Quinoa

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Quinoa (*Chenopodium quinoa* Willd.) is native to the Andean region and has attracted a global growing interest due its unique nutritional value. The protein content of quinoa grains is higher than other cereals while it has better distribution of essential amino acids. It can be used as an alternative to milk proteins. Additionally, quinoa contains a high amount of essential fatty acids, minerals, vitamins, dietary fibers, and carbohydrates with beneficial hypoglycemic effects while being gluten-free. Furthermore, the quinoa plant is resistant to cold, salt, and drought, which leaves no doubt as to why it has been called the "golden grain". On that account, production of quinoa and its products followed an increasing trend that gained attraction in 2013, as it was proclaimed to be the international year of quinoa. In this respect, this review provides an overview of the published results regarding the nutritional and biological properties of quinoa that have been cultivated in different parts of the world during the last two decades.

Keywords: quinoa ; Chenopodium quinoa Willd. ; functional food ; nutrition

1. Introduction

The exceptional nutritional value of quinoa relies on its balanced composition of high protein, amino acid profile, minerals, fibers, and minor compounds (such as antioxidants and vitamins)[1]. Moreover, due to the absence of gluten, quinoa is suitable for celiac patients or gluten related disorders. Several factors may affect the nutritional composition of quinoa seeds and the yield of the plant. Genetic and environmental conditions are two factors that may affect the yield and nutritional quality of quinoa. Accordingly, quinoa cultivation altitude can range from sea level to 4000 m high, and cultivation location ranges from Colombia (2° N) to Chile (47° S) in its origins. This variability in cultivation location and altitude, as well as rainfall regimes, has led to a high biodiversity of quinoa species, given that growing conditions are different for each location and thus plant adaptation was required[2]. Moreover, quinoa breeding programs are focused on developing high yielding varieties with desirable nutritional properties which are better environmentally adapted to several agroecological zones. Emphasis is placed on the consumer markets—namely rich westernized countries—as quinoa has gained recent attention as a 'superfood'[3].

2. Proximate Composition

The proximate composition of quinoa seeds, as reported in the literature, is presented in Table 1. Among the macronutrients, carbohydrates can be found mostly on the perisperm of quinoa seeds, while the endosperm and embryo are richer in protein, minerals, and fats[2][3].

Table 1. Proximate composition of quinoa seeds cultivated in different regions.

Growing Year	Country	Location	Cultivar	Observation	Carbohydrate	Protein	Fat	Fiber	Ash	Reference
					(values in % or g 100 g^{-1} Seeds DM)					
1998	Bolivia		Real		63.7	12.9	6.5	13.9 *	3.0	[4]
2006–07	Italy	Vitulazio	KVLQ520Y	early sow	55.6	16.2	7.8	16.1 *	4.3	[5]

			late sow	54.8	16.2	7.7	16.9*	4.1	
			Regalona Baer	52.8	16.8	7.9	18.6*	4.0	
2006–09	Argentina	[illegible] and Jujuy	mean value of 21 data entries	51.4	16.8	5.9	12.1*	4.7	[1]
2010	Chile	North	Ancovinto	68.1	13.0	6.2	1.5	3.4	[6]
			Cancosa	65.8	13.6	6.0	1.9	3.5	
		Center	Cáhuil	64.2	11.1	7.1	1.2	3.2	
			Faro	63.8	11.4	6.7	1.6	3.5	
		South	Regalona	59.4	14.4	6.4	1.8	3.7	
			Villarrica	56.5	16.2	5.6	2.9	3.7	
2010	Peru	Cusco	ND		13.2	6.5	4.2	2.3	[7]
			ND		13.5	6.3	7.0	2.3	
		Puno	03-21-0093		11.8	-	-	2.8	
			03-21-1181		13.5	4.0	2.9	3.1	
			Coito		14.7	5.3	1.8	2.8	
			Huaripongo		13.2	6.1	2.5	2.9	
			INIA-415 Pasankalla		12.7	6.9	2.2	2.5	
			Roja de Coporaque		11.5	5.2	2.3	2.9	
			Salcedo		13.2	5.3	1.8	2.4	
			Witulla		12.3	5.3	2.6	2.6	
2011			La Molina 89		13.6	6.0	3.0	4.8	
		Puno	Blanca de Juli		12.4	4.9	1.8	3.0	

