Research Paper

Future of Food: Journal on Food, Agriculture and Society
9 (2) May 2021

Nutritional, antioxidant and polyphenol content of quinoa *(Chenopodium quinoa Willd.)* cultivated in Iran

SEYED SAEED SEKHAVATIZADEH[1*], SAEID HOSSEINZADEH[2], GHOLAMHOSSEIN MOHEBBI[3]

[1]Fars Agricultural and Natural Resources Research and Education Center, AREEO, Shiraz, Fars, Iran.
[2]Department of Food Hygiene and Public Health, School of Veterinary Medicine, Shiraz University, Shiraz, Iran.
[3]The Persian Gulf Marine Biotechnology Research Center, the Persian Gulf Biomedical Science Research Institute, Bushehr University of Medical Science, Bushehr, Iran.

* Corresponding author: s.sekhavati@areeo.ac.ir

Data of the article

First received : 25 September 2020 | Last revision received : 17 February 2021
Accepted : 01 May 2021| Published online :25 May 2021
DOI : 10.17170/kobra-202102163256

Keywords

Amino acid profile; Antioxidant activity; Quinoa; Vitamins and minerals

Quinoa is a pseudo cereal plant with high nutritional values. Recently, it was cultivated in Iran because of the water crisis. This study aimed to assess the physicochemical and antioxidant properties of quinoa cultivated in Iran for the first time. The macronutrients and energetic value, polyphenol, total phenol content and DPPH of quinoa were measured. Some B group vitamins, the free fatty acid profile and trace elements were assessed. Trace elements were also evaluated by ICP. The amounts of dry matter, protein, fat, ash, and available carbohydrates were, 90.30±0.89, 16.30±1.52, 6.09 ±0.30, 4.43±0.47, and 73.14±1.59 %, respectively. The total bacterial count of quinoa was 5.22±0.23 (LOG_{10} CFU/g). Escherichia coli and sulphite-reducing Clostridia were lower than 1.0 (LOG10 CFU/g). *Salmonella* was absent in all samples. According to the DPPH method, the half-maximal inhibitory concentration (IC_{50}) of quinoa seed was approximately 6232.0 mg/L compared to the equivalent Gallic acid as a standard (IC_{50}: 184.15 µg/mL). Quinoa seed contained the highest niacin level (0.881 mg/100g) among the vitamin B groups. The amino acid profile analysis revealed the highest contents of glutamic acid (1.230 g/100g) and lysine (3.08 g/100g). The linoleic acid content was 63.5 g/100g (fat). The concentrations of minerals including calcium, magnesium, and potassium, were 0.07, 0.086 and 0.35 g/100g $_{(dw)}$, respectively. Quinoa is a valuable nutritional product that can provide health benefits to humans, mainly because of its linoleic acid content.

1. Introduction

According to the World Bank definition, a geographic area concealing less than 1,700 m3 per capita of water is considered a most water-scarce region in the world. The Middle East and North Africa (MENA), which have an average of 1,274 m3 per capita, are included in these regions. Around 69.56 % of the nations in the MENA regions were reported to be suffering life-threatening water stress, i.e., less than 1,000 m3 per capita (Verdier, 2011). Few countries such as Iran, Iraq and Egypt are presently included in these critical areas. In general, nearly 80% of water is used in agriculture in the MENA region due to low irrigation efficiency (Negewo, 2012). Other important restrictions are water and soil salinity, which reduce the quality of crops and finally influence the crops' economic yield. Therefore, the quinoa plant is a valuable alternative crop because of its capability to lifecycle at 400 mM salinity (Hariadi et al., 2010). For this purpose, the

Iranian Ministry of Agriculture offers this plant as a substitute for water-intensive plants and provides facilities for its cultivation (Ranjbar et al., 2019).

