Original Research Article

Evaluation and comparative study of the nutritional profile and antioxidant potential of new quinoa varieties

ABSTRACT

Aims: Quinoa (*Chenopodium quinoa*) is an ancient crop known for its high nutritive potential. The goal of the present work is to study the nutritional composition, identify some antinutritional factors and antioxidant compounds, and evaluate their antioxidant activity in four advanced lines of quinoa seeds obtained in experimental plots.

Methodology: For this purpose, proteins, total lipids, fiber, moisture, ash and carbohydrates, as well as fatty acid composition and mineral content, were determined in whole meal flours of these advanced lines. The presence of trypsin inhibitors, saponins, nitrates, oxalates and phytate was also evaluated, as well as total phenols and antioxidant activity.

Results: These new quinoa varieties have good nutritional properties, with high protein content in comparison to cereals. In this work, the analysis of proximate and mineral profile of quinoa showed that this pseudocereal has a similar profile but significantly higher than rice, a traditional cereal. Quinoa is a rich source of magnesium, iron, manganese, copper and molybdenum, which are elements that are deficient in almost all gluten-free cereals. The tests performed on the evaluated antinutrient compounds resulted within the acceptable values for human consumption.

The seed extract showed a total phenol content between 43.42 ± 1.35 and 25.82 ± 1.47 mg of gallic acid equivalent/100 g dry weight. The antioxidant activities were estimated by DPPH, β carotene and nitric oxide scavenging activity. The results of the methanolic extract were, in average, 88.95 for %DPPH, 26.56 for %β carotene, and varied between 85.82 ± 8.32 to 22.20 ± 1.80 for %NO.

Conclusion: Therefore, it can be concluded that the new quinoa lines obtained in the central-west region of Argentina, which present agronomic advantages, are safe for human consumption and beneficial due to the content of nutrients and bioactive compounds that exert protection against many diseases.

Keywords: Quinoa; nutrient; antinutrient; phenols; antioxidant activity.

1. INTRODUCTION

Recent studies have highlighted the need of improving the nutritional quality of cereal-based gluten-free products. There are many gluten-free grains, such as amaranth, quinoa and buckwheat pseudocereals, which are characterized by an excellent nutritional profile [1].

Quinoa (*Chenopodium quinoa*) is a native pseudocereal in the Andean region. The cultivation of the plant goes back to at least 5000 years, being the main food of the entire Inca Empire. Currently, quinoa is under an expansion process, due to that it represents a great potential for global food security. Quinoa belongs to the genus *Chenopodium* of the *Chenopodiaceae* family, and is widely distributed worldwide, with around 250 species. Furthermore, it has demonstrated to be a strategic crop due its wide genetic diversity, which allows it to adapt to diverse agro-climatic and soil conditions [2].

The grain is the most consumed part, and represents an excellent resource of macronutrients, in particular proteins with high content of essential amino acids, thus, differentiating themselves from traditional cereals. In addition, it represents a good source of micronutrients, such as vitamins and minerals [3].

Many studies have demonstrated that quinoa seeds present a significant polyphenols content (such as flavonoids and phenolic acids) with antioxidant capacity [4, 5], and other bioactive compounds with beneficial health effects.

Another characteristic of this grain is the presence of antinutritional factors such as saponins, proteases inhibitors and lectins [6]. These compounds can be responsible of affecting proteins digestibility and nutrients availability; nevertheless, they are attributed with bioactive properties.

Quinoa, along with amaranth and buckwheat, is recommended by the World Gastroenterology Organization in celiac patient's diets, given that they are gluten-free cereals [7]. Alvarez-Jubete et al. [1] also recommend the use of quinoa and amaranths as possible healthy ingredients to enrich the nutritional value of gluten-free baked goods.

The United Nations General Assembly declared the year 2013 as the "International Year of Quinoa", in recognition to its elevated nutritional quality, genetic diversity and potential role in poverty eradication [8]. In addition, in 2011, the FAO classified quinoa as one of the promising crops that can contribute to food security in the 21st century [9].