References

1. S.M. Vidueiros; R.N. Curti; L.M. Dyner; M.J. Binaghi; G. Peterson; Hector Daniel Bertero; A.N. Pallaro; Diversity and interrelationships in nutritional traits in cultivated quinoa (Chenopodium quinoa Willd.) from Northwest Argentina. *Journal of Cereal Science* **2015**, *62*, 87-93, 10.1016/j.jcs.2015.01.001.
2. Peter J. Maughan; Alejandro Bonifacio; Craig E. Coleman; Eric N. Jellen; Mikel R. Stevens; Daniel J. Fairbanks; Quinoa (Chenopodium quinoa). *Pulses, Sugar and Tuber Crops* **2007**, *3*, 147-158, 10.1007/978-3-540-34516-9_9.
3. Maria Reguera; Carlos Conesa; Alejandro Gil-Gómez; Monika Haros; Miguel Ángel Pérez-Casas; Vilbett Briones-Labarca; Luis Bolaños; Ildefonso Bonilla; Rodrigo Alvarez; Katherine Pinto; et al. The impact of different agroecological conditions on the nutritional composition of quinoa seeds. *PeerJ* **2018**, *6*, e4442, 10.7717/peerj.4442.
4. Hitomi Ando; Yi-Chun Chen; Hanjun Tang; Mayumi Shimizu; Katsumi Watanabe; Toshio Mitsunaga; Food Components in Fractions of Quinoa Seed.. *Food Science and Technology Research* **2002**, *8*, 80-84, 10.3136/fstr.8.80.
5. Cataldo Pulvento; Maria Riccardi; A. Lavini; R. D’Andria; G. Iafelice; E. Marconi; Field Trial Evaluation of Two Chenopodium quinoa Genotypes Grown Under Rain-Fed Conditions in a Typical Mediterranean Environment in South Italy. *Journal of Agronomy and Crop Science* **2010**, *196*, 407-411, 10.1111/j.1439-037x.2010.00431.x.
6. Margarita Miranda; Antonio Vega-Gálvez; Enrique Martínez; Jéssica López; Maria José Rodríguez; Karem Henriquez; Francisco Fuentes; Genetic diversity and comparison of physicochemical and nutritional characteristics of six quinoa (Chenopodium quinoa willd.) genotypes cultivated in Chile. *Food Science and Technology* **2012**, *32*, 835-843, 10.1590/s0101-20612012005000114.
7. FAO/INFOODS Databases “Food Composition Database for Biodiversity Version 4.0–BioFoodComp4.0. 2007. Available online: http://www.fao.org/3/a-i7364e.pdf (accessed on 22 November 2019).
8. Pier Giorgio Peiretti; Francesco Gai; S. Tassone; Fatty acid profile and nutritive value of quinoa (Chenopodium quinoa Willd.) seeds and plants at different growth stages. *Animal Feed Science and Technology* **2013**, *183*, 56-61, 10.1016/j.anifeedsci.2013.04.012.
9. Verena Nowak; Juan Du; U. Ruth Charrondière; Assessment of the nutritional composition of quinoa (Chenopodium quinoa Willd.). *Food Chemistry* **2016**, *193*, 47-54, 10.1016/j.foodchem.2015.02.111.
10. Achim Präger; Sebastian Munz; Peteh Mehdi Nkebiwe; Benjamin Mast; Simone Graeff-Hoenninger; Yield and Quality Characteristics of Different Quinoa (Chenopodium quinoa Willd.) Cultivars Grown under Field Conditions in Southwestern Germany. *Agronomy* **2018**, *8*, 197, 10.3390/agronomy8100197.
11. Rao, N.; Shahid, M.; Quinoa-a promising new crop for the arabian peninsula. *J. Agric. Environ. Sci.* **2012**, *12*, 1350–1355, 10.5829/idosi.aejaes.2012.12.1.
12. FAO Dietary Protein Quality Evaluation in Human Nutrition Report of an FAO Expert Consultation. 2011. Available online: http://www.fao.org/3/a-i3124e.pdf (accessed on 24 September 2019).
13. FAO Origin and History, International Year of Quinoa 2013. Available online: http://www.fao.org/quinoa-2013/what-is-quinoa/nutritional-value/en/?no_mobile=1 (accessed on 23 August 2019).
14. Kozioł, M.J. Chemical composition and nutritional evaluation of quinoa (Chenopodium quinoa Willd.). J. Food Compos. Anal. 1992, 5, 35–68.
15. Ritva Repo-Carrasco-Valencia; C. Espinoza; Sven-Erik Jacobsen; Nutritional Value and Use of the Andean Crops Quinoa (Chenopodium quinoa) and Kañiwa (Chenopodium pallidicaule). *Food Reviews International* **2003**, *19*, 179-189, 10.1081/fri-120018884.
16. Atul Bhargava; Sudhir Shukla; Deepak Ohri; Chenopodium quinoa—An Indian perspective. *Industrial Crops and Products* **2006**, *23*, 73-87, 10.1016/j.indcrop.2005.04.002.
17. Antonio Vega-Gálvez; Margarita Miranda; Judith Vergara; Elsa Uribe; Luis Puente; Enrique A Martínez; Luis A. Puente Diaz; Nutrition facts and functional potential of quinoa (Chenopodium quinoa willd.), an ancient Andean grain: a review. *Journal of the Science of Food and Agriculture* **2010**, *90*, 2541-2547, 10.1002/jsfa.4158.
18. Antonio Manoel Maradini Filho; Mônica Ribeiro Pirozi; João Tomaz Da Silva Borges; Helena Maria Pinheiro Sant'ana; José Benício Paes Chaves; Jane Sélia Dos Reis Coimbra; Quinoa: Nutritional, functional, and antinutritional aspects. *Critical Reviews in Food Science and Nutrition* **2015**, *57*, 1618-1630, 10.1080/10408398.2014.1001811.
19. Y. Konishi; Shigeru Hirano; Hideki Tsuboi; Masao Wada; Distribution of Minerals in Quinoa (Chenopodium quinoa Willd.) Seeds. *Bioscience, Biotechnology, and Biochemistry* **2004**, *68*, 231-234, 10.1271/bbb.68.231.