Quinoa (Chenopodium quinoa Willd.) is a grain of the Chenopodiaceae family; it was a crop for the Incas who called it "the mother grain." It grows mainly in the Andean region of Colombia to northern Argentina, with Peru and Bolivia being the most important producers (Olivera-Montenegro et al., 2021).
However, it was unexplored in Middle East countries such as Iran (Konishi, 2002). Iran has great agricultural potentials for its vast area of arable land. However, climate changes and water resources insufficiencies are serious challenges to the Iranian agricultural and food production sectors. Altogether, 12% of land areas are under cultivation (arable land, orchards, and vineyards), but less than one-third of the cultivated area is irrigated; the rest is devoted to dry farming (Nanduri et al., 2019). The introduction of new crops and underutilised crops, especially those with higher water productivity and adapted to harsh conditions may be an option to tackle these challenges. It is expected that after five years, the cultivation of quinoa will reach 6,000 hectares in Iran. Quinoa is one of the few non-animal proteins from quantitative and qualitative opinion. It is believed that the quinoa protein is better than other cereals, and its content is twice as much as wheat and rice. Among the genotypes, Titicaca attained the highest yield (4.48 t/ha) in Iran (Bazile et al., 2016).

According to the literature, quinoa grain is considered a rich source of the lysine, methionine, and threonine; their essential amino acids are wealthier than conventional cereals (Lin et al., 2019), and the quality of animal proteins (Escudero et al., 2004). All essential amino acids have been found in quinoa, similar to those value of casein milk. Similar to wheat and rice, quinoa is an appropriate source of carbohydrates. One of the major components of quinoa is starch. The quinoa's dietary and soluble fibres are the same as conventional cereals such as wheat (James, 2009).

Quinoa's nutritional profile is comparable to major cereals and contains vitamins (thiamine, folic acid, vitamin C, α -carotene, and niacin) (Woomer & Adedeji, 2021). Fat content is another specific feature of the pseudo cereals; for instance, quinoa's lipid composition is substantially higher than that of the common cereals (Alvarez-Jubete et al., 2010). Their seeds contained the highest α-linolenic acid (ALA, 14C18:3 n-3) among all the pseudo cereals ranging from 385 to 473 g/kg of total fatty acid (Alvarez-Jubete et al., 2009; Jancurová et al., 2009). Quinoa contains higher linoleic acid (Omega-6) and other saturated fatty acids without compromising colour and texture when added to bread (Wang et al., 2015).

Quinoa is used in products such as salad, cakes, cookies and astronaut food because of its high nutritional value. In addition, it is suitable for diabetics, anaemia and lactose intolerance patients. Climatic conditions and the course of the weather are affecting the growth and nutritional value of quinoa. Titicaca is the species with the largest cultivation areas in Iran (Bazile et al., 2016; Sezgin & Sanlier, 2019). So far, little is known about trace substances of quinoa seed in Iran due to its limited cultivation. Therefore, this study was focused on the nutritional values, antioxidant activity, microbial properties and phenolic content of Titicaca seeds.

2. Materials and Methods

2.1. Chemicals

The chemicals, solvents, and standards including the hydrochloric acid, sodium 1-hexanesulfonate, methanol (HPLC grade), glacial acetic acid, gallic acid, catechin, chlorogenic acid, caffeic acid, quercetin, hesperedin, coumarin, p-coumaric acid, carvacrol, vanilin, trans-ferulic acid, sinapic acid, ellagic acid, hesperetin, eugenol, rosmarinic acid, thymol, and Folin–Ciocalteu phenol reagent and the other standard reagents were provided by Merck (Darmstadt, Germany). 1,1-diphenyl-2-picrylhydrazyl free radical (DPPH) was obtained from Sigma Chemicals Co. (St. Louis, USA). Gallic acid was provided by Acros Organics (New Jersey, USA).