The goal of the present work is to characterize the nutritional composition, identify some antinutritional factors and antioxidant compounds, and evaluate their antioxidant activity in four advanced lines of quinoa seeds obtained in experimental plots, which is important considering that the new varieties studied in this work have agronomic advantages that improve the crop and the resistance towards some pathogens.

2. MATERIALS AND METHODS

2.1 Sample and reagents

Work was performed on seeds of advanced lines (LAQ) of *Chenopodium quinoa* (LAQc/31, LAQb/41, LAQf/104 and LAQp/16), from experimental crops of the Faculty of Agronomy and Veterinary of the National University of Río Cuarto, Cordoba, Argentina (2016 vintage). The dry seeds were ground and sieved, obtaining a beige-color whole flour, which was conserved in a hermetically sealed container, protected from light, and stored at 4ºC. All reagents were of analytical grade. The analyses were performed in triplicate, and the mean value of dry matter was obtained.

2.2 Proximate chemical composition

The determination of proteins, lipids, dietary fiber, moisture and ashes, was performed according to the methodology proposed by the AOAC [10]. The carbohydrates content was calculated by difference.

2.3 Minerals

Mineral elements quantification was performed by Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES). The standards and reagents used were of spectroscopic grade. The procedure was carried out following the methodology used by Aguilar et al. [11].

2.4 Fatty acids

Fatty acids were determined as methyl esters by gas chromatography [12,13]. For their analysis, the chromatographic method was applied in a Varian chromatograph *(Berkeley, NC)* with a 10% SP-2330 packed column and flame ionization detector. Standard solutions of fatty acids were acquired from Sigma (St. Louis, MO).

2.5 Antinutrients

The determined antinutrients were: antitryptic factors [14], saponins [15], nitrates [16], oxalates [17] and phytates [18].

2.6 Total phenol

The extraction of total phenols was performed from flour using a 1.2 mol/L HCl, 50% methanol:water solution. The sample was heated at 90 °C for 3 h, and then cooled and

105 diluted with methanol [19]. The supernatant was used for the determination of phenols
106 and antioxidant activity. The determination of total phenols was performed using Folin
107 Ciocalteu reagent with gallic acid as standard. The absorbance was measured at 750
108 nm (UV–vis Beckman DK-2ª). The results were expressed as mg/100 g of dry weight of
109 gallic acid equivalent [20].

110 **2.7 Antioxidant activity**

111 The DPPH scavenging assay is related to the sample capacity to inhibit the action
112 of free radicals generated by a 0.004% methanolic solution of 1,1-diphenyl-2-
113 picrylhydrazyl (DPPH) [21]. In this case, the absorbance was measured at 517 nm.

114 The β-carotene scavenging assay involves measuring β-carotene bleaching at
115 470 nm, resulting from the β-carotene oxidation by linoleic acid degradation products at
116 50 °C [22]. The absorbance at 470 nm was taken at time zero (t = 0), and then
117 measured at 15 min intervals until the color of β-carotene disappeared in the control
118 tube (t = 60 min). A mixture prepared without β-carotene served as blank.

119 Nitric oxide scavenging activity uses sodium nitroprusside in 0.02 mol/L
120 phosphate buffer (pH 7.4) to generate nitric oxide (NO), which interacts with oxygen to
121 produce stable nitrite ions. These ions can be estimated by using Griess reagent at 542
122 nm [23].

123 In all cases, buthylated hydroxytoluene (BHT) was used as positive control, and
124 the results were expressed as percentage (%) of radical scavenging activity (RSA).

125 **2.8 Statistical analysis**

126 Results were expressed as mean ± standard deviation. Statistical differences were
127 tested by variance analysis ANOVA, and the means were compared using the Tukey
128 test. Probabilities of 0.05 or less indicate significant difference [24].

129

130 **3. RESULTS AND DISCUSSION**

131 The presence of macronutrients, minerals, antinutrients and bioactive compounds such
132 as polyphenols, was studied in seeds of advanced lines of *Chenopodium quinoa*:
133 LAQc/31, LAQb/41, LAQf/104 and LAQp/16.