			Kcancolla			13.5	5.1	2.7	3.1	
			Sajama			12.7	4.1	1.7	2.7	
2010	Italy	Vitulazio	Titicaca, Q100	100% irrigation	49.0	14.6	5.1	17.6 *	3.4	
			Titicaca, Q25	25% irrigation	49.9	14.4	5.2	14.6 *	3.3	
			Titicaca, Q50	50% irrigation	51.9	14.7	5.1	16.9 *	3.5	
			Titicaca, Q100S		49.7	13.3	5.2	19.5 *	3.7	
			Titicaca, Q25S	same irrigation as above but with saline water	48.6	13.3	4.7	18.7 *	3.5	
			Titicaca, Q50S		49.0	14.0	5.2	17.5 *	3.3	
2013	Peru	Mantavaro valley	Ayni			14.8	4.7			[8]
2015	USA			USDA database	57.2	14.1	6.1		2.4	[9]
				Various primary sources †	59.9	13.1	5.7	3.3	3.3	
2015	Germany	Stuttgart	Zeno			12.0	5.5 ‡			[10]
			Jessie			16.1	7.3 ‡			
			Puno			13.0	6.5 ‡			
			Titicaca			13.4	7.5 ‡			
2016	Germany	Stuttgart	Zeno			12.0	5.5 ‡			
			Jessie			13.1	7.3 ‡			
			Puno			13.0	6.5 ‡			