2.2. Collection and further identification of seeds

Dried saponin-free quinoa (Chenopodium quinoa Willd.) was collected from growing plants in Koohenjan station, Sarvestan city, Fars province (South of Iran). Further identification of the plant was performed by the herbarium of the Fars Research Center for Agriculture and Natural Resources (FRCANR), Shiraz, Iran. A voucher specimen is deposited in the

ISSN-Internet 2197-411x OLCL 862804632

herbarium of the FRCANR, Shiraz, Iran.

2.3. Macronutrients and energetic value

The samples were analysed for moisture, energetic values, and macronutrient contents (fat, ash, proteins and carbohydrates) according to the method described by AOAC (AOAC, 2016). The Macro-Kjeldahl method (6.25 for quinoa flour) (KjelFlex K-360, Büchi, Flawil, Switzerland) was employed to measure the protein. The Soxhlet apparatus was used to measure crude fat and to determine the ash content samples were incinerated at 550 ± 15 °C (Mariotti et al., 2008).

The following equations were used to evaluate total carbohydrates and energetic values according to (Bazile et al., 2016):

Total carbohydrates (g/100 g) =100– (m_{fat}+ m_{ash}+ $m_{proteins}$) (I);
Energy (kcal/100 g) =4× ($m_{proteins}$+ $m_{carbohydrates}$) +9× (m_{fat}) (I I) (Cardoso et al., 2019).

2.4. Microbiological analyses

The microorganisms *Salmonella, Coliforms, E. coli, Yeasts, Molds, Sulphite-reducing clostridia (SRC)* and Aerobic plate count (APC) were conducted in accordance with the Iranian National Standards (NO.11603) (Rahamifard et al., 2019).

2.5. Preparation of extract

The preparation and extraction methods were carried out based on Bahmanzadegan et al., 2019).

2.6. Extraction of polyphenol and HPLC analysis

Polyphenols were extracted according to the method given by Mišan et al. (2011) with some modifications. The chromatographic analysis was carried out using an autosampler HPLC Agilent 1200 series, equipped with a photodiode array detector (PDA), and a Zorbax Eclipse XDB-C18 column (4.6 × 5 µm i.d.; 150 mm film thickness (FT); 5µm. The elution was separately monitored at 320 and 280 nm for chlorogenic acid and the other polyphenols. Linear calibration graphs were obtained with an acceptable correlation for standard solutions (Mišan et al., 2011).

2.7. Total phenolic content analysis

Total polyphenols content (TPC) was quantified using Folin–Ciocalteu reagent (Ainsworth & Gillespie, 2007). The aqueous extract was also added to the Folin–Ciocalteu reagent in the presence of sodium carbonate anhydrous, creating a dark blue solution. Then, the absorbance was measured at 765 nm to obtain the total phenolic content using the Gallic acid calibration curve as the standard (Mišan et al., 2011).

2.8. Evaluation of antioxidant activity by DPPH methods

The extracts' antioxidant activity was spectrophotometrically measured using an ELx808 microplate reader (BioTek Instruments Inc., Winooski, VT, USA), by monitoring the disappearance of DPPH at 517 nm, according to the described procedure. The antiradical activity was expressed based on the number of antioxidants, necessary to decrease the initial DPPH absorbance by 50 % (IC50) which was then calculated from the nonlinear regression curve of Log (concentration of the test extract g/ml) against the mean values of the radical scavenging activity (Bahmanzadegan et al., 2019).

2.9. Determination of vitamins (thiamine, riboflavin, niacin)

The concentrations of thiamine, riboflavin, niacin were measured using HPLC Shimadzu LC (Kyoto, Japan) equipped with a UV detector. The Sample preparation and analysis were done based on Anyakora et al. (2008) and the Iranian National Standard (NO. 5333). Samples were extracted by acid hydrolysis. The separation was carried out using a Supelco column C-18 (x 25 cm, 4.6mm, ODS), 30 °C, with a flow rate of 1.0 mL/min in HPLC, the vitamin content was expressed as mg/100g d. m (Anyakora et al., 2008; Farrahi et al., 2001).