134 Several studies have confirmed that quinoa has high-quality protein in terms of
135 digestibility and nutritional balance, presenting a high biological value due to the
136 balanced composition of essential amino acids similar to casein, the milk protein [2].
137 Specifically, quinoa proteins are rich in lysine (6.2 g / 100 g of protein) and threonine
138 (4.8 g / 100 g of protein), which are usually the limiting amino acids in conventional
139 cereals [25].

140 In addition, these pseudocereals are characterized by having a high lipid content
141 with respect to common cereals, with a high proportion of unsaturated fatty acids.
142 Linoleic acid is the most abundant fatty acid in quinoa (50%), followed by oleic acid
143 (25%) [1].

144 It is known that the consumption of natural foods rich in dietary fiber is beneficial for
145 maintaining a good health [26]. Studies have demonstrated that pseudocereals like
146 quinoa present fiber levels comparable to the ones found in common cereals [1].

147 Table 1 shows the proximate chemical composition of the quinoa lines under
148 study. The highest protein content found was of 17.29 ± 0.37 g/100 g (LAQb/41), 30%
149 higher than the line that presented the lowest value (LAQc/31). The highest fat content
150 was of 9.48 ± 0.75 g/100 g (LAQb/41), being 24% higher than for LAQp/16. The
151 highest carbohydrate content was of 68.77 ± 0.31 g/100 g (LAQf/104), being 11%
152 higher than for LAQb/41. The highest crude fiber content was of 3.17 ± 0.03 g/100 g
153 (LAQf/104), being 26% higher than for LAQp/16. The values and variations found
154 between lines are also in agreement with the ones published by other authors [1, 27,
155 28]. It is noteworthy that the content of quinoa nutrients varies significantly between
156 lines. In the available literature, there is no clear foundation for such differences. Some
157 possible explanations are attributed to the interaction of several factors, such as the

158 crop genetics, the analytical methods used for the determination, and the
159 environmental conditions [26].

160 **Table 1. Proximate chemical composition (g/100 g) of quinoa grains**

Nutrient	LAQc/31	LAQb/41	LAQf/104	LAQp/16	Mean
Moisture	9.14±0.52 [a]	6.06±0.23 [b]	7.57±0.06 [c]	5.99±0.06 [b]	7.19
Total protein	12.14±0.20 [a]	17.29±0.37 [b]	13.13±0.06 [c]	16.15±0.14 [d]	14.67
Total fat	9.02±0.39 [a b]	9.48±0.75 [a c]	7.75±0.21 [b c d]	6.82±0.11 [d]	8.27
Ash	2.32±0.17 [a]	5.87±0.03 [b]	2.77±0.10 [a]	6.30±0.14 [b]	4.31
Crude fiber	3.12±0.11 [a]	2.55±0.14 [b]	3.17±0.03 [a]	2.36±0.19 [b]	2.80
Carbohydrates*	65.84±1.28 [a b]	61.28±0.92 [c]	68.77±0.31 [a]	63.23±1.68 [b c]	64.53

161 * Calculated as: 100 - (moisture + protein + fat + ash).

162 LAQc/31, LAQb/41, LAQf/104, LAQp/16: advanced lines of *Chenopodium quinoa*

163 Results are expressed as mean ± standard deviation from three replicates.

164 Values that do not share letters in common are significantly different by the Tukey's
165 test (*P*= .05).

166 Compared in Table 2 are the average values of the proximate chemical
167 composition of quinoa, amaranth and rice, provided by the composition tables of the
168 United States Department of Agriculture database, 2013 [29].

169 **Table 2. Proximate chemical composition (g/100 g) of quinoa grains, compared to**
170 **uncooked quinoa, uncooked amaranth grain, and unenriched and uncooked rice**
171 **white, in the USDA nutrient database**

Nutrient	Mean LAQ	Quinoa (uncooked)	Amaranth grain	Rice (white, unenriched

			(uncooked)	and uncooked)
Moisture	7.19	13.28	11.29	10.46
Total protein	14.67	14.12	13.56	6.81
Total lipid	8.27	6.07	7.02	0.55
Carbohydrates	64.53	64.16	65.25	81.68

USDA nutrient database (U.S. Department of Agriculture, Agricultural Research Service, 2013).