20. Sanders, M. Estudio del Secado Industrial de la Quinoa (Chenopodium Quinoa Willd.) Cultivada en Chile: Efecto de la Temperatura Sobre su Composición. Bachelor’s Thesis, Department of Food Engineering, Universidad de La Serena, La Serena, Chile, 2009.
21. Ilja C.W. Arts; Peter C H Hollman; Polyphenols and disease risk in epidemiologic studies. *The American Journal of Clinical Nutrition* **2005**, *81*, 317S-325S, 10.1093/ajcn/81.1.317s.
22. Urszula Gawlik-Dziki; Michał Świeca; Maciej Sułkowski; Dariusz Dziki; Barbara Baraniak; Jarosław Czyż; Antioxidant and anticancer activities of Chenopodium quinoa leaves extracts – In vitro study. *Food and Chemical Toxicology* **2013**, *57*, 154-160, 10.1016/j.fct.2013.03.023.
23. Andrés Ahumada; Andrés Ortega; Diana Chito; Ricardo Benítez Benítez; Saponinas de quinua (Chenopodium quinoa Willd.): un subproducto con alto potencial biológico. *Revista Colombiana de Ciencias Químico-Farmacéuticas* **2016**, *45*, 438-469, 10.15446/rcciquifa.v45n3.62043.

			Titicaca	12.3	7.5 ‡		
2016	Chile	Río Hurtado	Regalona	15.2		3.1	[3]
			Salcedo	18.1		3.3	
			Titicaca	16.4		3.6	
2016	Spain	El Pobo	Regalona	17.8		3.0	
			Salcedo	15.7		3.2	
			Titicaca	15.3		3.5	
2016	Peru	Arequipa	Salcedo	14.6		3.3	

* values for fiber are reported as total dietary fiber. † n= 34 for carbohydrate, 37 for protein, 37 for fat, 23 for fiber, and 37 for ash. ‡ mean values for two growing years.

Briefly, a thorough assessment of the reported data regarding the nutritional composition of quinoa by Nowak et al. presenting the data from 27 articles (103 data lines) found considerable variation of nutrient values among different varieties from different locations[9]. Values reported in g 100 g^{-1} edible portion—Fresh weight basis ranged as follows: protein (9.1–15.7 g), total fat (4.0–7.6 g), and dietary fiber (8.8–14.1 g) while the moisture content of quinoa is reported to be around 15%. In their report of the data, the majority of entries (68) were from samples from South America—mainly from Peru and Bolívia (the biggest producer of quinoa in the world)—followed by data from Europe (23) and Asia and North America (six each). This reflects the traditional production of quinoa in South America but also the expansion of its production worldwide[9].

2.1. Protein and Amino Acid Content

The protein content of quinoa seeds ranges between 11% and 19% (Table 1). Moreover, quinoa seeds contain all nine essential amino acids (EAA) for proper human health as noted in Table 2[11].

Table 2. Amino acid composition of quinoa seeds (g 100 g^{-1} crude protein).

