidiabetic, antioxidant, anti-obesity, and cardio-beneficial properties. Consumption of green quinoa provides excellent quantity of protein, amino acids, essential minerals, and omega-3 fatty acids. Furthermore, the regular consumption of green quinoa and quinoa grains has to be observed as functional food with several advantages as compared to other cereals. Presence of higher amount of antioxidants and phenolic compounds in sprouted and germinated quinoa has been significantly helpful in the human-health promotion.

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