2.10. Folic acid

The folic acid analysis was performed after hydrolysis of seed samples based on Qureshi et al. (2005). The separation was carried out using a Supelco column C-18 (x 25 cm, 4.6mm, ODS), 30 °C, with a flow rate of 1.0 mL/min in HPLC, Shimadzu LC (Kyoto, Japan) equipped with a UV detector (SPD-A series) with de-

tection at λ = 245 nm. The folic acid content was expressed as mg in (100g d/m) (Qureshi et al., 2005).

2.11. Amino acid composition

The amino acid analysis was performed after hydrolysis of seed samples based on protocols of the U.S. Pharmacopeia. The separation was carried out using a 4 mm x 25 cm with precolumn (PS Spheribond 80-5 ODS 2), AK351, Vertex Plus column, 40 °C, with a flow rate of 1.0 mL/min in HPLC, Shimadzu LC (Kyoto, Japan) equipped with a fluorescence detector (RF-20A series) at λ excitation 348nm and λ emission 450 nm. The amino acid content was expressed in mg/100g (d.m). For lysin analysis HPLC system an autosampler system (Perkin Elmer, Australia) was used with the same procedure (United States Pharmacopeia, 2017).

2.12. The free fatty acid profile

The n-hexane extract of the sample was placed at a temperature of -40 °C for stability and freeze-dried for 24 hours by freeze-dryer FD-5003-BT, Dena vacuum, (Iran). The free fatty acid analysis was carried out using a 7890B GC System (Agilent Technologies, Santa Clara, USA). The components were separated on HP-5ms column (30 m _ 0.25 mm i.d., 0.25- Agilent 19091s-443) based on Pastor et al. (2020).

2.13. Determination of trace elements

In order to analyse the total values of Ag, Ba, Co, Ga, Mg, Ni, Zn, T1, A1, Bi, Cr, In, Mn P, Sr, V, As, Ca, Cu, K, Mo, Pb, Sn, B, Cd, Fe, Li, Na and Sb, an inductively coupled plasma-optical emission spectrometry (ICP OES, model iCAP 6000, Thermo Fisher Scientific, Madison, WI, USA) was used after acid digestion and treatment in the quinoa sample. Concentration in the sample was measured according to the USA EPA method 3050 (Zhang & Lin, 2019).

3. Results and Discussion

3.1. Macronutrients and Energetic Value

Details of the physicochemical parameters are summarised in Table 1. Quinoa flour has a higher protein content than corn or rice flours. It has higher contents of certain amino acids such as lysine (710 mg/100 g vs 141 and 194 mg/100 g in corn and rice flours, respectively) and aspartic acid (1160 mg/100g vs 400 and 758 mg/100 g, respectively) (Jancurová et al., 2009). The protein content of 14.8 % and 15.7 % respectively for sweet and bitter quinoa, from Bolivia, was reported by Wright et al. (2002). A protein range of 9.1% -15.5% was also considered for 11 genotypes of quinoa (González et al., 2012). In similar research, the cultivar BRS Alegria showed a crude protein level (20.92 ± 0.23%) which was a greater value than obtained in this study (16.30±1.52) (Palombini et al., 2013). Therefore, the cultivar and nitrogen source may affect protein content (Miranda et al., 2011). Previous research has established that the crude fat, carbohydrate, and ash were (4.48+0.32, 63.58+1.25 and 3.1+0.43), respectively. These results are not in agreement with the findings of this research. One reason for this difference could be related to quinoa varieties (Marmouzi et al., 2015).

The pH value is an important factor to detect the treatment strategy supplied to the flour if it shows excessive alteration as in the case of chlorine bleaching. It is also considered as a significant factor in the capacity of microorganisms to develop in foodstuff. A lower pH value (less than 5.5) is mainly caused by contaminated flour with some live yeast or other bacteria due to the excess biological activity (Souza et al., 2008). High levels of moisture can provide a proper environment for microorganisms' growth and is a critical factor in mycotoxin production (Hădărugă et al., 2016). The moisture of quinoa was about 3.66 %. As a result, a low moisture level is always advantageous for a longer shelf-life of a product.