			Essential									Semi-Essential					Non-Essential							
Year	**Country**	**Variety**	**Ile**	**Leu**	**Lys**	**Met**	**Phe**	**Thr**	**Trp**	**Val**	**His**	**Cys**	**Tyr**	**Gly**	**Arg**	**Pro**	**Ser**	**Asp**	**Glu**	**Ala**	**Asn**	**Hyp**	**Glu**	**Reference**
2010	Chile	Ancovint	3.8	6.8	4.2	1.4	4.1	3.5	-	4.9	2.7	-	2.8	4.4	10.7	7.1	4.2	6.6	-	4.6	-	-	10.9	[6]
		Cancosa	3.4	6.5	4.1	1.5	3.9	3.2	-	4.6	2.8	-	2.8	4.5	10.9	7.7	4.1	6.9	-	4.2	-	-	10.8	
		Cáhuil	2.9	6.4	4.1	1.7	3.9	3.3	-	4.7	2.7	-	3.1	5.3	10.9	9.4	4.1	5.5	-	4.5	-	-	10.7	
		Faro	3.4	7.0	4.4	1.7	4.2	3.6	-	4.9	3.1	-	3.3	5.4	12.0	9.0	4.4	7.0	-	4.7	-	-	11.0	
		Regalona	3.0	6.6	4.3	1.7	4.0	3.3	-	4.3	3.0	-	2.9	5.4	11.9	7.4	4.3	6.5	-	4.2	-	-	11.5	
		Villarrica	3.1	7.2	4.8	1.9	4.5	3.4	-	4.4	3.5	-	3.1	6.1	11.9	6.7	4.8	6.7	-	4.5	-	-	11.4	

2015	USDA		3.6	5.9	5.4	2.2	-	3.0	1.2	4.2	2.9	1.4	-	-	-	-	-	-	-	-	-	-	-	[9]
2015	Germany	Zeno	2.0	3.7	2.8	1.1	2.2	2.1	1.0	4.2	1.3	1.0	1.6	3.0	3.8	2.3	2.8	5.2	6.9	2.8	-	-	-	[10]
		Jessie	2.4	4.3	3.5	1.4	2.7	2.6	0.9	4.4	1.8	1.2	2.0	3.8	5.2	2.7	3.3	6.0	8.5	3.3	-	-	-	
		Puno	3.2	5.4	4.0	1.5	3.6	3.3	1.0	4.0	1.9	1.3	2.3	4.7	5.2	3.1	3.8	7.1	11.8	3.9	-	-	-	
		Titicaca	2.7	4.8	3.7	1.4	3.0	2.8	0.9	4.9	1.9	1.2	2.0	4.1	5.2	3.2	3.3	5.9	8.3	3.3	-	-	-	
2016	Germany	Zeno	2.5	4.5	4.0	1.4	2.8	2.6	0.9	4.4	1.9	1.1	1.9	3.7	5.6	2.9	2.8	5.2	6.9	2.8	-	-	-	
		Jessie	2.8	5.3	4.9	1.8	3.2	3.2	1.0	5.7	2.3	1.4	2.3	4.6	6.6	3.2	3.3	6.0	8.5	3.3	-	-	-	
		Puno	3.2	5.6	5.0	1.8	3.5	3.2	1.1	3.8	2.5	1.5	2.4	5.0	7.5	3.3	3.8	7.1	11.8	3.9	-	-	-	
		Titicaca	2.6	4.6	4.2	1.6	2.8	2.7	1.0	4.9	2.0	1.3	2.0	4.1	6.0	3.0	3.3	5.9	8.3	3.3	-	-	-	

Quinoa has garnered attention as a protein source due to the high quality and balanced composition of amino acids content of its protein—superior to wheat, barley, and soybean. Quinoa essential amino acid scoring patterns (Scoring patterns, as defined by FAO, are based upon on the amino acid requirement values divided by the mean protein requirement[12]) can be seen in Table 3, which shows quinoa exceeds the scoring patterns for 8 essential amino acids[12][13][14].

Table 3. Essential amino acid profile of quinoa and other grains, compared to the FAO recommended amino acid scoring pattern for older children (3 to 10 years old), adolescents, and adults[12][13][14].