Water content was lower in LAQ with respect to the compared grains. In LAQ, the total protein values are within the range informed for pseudocereals (quinoa and amaranth), and two times higher than traditional cereals such as rice. The total lipids results informed for LAQ were slightly higher with respect to pseudocereals, and 14 times higher with respect to rice. Carbohydrate data are within the range informed for pseudocereals and slightly lower than rice. The USDA nutrient database did not informed ashes nor crude fiber.

Table 3 shows the LAQs fatty acid composition. These grains have a relatively high amount of unsaturated fatty acids. They present a high content of omega 6 linoleic acid, 54.30 mg/g in average, followed by omega 3 linolenic acid, 5.55 mg/g in average.

Table 3. Fatty acids composition (mg/g total lipid) of quinoa grains

Fatty acid	LAQc/31	LAQb/41	LAQf/104	LAQp/16	Mean
14:0 (myristic acid)	0.20±0.01 [a]	0.30±0.01 [a]	0.20±0.08 [a]	0.30±0.01 [a]	0.25

16:0 (palmitic acid)	11.00±0.55 [a]	11.00±0.43 [a]	10.00±0.40 [ab]	11.60±0.60 [ac]	10.90
18:0 (stearic acid)	0.50±0.02 [a]	0.80±0.04 [a]	0.60±0.03 [ab]	0.60±0.03 [ac]	0.62
18:1(cis-vaccenic acid)	1.40±0.07 [a]	1.30±0.06 [a]	1.30±0.07 [a]	1.40±0.06 [a]	1.35
18:1(oleic acid)	15.40±0.7 [a]	19.50±0.92 [b]	20.30±1.01 [b]	15.50±0.62 [a]	17.67
18:2 (linoleic acid)	55.40±2.5 [a]	53.70±1.8 [a]	53.60±1.70 [a]	54.50±1.80 [a]	54.30
18:2 (trans linoleic acid)	0.20±0.01 [a]	0.20±0.01 [a]	0.20±0.01 [a]	0.2±0.01 [a]	0.20
18:3 (linolenic acid)	6.20±0.30 [a]	4.80±0.25 [a]	4.80±0.22 [a]	6.40±0.31 [a]	5.55
20:0 (araquidic acid)	0.50±0.02 [a]	0.50±0.02 [a]	0.50±0.02 [a]	0.60±0.03 [b]	0.52
20:1(eicosanoic acid)	1.30±0.06 [a]	1.50±0.05 [a]	1.50±0.06 [a]	1.50± 0.04 [a]	1.45
22:0 (docosanoic acid)	1.20±0.06 [a]	1.00±0.04 [b]	0.90±0.05 [b]	1.30±0.06 [a]	1.10
22:1 (erucic acid)	1.80±0.09 [a]	1.80±0.08 [b]	2.00±0.10 [b]	1.70±0.08 [b]	1.82

24:0 (lignoceric acid)	0.50±0.21 [a]	0.50±0.02 [a]	0.40±0.02 [b]	0.60±0.02 [c]	0.50
24:1 (nervonic acid)	0.30±0.01 [a]	0.30±0.01 [a]	0.30±0.01 [a]	0.30±0.01 [a]	0.30
Unidentified	4.10	2.80	3.40	3.50	3.45
Total saturated fatty acids	13.90	14.10	12.60	15.00	13.90
Total monounsaturated fatty acids	20.20	24.40	25.40	20.40	22.60
Total polyunsaturated fatty acids	61.18	58.60	58.60	61.10	59.90
unsat/sat ratio	5.85	5.89	6.66	5.43	5.95

LAQc/31, LAQb/41, LAQf/104, LAQp/16: advanced lines of *Chenopodium quinoa*

Results are expressed as mean ± standard deviation from three replicates.

Values that do not share letters in common are significantly different by the Tukey's test (P= .05).

In Table 4, it can be observed that the linoleic acid composition of LAQ is almost double the informed by the USDA for quinoa and amaranth pseudocereal, and 28 times higher than in rice.

The linolenic acid composition of LAQ is double the informed for quinoa, 13 times higher than in amaranth and much higher than in rice. These results follow the tendency reported in the literature [2, 30, 1].