3.2. Microbiological analyses

Table (1) illustrates the results of microbiological counts in the quinoa. The APC microorganisms acquired in the present study for the quinoa flours were greater than other results (Eglezos, 2010; Cardoso et al., 2019), respectively, reported values of 4.2 and 4.44 LOG10 CFU/g for wheat. The cereal grains are commonly susceptible to contamination during various stages of ripening, harvesting, processing, and storage. The constant contaminants of grain flours are microorganisms because they originate from the cereals vegetation period as they are an integral part of the grain mass. Such microorganisms are less active un-

ISSN-Internet 2197-411x OLCL 862804632

der unfavourable conditions and are not considered potential hazards (Cardoso et al., 2019).

3.3. Polyphenol, total phenol and antioxidant activity

The quantitative analysis of quinoa has revealed six phenolic compounds in the methanolic extract (Table 2 and Fig 1), and consequently, a high IC50 about 6232.0 mg/L compared to equivalent Gallic acid as a standard (IC50: 184.15 µg/mL). Total phenolic content was also reported at 8.298 mg/g dwequivalent Gallic acid. In previous studies by Marmouzi et al. (2015) phenolic content of quinoa was higher (20.63 mg/g dw) than our results. One reason for this difference may be associated with genetic and environmental conditions, which can influence the presence of phenolic compounds. Phenolic content is responsible for antioxidant activity. However, numerous discrepancies have resulted from a lack of standardised extraction methods, an issue previously addressed in the literature (Marmouzi et al., 2015). In the last

Table 1. Proximate and microbiological analyses of quinoa seed

Parameters	Quinoa seed	***Microorganisms analysed	Quinoa seed
pH	4.96±0.02	[c]APC $_{(LOG10\ ^{c}CFU/g)}$	5.22±0.23
Acidity	9.67±0.33	*Coliforms* $_{(LOG10\ CFU/g)}$	2.47±0.14
Dry matter (g/100 g as fed)	90.30±0.89	*Yeasts* $_{(LOG10\ CFU/g)}$	2.39±0.21
protein (g/100 g dw)	16.30±1.52	*Molds* $_{(LOG10\ CFU/g)}$	2.31±0.28
fat (g/100 g dw)	6.09±0.30	*Escherichia coli* $_{(LOG10\ CFU/g)}$	<1.0
ash (g/100 g dw)	4.43±0.47	[c]SRC $_{(LOG10\ CFU/g)}$	<1.0
[a]carbohydrates (g/100 g dw)	73.14±1.59	*Salmonella spp.* $_{(LOG10\ CFU/g)}$	Absent
[b]Energy (kcal/100 g dw)	412.73±0.70		

Values are expressed as mean ± SD; dw: Dry weight

[a] Total carbohydrates (g/100 g) =100− (m_{fat}+ m_{ash}+ $m_{proteins}$)

[b] Energy =4× (% protein + %carbohydrates) + 9× (% fat)

Table 2 Polyphenol content of quinoa seed

Polyphenol content	**quinoa extract (mg.L^{-1})**	**Retention time (min)**
Sinapic acid	ND[a]	16.5
Gallic acid	51.75007	3.3
Catechin	ND	8.3
Caffeic acid	0.264	11.6
Chloregenic acid	ND	10.5
Quercetin	ND	21.6
p-Coumaric acid	1.890197	15.6
Coumarin	ND	17.4
Carvacrol	ND	28.4
Vanilin	6.27276	13.5
Trans-ferulic acid	27.2985	16.3
Hesperedin	13.36627	18.5
Ellagic acid	ND	19.02
Eugenol	ND	23.7