Amino Acids	FAO	Quinoa	Maize	Rice	Wheat
Isoleucine	3.0	4.9	4.0	4.1	4.2
Leucine	6.1	6.6	12.5	8.2	6.8
Lysine	4.8	6.0	2.9	3.8	2.6
Methionine	2.3	5.3	4.0	3.6	3.7
Phenylalanine	4.1	6.9	8.6	10.5	8.2
Threonine	2.5	3.7	3.8	3.8	2.8
Tryptophan	0.7	0.9	0.7	1.1	1.2
Valine	4.0	4.5	5.0	6.1	4.4

The appreciation of quinoa as a food by Andean populations relies on its high nutritional value, as it is the principal protein source for rural populations, substituting the lack of animal protein[15]. Moreover, due to its high protein content and amino acid profile, quinoa is suggested to be an alternative to dairy products[15][16].

The protein and respective amino acid profile of quinoa can vary significantly from cultivar and location (Tables 1 and 2). Quinoa can be grown on various types of soils; nevertheless, the plant responds well to nitrogen fertilization, increasing yields, and protein content of seeds. The application of organic matter is important for topping nutrients and promoting water use efficiency in arid regions and sandy soils, thus enhancing the seed yield[17].

2.2. Carbohydrates

The carbohydrate content of quinoa seeds ranges between 49% and 68% (dry matter weight) (Table 1). Starch is the main biopolymer constituent of plant organs, and is the most abundant carbohydrate present in the seeds. Native quinoa starch consists of uniform small granules less than 3 µm in diameter[16][18]. Quinoa starch also presents interesting functional applications, due to its low temperature of gelatinization (range of 54–71 °C) and enthalpy (11 J g^{-1} starch)[4]. Compared to the starch of wheat and barley, quinoa presents a higher maximum viscosity, water absorption capacity, and greater swelling power[18]. Its excellent freeze-thaw stability makes it an ideal thickener for food products where resistance to retro degradation is desired[4][18]. Additionally, due to the small-sized granules and high viscosity, quinoa starch has the potential to be used in specialized industrial applications, such as dusting starches in cosmetics and rubber type mold release agents[16].

Another carbohydrate group present in quinoa seeds is dietary fiber. The total dietary fibers content of quinoa seeds is close to what is found in other cereals ranging from 7.0% to 9.7 % (DM)[18]. Pulvento et al. reported an average of 17.2% of dietary fiber in quinoa harvested in the south of Italy. Although representing a high content, dietary fiber can decrease significantly after post-harvest processes to eliminate anti-nutritional micro components present in seed coats[5]. Table 1 notes the fiber content of quinoa found in the literature.

2.3. Fat

The fat content of quinoa seeds varies between 2 and 9.5%, which is higher than maize and other cereals but less than soybean (Table 1). Quinoa oil is rich in essential fatty acids such as oleic [C18:1] (19.7%–29.5%), linoleic [C18:2] (49.0%–56.4%), and linolenic [C18:3] (8.7%–11.7%). The portion of (poly-) unsaturated fatty acid accounts to 87%–88% of total fatty acids of the seed[4][18]. These compounds have gained importance since they promote health benefits such as positive effects on the immune system, cardiovascular diseases, cell membrane function, and increased insulin sensitivity[10][18]. Table 4 shows the reported results of determining the fatty acid content and profile of quinoa seeds of different varieties cultivated in different locations. Quinoa may also be considered an alternative oilseed. The oil contains a high concentration of antioxidants such as α- and γ-tocopherol, which ensures quinoa oil a long shelf life due to its natural antioxidant potential at the level of cell membrane, protecting fatty acids against damage by free radicals[18].

Table 4. Most relevant fatty acids content of quinoa seeds.