Table 4. Fatty acid composition (mg/g total lipid) of quinoa grains, compared to uncooked quinoa, uncooked amaranth grain, and uncooked and unenriched white rice, in the USDA nutrient database

Fatty acid	Mean LAQ	Quinoa (uncooked)	Amaranth Grain (uncooked)	Rice (white, unenriched and uncooked)
18:2 (linoleic acid)	54.3	29.77	27.36	1.89
18:3 (linolenic acid)	5.55	2.60	0.42	0.08
Total saturated	13.90	7.06	14.59	11.10
Total monosaturated	22.60	16.13	16.85	20.00
Total polyunsaturated	59.90	32.92	27.78	19.80
unsat/sat ratio	5.95	6.94	3.06	3.58

USDA nutrient database (U.S. Department of Agriculture, Agricultural Research Service, 2013).

Presented in Table 5 are the results of the main and trace essential minerals of nutritional interest, and of chemical elements, such as zinc and copper, with antioxidant activity. It is noteworthy the levels (mg/100g) of magnesium (204.36), calcium (54.76), iron (4.51), manganese (2.66), copper (0.56), molybdenum (0.03) and zinc (2.24). Potassium and phosphorus contents were above the upper limit of quantification. The data obtained for the minerals of LAQ are adequate for grains, being in the order of the reported in the literature for quinoa [31, 28]. Calcium, magnesium and iron are minerals

that are deficient in gluten-free products; pseudocereals such as quinoa are usually a good source of these elements and other important minerals [1]. However, it can be observed that the mineral values vary significantly, and this can be explained by the same factors that affect the nutritional composition of vegetable foods such as cultivation and climatic conditions, as well as the analytical determination methods.

Table 5. Minerals (mg/100 g) of quinoa grains

	Element	LAQc/31	LAQb/41	LAQf/104	LAQp/16	Mean
Main Essential Elements	K	> ULOQ	> ULOQ	> ULOQ	> ULOQ	> ULOQ
	Ca	52.54±1.20 ^{a}	53.29±1.30 ^{a}	50.55±0.90 ^{a}	64.62±1.70 ^{b}	54.76
	Mg	205.67±8.10 ^{a}	197.22±6.30 ^{ab}	217.54±5.20 ^{ac}	198.27±7.10 ^{ab}	204.36
	P	> ULOQ	> ULOQ	> ULOQ	> ULOQ	> ULOQ
	Na	13.09±0.60 ^{ab}	12.82±1.10 ^{ab}	8.08±0.90 ^{c}	14.56±1.80 ^{ab}	11.53
	Fe	4.82±0.12 ^{a}	4.50±0.06 ^{b}	4.09±0.10 ^{c}	4.70±0.08 ^{ab}	4.51
	Mn	2.19±0.07 ^{a}	3.05±0.09 ^{b}	2.37±0.06 ^{a}	3.32±0.11 ^{c}	2.66
	Zn	2.00±0.05 ^{a}	2.49±0.12 ^{b}	2.05±0.08 ^{a}	2.53±0.16 ^{b}	2.24
Trace Essential Elements (oligoelements)	Cr	0.011±0.003 ^{a}	0.014±0.007 ^{a}	0.018±0.009 ^{a}	0.011±0.006 ^{a}	0.01
	Cu	0.551±0.01 ^{a}	0.594±0.03 ^{a}	0.457±0.02 ^{c}	0.706±0.01 ^{d}	0.56
	Mo	0.04±0.001 ^{a}	0.072±0.005 b	0.018±0.007 ^{c}	0.038±0.003 ^{a}	0.03
	Se	<LOD	<LOD	<LOD	<LOD	<LOD
	I	<LOD	<LOD	<LOD	<LOD	<LOD

LAQc/31, LAQb/41, LAQf/104, LAQp/16: advanced lines of *Chenopodium quinoa*

Results are expressed as mean ± standard deviation for analysis in three replicates.

Values that do not share letters in common are significantly different by Tukey's test (*P*= .05).

ULOQ: upper limit of quantification.

LOD: limit of detection.