decade, more attention has been paid to naturally occurring antioxidants to inhibit both free radical function and oxidative chain reactions within tissues and membranes (Nsimba et al., 2008). Antioxidants can effectively delay or inhibit the oxidation of lipids and other macromolecules. They can delay or inhibit the initiation stage of fat oxidising chain reactions. Therefore, the rancidity of foods decreases the formation of toxic products but increase shelf life. The presence of antioxidants in food makes it more valuable (Paśko et al., 2009). In this research, the IC50 of quinoa seed was 6232.0 mg/L. The pseudo-cereal seeds and sprout revealed relatively high antioxidant activities (Paśko et al., 2009). Abderrahim et al. (2015) evaluated the antioxidant activities of various extracts of quinoa (Japan) and from its relative Amaranthus, finding different values among the samples (Abderrahim et al., 2015). In other research, IC50 of quinoa was (461.89 mg/L) lower than our result. The different ecotypes of quinoa, presented IC50 values between 100-15800 mg/L. Data variation in the antioxidant capacity of quinoa ecotypes is expected, as many factors such as genetic, agrotechnical processes and environmental conditions can influence the presence of phenolic compounds (Miranda et al., 2011).

Over 20 phenolic compounds have been found in both free and conjugated forms (mainly liberated by alkaline, acid, and enzymatic hydrolysis). Vanillic acids, ferulic acids, and their derivatives, as well as the flavonoids quercetin, kaempferol, and their glycosides, are among the most common phenolic acids compounds (Tang et al., 2015; Tang et al., 2016). Apart from their antioxidant activities, they utilise α-glucosidase and inhibit pancreatic lipase function (Tang et al., 2016). The plant is mainly associated with phytoecdysteroids (polyhydroxylated steroids) because their structure is related to insect-moulting hormones. Wide ranges of beneficial effects such as anabolic, performance-enhancing, anti-osteoporotic, anti-diabetic, anti-obesity, and wound healing properties, have been demonstrated for these components (Graf et al., 2014).

3.5. Group B vitamins

Table (3) shows some B vitamins measured in quinoa. Mohyuddin et al. (2019) have reported appreciable amounts of thiamine and folic acid (respectively, 0.4, and 78.1 mg.100 g−1). Other researchers report B vitamin quantities as follows: thiamine (vitamin B1) (0.4 mg/100g), riboflavin (vitamin B2) (0.39 mg/100g), niacin (vitamin B3) (1.06 mg/100g) and folic acid (vitamin B9) (112 µg/100 g) (Graf et al., 2015). Miranda et al. (2012) reported significant differences in the vitamin B contents in grain due to variety, growing location (for thiamine and riboflavin) and soil type. It was shown that quinoa contains substantially more riboflavin (B2) than those cereals. Thiamine values in quinoa are lower than those in oat or barley, but not higher than those of niacin, riboflavin, vitamin B6 and total folate (James, 2009). Surprisingly, the levels folic acid in 100 g of quinoa is reported to meet the adult daily requirement, while riboflavin meets 80% of children's needs and 40% of adult daily prerequisites (James, 2009).

3.6. Amino acids

Table (3) and Fig (1) show some amino acid measured in quinoa. In this research, the highest concentrations belonged to lysin and glutamic acid, followed by aspartic acid, asparagine serin and arginine. These results are different from the findings of Escuredo et al. (2015). The variability could be due to diverse quinoa genotypes and growth years, both in the calibration and external validation sets, which was important for developing calibration equations for future predictions (Escuredo et al., 2014).

According to the values indicated by FAO/WHO/UNU, quinoa protein can supply around 180% isoleucine, 338% lysine, 212% methionine+cysteine, 320% phenylalanine+tyrosine, 331% threonine, 228% tryptophan and 323% valine of the suggested amounts in protein sources for adult nutrition. Besides, cysteine and methionine, the sulphur-containing amino acids, are present at high concentrations than other plants (James, 2009). Quinoa proteins are particularly high in lysine, the limiting amino acid in most cereal grains. Lysine and leucine in quinoa proteins are limiting amino acids for 2–5-year-old infants or children, while all the essential amino acids of this protein are sufficient according to FAO/WHO (James, 2009).