	Fatty Acid Profile								
	Saturated			**Unsaturated**					
Variety	**C16:0**	**C18:0**	**C23:0**	**C18:1** n-9	**C18:1** n-7	**C18:2**	**C18:3**-α	**C18:3**-γ	**Reference**
21 accessions				25.40		50.40	6.6		[1]*
Ancovinto	7.87	0.75	4.44	27.87		45.17	8.30	0.51	[6] †
Cancosa	8.14	0.70	3.49	26.91		46.57	8.27	0.50	
Cáhuil	8.32	0.63	4.30	23.45		52.90	5.45	0.49	
Faro	8.19	0.67	4.88	22.25		53.89	4.64	0.48	
Regalona	8.56	0.61	6.81	18.68		54.18	5.35	0.43	

Villarrica	8.97	0.54	3.79	20.77		53.36	5.88	0.34	
Ayni	96.00	26.00		239.00	8.00	488.00	49.00		[8]‡
Zeno	6.96	0.45		13.14	0.92	40.67		4.55	[10]†
Jessie	8.56	0.65		16.55	1.04	45.68		4.98	
Puno	8.48	0.71		14.41	1.07	40.39		4.59	
Titicaca	6.97	0.45		13.08	0.79	33.07		3.29	

* Reported values are average for 21 accessions (from Northwest Argentina) in g 100 g^{-1} of total fatty acids. † Reported values in g 100 g^{-1} fat. ‡ Reported values in g kg^{-1} of total fatty acids.

3. Micro Components

Distributed across the macro components of quinoa seeds are micro constituents such as minerals and bioactive compounds are present in minor scales. Such micro constituents contribute to not only the nutritional composition of quinoa but also may be used due to their functionality. Moreover, the exceptional nutrient profile from quinoa can provide valuable therapeutic properties such as enhancing immune function, assisting in cell repair, calcium absorption and transport, participation in the metabolism of fatty acids for human health, and even preventing cancer metastasis[11][18].

3.1. Minerals

As it can be seen in Table 1, the ash content of quinoa seeds ranges from 2.4% to 4.8%. The ash contains a diversified profile of minerals including a high content of calcium, magnesium, iron, copper and zinc. The mineral content of quinoa seeds is found to be at concentrations greater than most grain crops[17]. Table 5 shows the mineral content of quinoa and its comparison with other grains[13][14].

Table 5. Mineral content of quinoa and other grains[13][14].

Mineral (mg 100 g^{-1} Seeds DM)	Quinoa	Maize	Rice	Wheat
Calcium	148.7	17.1	6.9	50.3
Iron	13.2	2.1	0.7	3.8
Magnesium	249.6	137.1	73.5	169.4
Phosphorus	383.7	292.6	137.8	467.7
Potassium	926.7	377.1	118.3	578.3
Zinc	4.4	2.9	0.6	4.7

Vega-Gálvez et al. reported that mineral concentrations seem to change drastically when quinoa is cultivated in different soil types—thus with particular mineral compositions—and fertilizer application[17]. Table 6 summarizes the reported values for mineral content of quinoa seeds reported in the literature.

Table 6. The mineral content of quinoa seeds of different varieties.

Year	Country	Location	Variety	Ca	Fe	Mg	P	K	Na	Zn	Cu	Mn	Reference
				mg kg^{-1} Seed DM									
2003	Peru		Huancayo	940.0	168.0	2,700.0	1400.0		115.0	48.0	37.0		[15]
2004				863.0	150.0	5,020.0	4110.0	7320.0		40.0			[19]
2006				1,274.0	20.0		3869.0	6967.0		48.0			[16]
2009				565.0	14.0	1760.0	4689.0	11,930.0		28.0			[20]
2016	Chile	Río Hurtado	Regalona	1265.5	91.0	2278.5	3437.9	13,856.5	12.1	40.9			[3]
			Salcedo	1360.2	83.3	2238.1	3246.1	10,006.3	11.4	42.7			
			Titicaca	619.0	82.5	1814.0	2846.4	10,250.3	5.2	40.8			
	Spain	El Pobo	Regalona	729.0	55.4	1962.9	4232.9	11,440.3	3,117.0	25.4			
			Salcedo	934.5	66.8	1741.2	3155.8	8866.9	16.7	25.3			
			Titicaca	888.4	69.3	1863.9	3915.4	14,678.5	16.7	25.1			
	Peru	Arequipa	Salcedo	514.0	62.8	1924.1	3934.6	9648.7	5,147.0	33.0			
2015	Various			870.0	94.7	3620.0	4060.0	9070.0	200.0	21.5	78.4		[9]
	Bolivia			1,130.0	50.2		2510.0						
	Peru			630.0	84.7		2730.0			37.3			
	USA			540.0	52.7	2270.0	5270.0	6490.0	60.0	35.7	6.8		