In Table 6, it can be observed that the pseudocereals studied by the USDA, have 7 times more potassium and phosphorus than rice. According to this database, magnesium in the LAQs was in the order reported for quinoa and amaranth, being 9 times higher than rice. Calcium was in the order of quinoa, 3 times lower than amaranth and 5 times higher than rice. Iron presented a tendency similar to calcium. Manganese, copper and zinc were similar in the three pseudocereals, presenting an amount of almost 3 times higher than rice. All analyzed samples are considered as of low-sodium content according to the publications of the WHO [32].

Table 6. Minerals (mg/100 g) of quinoa grains compared to uncooked quinoa, uncooked amaranth grain, and uncooked and unenriched white rice, in the USDA nutrient database

Element	Mean LAQ	Quinoa (uncooked)	Amaranth grain (uncooked)	Rice (white, Unenriched and uncooked)
K	> ULOQ	563.00	508.00	77.00
Ca	54.76	47.00	159.00	11.00
Mg	204.36	197.00	248.00	23.00
P	> ULOQ	457.00	557.00	71.00
Na	11.53	5.00	4.00	7.00
Fe	4.51	4.57	7.61	1.60
Mn	2.66	2.03	3.33	0.97

Zn	2.24	3.10	2.87	1.20
Cu	0.56	0.59	0.52	0.17
Se	<LOD	8.50	18.70	15.10

USDA nutrient database (U.S. Department of Agriculture, Agricultural Research Service, 2013).

ULOQ: upper limit of quantification.

LOD: limit of detection.

In general, it is known that pseudocereals cover higher nutritional demands than traditional cereals. In Table 7, it can be observed the contribution of quinoa to the intake of macronutrients and chemical elements. According to the international nutritional requirements, the LAQs provide, for every 100 g of intake, 26% of the required daily proteins for adults, which is a high content compared to cereals, and 50% of carbohydrates.

Table 7. Macronutrients and elements contribution of quinoa according to the Dietary Reference Intakes (DRIs).

Nutrient	**Mean LAQ (g/100g)**	**Requirements for adults (g/d)**	**Contribution of quinoa (%)**
Total protein	14.67	56.00	26.20
Carbohydrates*	64.53	130.00	49.64
Fatty acid			
18:2 (linoleic acid)	5.43	17.00	31.94
18:3 (linolenic acid)	0.55	1.60	34.37
Element			

Ca	54.76	1000.00	5.48
Mg	204.36	420.00	48.66
Na	11.53	1500.00	0.77
Fe	4.51	8.00	56.37
Mn	2.66	2.30	>100
Zn	2.24	11.00	20.36
Cr	0.01	0.035	28.57
Cu	0.56	0.90	62.22
Mo	0.03	0.045	66.66

DRI adapted from the Food and Nutrition Board, Institute of Medicine, National Academies suggested indispensable nutrients and elements requirements for adults (Life Stage Group: males, 35-50 years).

https://ods.od.nih.gov/Health_Information/Dietary_Reference_Intakes.aspx

The mineral results show that quinoa presents a significant content of elements that are considered essential for human nutrition, providing 50% or more of the daily required magnesium, iron, copper and molybdenum, and more than 100% of manganese. It is noteworthy the contribution of more than 30% of linoleic and linolenic acids.

These results confirm that a diet balanced in proteins, fats and minerals, could be obtained from quinoa and other Andean cereals such as amaranth, as a significant part in gluten-free diets.

In order to optimize the information on the nutritional potential of these seeds, it is important to identify the antinutritional factors that interfere in the metabolic processes or nutrient bioavailability, and thus affect the consumer's health.

258 The antinutrients quantified in this study are presented in Table 8. Proteases
259 inhibiting factors inhibit the action of digestive enzymes, in particular trypsin and
260 chymotrypsin, causing a digestibility decrease in the protein; however, many studies
261 suggest that these compounds can have a beneficial effect through their
262 anticarcinogenic action [33]. The results of the antitryptic factors determination are, in
263 average, around 0.72 UTI/mg for the lines studied, being below the maximum
264 acceptable value for foods, which according to the FAQ is of 5 UTI/mg. Furthermore,
265 this thermolabile component can be reduced through different food preparation
266 processes involving a thermal treatment.