3.7. Free fatty acid profile

Fat content in quinoa ranged from 1.8 to 9.5 g/100g(dw), with an average of 5.0–7.2 g/100g(dw).

ISSN-Internet 2197-411x OLCL 862804632

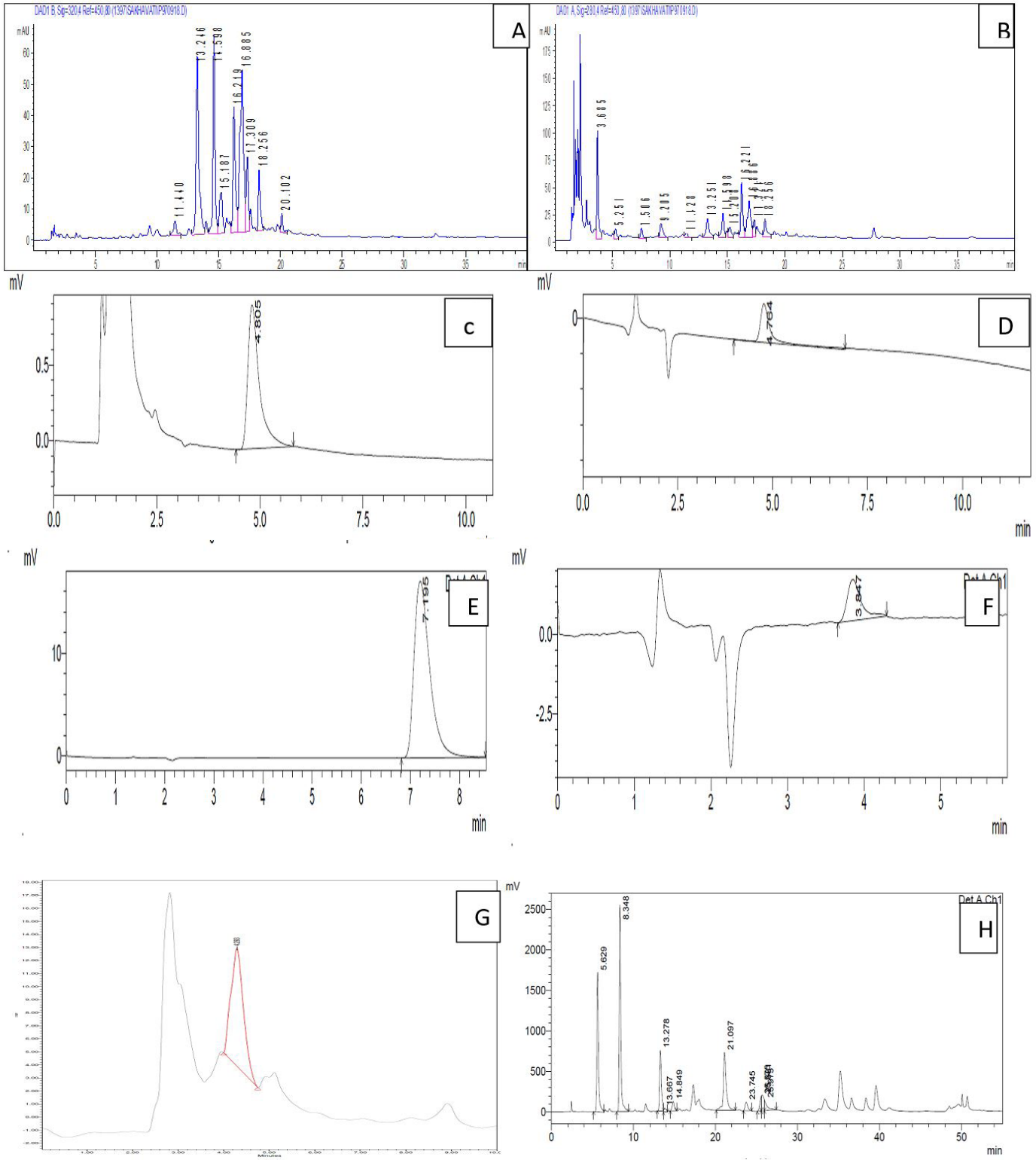

Fig 1. High-performance liquid chromatograms of the A: methanolic extract of quinoa seeds (280 nm), B: (320 nm), C: Riboflavin, D: Niacin, E: Folic acid, F: Thiamin, G: Lysin and H: Amino acids UV–visible spectrum

Table (3) shows some free fatty acid measured in quinoa. In this study, the majority of the fatty acids in quinoa seeds were unsaturated fatty acids (UFA). Approximately two-thirds were polyunsaturated fatty acids (PUFA), and one-third were monounsaturated fatty acids (MUFA). These results are similar to those reported by Tang et al. (2015). PUFA were

mainly from two essential fatty acids, linoleic acid (18:2n6, an omega-6 fatty acid) and a-linolenic acid (18:3n3, an omega-3 fatty acid) (Tang et al., 2015). Linoleic acid impacts the risk of many chronic diseases, including cardiovascular diseases, certain cancers and Type 2 diabetes (Belury et al., 2018). Some fatty acids in quinoa are saturated (11 g/100g(dw fat)), while (88.31 g/100g(dw fat)) of the total fatty acids of quinoa is an unsaturated fatty acid. Similar levels of linoleic (C18:2), oleic (C18:1), and alpha-linolenic (C18:3) were recorded with corn and soybeans. These fatty acids equal nearly 88 g/100g(dw) of the total fatty acid amount of quinoa seeds (Navruz-Varli & Sanlier, 2016; Repo-Carrasco et al., 2003). The role of α-linolenic acid in preventing many degenerative diseases such as cardiovascular disease, cancer, osteoporosis, inflammatory and autoimmune diseases is