3.2. Bioactive Compounds

Quinoa seeds are the main edible part of the quinoa plant, nevertheless quinoa leaves are rich in phenolic compounds that present antioxidant and anticancer properties. Plant polyphenols and phenolic content are beneficial to human health, due to their antioxidative potential. It has been suggested that such compounds can aid the risk reduction of cardiovascular diseases, neurodegenerative disorders, and diabetes[21][22].

Considerable amounts of ferulic, sinapinic, and gallic acids, kaempferol, isorhamnetin, and rutin were obtained in quinoa extracts. These named compounds were linked to an inhibitory effect on prostate cancer cell proliferation and motility[22].

3.3. Saponins

Saponins are grouped among the minor components, secondary metabolites, broadly studied due to their biological properties. They are considered to be the most anti-nutritional factor in quinoa seeds, acting as a natural protection against pathogens and herbivorous. Over 30 types of saponins can be found distributed in quinoa plant parts[23]. The quantification of saponin content is important in order to differentiate between ‘sweet’ (having saponin content of 20–40 mg g^{-1} dry weight) and ‘bitter’ genotypes (>470 mg^{-1} dry weight)[5]. The saponin content found in quinoa seeds reported in the literature is presented in Table 7. Saponins confer the bitter taste and are mostly found in the outer seed coat. The compound is removed by post-harvest processing techniques like cold water washing, abrasion, and dehulling[11]. In addition, saponins extracted from quinoa seeds can be used in other industries such as cosmetics and pharmaceuticals.

Table 7. Saponin content of quinoa seeds of different varieties.

Year	**Country**	**Location**	**Variety**	**Saponin**	**Reference**
				g 100 g^{-1} Seed DM	
2006–07	Italy	Vitulazio	Regalona Baer	3.3	[5]
2016	Chile	Río Hurtado	Regalona	1.3	[3]
			Salcedo	1.0	
			Titicaca	1.2	
	Spain	El Pobo	Regalona	1.4	
			Salcedo	0.9	
			Titicaca	1.3	
	Peru	Arequipa	Salcedo	0.8	
2015	Germany	Stuttgart	Zeno	2.7	[10] *
			Jessie	0.7	
			Puno	2.6	
			Titicaca	2.6	
2016	Germany	Stuttgart	Zeno	2.8	
			Jessie	0.0	
			Puno	2.9	
			Titicaca	3.4	
	Argentina		Sajama	0.8	[23]
			N.R.	2.9	
	Bolivia		Real	2.6	
	Brazil		BRS-Piabiru	3.3	

Denmark	Olav	1.8
	Q52	6.1

* mean value of two years in mg g^{-1}.

3.4. Vitamins

Quinoa is also a source of vitamins, namely riboflavin and folic acid, offering similar values of thiamine, but is a lesser source of niacin. It has been noted that the removal of the saponins (to reduce the bitter taste) does not seem to affect the vitamin content[13][14]. Vitamin content of quinoa and compared to the other grains can be seen in Table 8.

Table 8. The vitamin content of quinoa seeds compared to other grains (mg 100 g^{-1} DM)[13][14].

Vitamin	Quinoa	Maize	Rice	Wheat
Thiamine	0.2–0.4	0.42	0.06	0.45–0.49
Riboflavin	0.2–0.3	0.1	0.06	0.17
Folic Acid	0.08	0.03	0.02	0.08
Niacin	0.5–0.7	1.8	1.9	5.5