267 Even though saponins can affect zinc and iron absorption, many studies
268 indicate that they have a wide range of biological activities and beneficial effects, such
269 as their hypocholesteremic and hypoglycemic actions, among others [34]. According to
270 the FAO, the maximum allowed saponin content is of 0.11% [9]. The saponin content
271 reported for quinoa varies between 0.1 and 5% [30]. The culture lines under study
272 presented an average saponin content of 0.43 g/100g or 0.43%. The quinoa grain
273 pericarp is the one containing the saponins, giving it a bitter taste, and it has to be
274 removed for the grain to be consumed. A dry-heat toasting process is used by some
275 companies to remove the shell. It has to be considered that the quinoa grain is
276 preferentially consumed cooked.

277 Nitrates can be reduced to nitrites by the intestinal flora, and cause the
278 transportation of hemoglobin into methemoglobin. In addition, nitrites can react with
279 amines, forming carcinogenic nitrosamines [35]. The FAO/OMS have determined, as
280 nitrates acceptable daily intake (ADI), a value of 0 - 3.7 mg/kg of body weight,
281 equivalent to 222 mg of nitrate for a 60 kg adult [3]. Thus, the nitrate contents in the
282 studied quinoa seeds can be considered as non-toxic (0.45 mg/100g). On the other
283 hand, it is known that cooking foods in boiling water can be an efficient way of reducing
284 the seeds antinutritional effects, mainly from nitrates and oxalates.

285 Oxalates are present in plants as sodium oxalate, and are mainly accumulated
286 in the leaves. This compound is soluble and combines with calcium and magnesium in
287 the bloodstream, resulting in insoluble salts. These salts, when present in large
288 amounts in human tissues, can provoke damages by oxidation and glutathione
289 depletion, and can also generate cascade inflammation by an immunological effect,
290 and the formation of kidney stones [36]. According to some authors, the oxalate in the
291 whole grains is higher in comparison to refined products, which suggests that oxalic
292 acid is also in the outer layers of cereals. The maximum allowed content of oxalic acid,
293 according to the FAO, is of 0.10% [9]. The oxalate values reported in this study
294 (1247.27 mg/100g, equivalent to 1.25%), could be reduced by cooking methods to
295 which quinoa can be subjected.

296 Phytic acid is present in most cereals and legumes, and in some fruits and
297 vegetables. The phytic acid antinutritional action is mainly due to its capacity to form
298 complexes with essential minerals, which decreases their absorption and
299 bioavailability; it can also interact with basic residues of proteins forming complexes,
300 interfering with enzymatic reactions at the digestive level [37]. In addition, phytic acid
301 beneficial health effects have been informed, such as lipid-lowering and antioxidant
302 actions [38]. In quinoa seeds, a phytic acid concentration of 1180 mg/100 g has been
303 informed in five quinoa varieties [30]. In the studied samples, the phytic acid values are
304 much lower than the reported in the literature, 0.267 mg/100g, being a food with a very
305 low content of this antinutrient.

Nutrient	**LAQc/31**	**LAQb/41**	**LAQf/104**	**LAQp/16**	**Mean**
Trypsin inhibitors (UTI/mg)	0.52±0.03 [a]	1.16±0.07 [b]	0.47±0.02 [a]	0.73±0.03 [c]	0.72

Saponins (g/100g)	0.91±0.04 [a]	0.50±0.01 [b]	0.19±0.02 [c]	0.60±0.02 [b]	0.43
Nitrates (mg/100g)	0.33±0.03 [a]	0.32±0.02 [a]	0.70±0.02 [b]	0.45±0.034 [c]	0.45
Oxalates (mg/100g)	1187.08±83.00 [a]	1056.00±63.00 [a]	466.00±12.00[b]	2280.00±86.00[c]	1247.27
Phytate P (mg/100g)	0.037±0.001[a]	0.963±0.007[b]	0.035±0.002[a]	0.036±0.001[a]	0.267

306 **Table 8. Antinutrient contents of quinoa grains**

307 LAQc/31, LAQb/41, LAQf/104, LAQp/16: advanced lines of *Chenopodium quinoa*

308 Results are expressed as mean±standard deviation for analysis in five replicates.

309 Values that do not share letters in common are significantly different by the Tukey's

310 test (*P*= 0.05).

311 The antinutrient values informed for LAQ are consistent with diverse author

312 [39], who concluded that the antinutrients present in quinoa, in particular saponins, do

313 not pose a significant risk for health. It is noteworthy that differences can be observed

314 between species in the values informed, which can be attributed to genetic differences

315 of the plant, cultivation area, seeding year, among others.

316 Quinoa also contains bioactive compounds that influence on the cell activity and

317 physiological mechanisms, with beneficial health effects, such as phenols. Polyphenols

318 are secondary metabolites of plants; they include several antioxidant compounds and

319 are usually considered involved in the defense against chronic human diseases,

320 including cancer and cardiovascular diseases [40]. The total phenols content and the

321 antioxidant activity evaluated by the DPPH, β-carotene and Nitric Oxide methods, are

322 shown in Table 9.

323 The highest phenolic content (mg gallic acid/100 g) was observed in LAQp/16
324 (43.42 ± 1.35) and LAQb/41 (43.01 ± 1.50), followed by LAQc /31 (38.45 ± 0.55) and
325 LAQf/104 (25.82 ± 1.47). Based on these results and the consulted literature [41], it is
326 deduced that the studied seeds have an adequate level of phenolic compounds, and
327 that the variations between lines could be attributed to genetic factors and other
328 agrotechnical aspects.

329 **Table 9. Total phenolic content and antioxidant activity of quinoa grains**

	LAQc/31	LAQb/41	LAQf/104	LAQp/16	Mean
Phenols (mg gallic acid /100g)	38.45 ± 0.55 [a]	43.01 ± 1.50 [b]	25.82 ± 1.47 [c]	43.42 ± 1.35 [b]	37.68
% DPPH	91.12 ± 0.63 [a]	88.88 ± 3.43 [a]	86.22 ± 1.33 [a]	89.57 ± 1.17 [a]	88.95
% β-Carotene	32.82 ± 1.68 [a]	22.12 ± 1.84 [a]	22.84 ± 3.66 [a]	28.47 ± 3.30 [a]	26.56
% NO	85.82 ± 8.32 [a]	41.60 ± 2.01 [b]	22.20 ± 1.80 [c]	28.82 ± 1.93 [c]	44.61

330 LAQc/31, LAQb/41, LAQf/104, LAQp/16: advanced lines of *Chenopodium quinoa*
331 Results expressed as mean ± standard deviation for analysis in three replicates.
332 Values that do not share letters in common are significantly different by the Tukey's
333 test (*P*= .05).

334 The free-radical scavenging capacity analyzed by DPPH was in the order of
335 88.95%, and the inhibition of fatty acids oxidation evaluated by β-carotene bleaching
336 was of 26.56%, without showing significant differences. The NO inhibition presented
337 the highest value for LAQc /31 (85.82 ± 8.32%), followed by LAQb/41 (41.60 ± 2.01%),
338 LAQp/16 (28.82 ± 1.93) and LAQf/104 (22.20±1.80). These results agree with the
339 informed by other authors, and are similar to other vegetable species considered as
340 with significant antioxidant activity [5].

4. CONCLUSIONS

Quinoa is currently recognized by its high nutritional value compared to traditional cereals, and for being a gluten-free food similar to amaranths, so it is considered as a crop with great potential for contributing to global food security.

The new quinoa lines evaluated in this work are rich in nutrients, such as proteins, essential fatty acids and some minerals, in accordance with the reported in the literature.

They are a significant source of calcium, magnesium and iron, which are minerals deficient in gluten-free food products.

Even though differences were observed between lines in the nutrient contents, due to vegetable specific factors and environmental conditions, these differences are not relevant from the nutritional point of view.

The evaluated antinutrients do not pose a risk for human health. Even though the saponin and oxalate contents are significant, they are reduced by the action of temperature and common cooking procedures.

It also presents natural bioactive compounds with significant antioxidant activity such as phenols.

Based on the results presented in this work, these quinoa lines are recommended as an important functional food in the diet of celiac patients.

CONFLICT OF INTEREST

The authors declare that have no conflict of interest.

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