well-established (Simopoulos, 2006). Furthermore, palmitic fatty acid, which exists in quinoa as a basic saturated fatty acid, constitutes 10 g/100g(dw) of its total fatty acids. From among unsaturated fatty acids, oleic (19.7-29.5 g/100g(dw)), linoleic (49.0-56.4 g/100g(dw)) and alpha-linolenic (8.7-11.7 g/100g(dw)) fatty acids constitute 87.2-87.8 g/100g(dw) of its total fatty acids in a similar way to soybean lipid composition (Repo-Carrasco et al., 2003; Navruz-Varli & Sanlier, 2016).

3.8. Minerals

Analysis of the trace elements is demonstrated in Table (4). High contents of calcium (0.07 g/100 g), magnesium (0.086 g/100 g) and iron (0.043 g/100 g) were reported in quinoa seeds, which is also of significant importance (Repo-Carrasco et al., 2003). Many of these minerals are present in higher concentrations compared to other common grains. Moreover, calcium, magnesium, and potassium found in quinoa can be absorbed and used by the body (bioavailable forms); thus, their contents are considered as adequate for a balanced diet (Vega-Gálvez et al., 2010). Phosphorus, along with calcium, is one of the most important minerals in the development and maintenance of skeletal tissue in animals. About 80% of phosphorus in the animal body is found in bones and teeth. Potassium deficiency is rare in animals; it can occur in high-level fattening cattle fed with concentrated feed. On the other hand, an excess of this mineral reduces the absorption and evaluation of magnesium (Tan, 2020).Variations in the mineral concentrations of quinoa are possibly associated with the soil type, mineral composition of the geographic region and the application of a specific fertiliser (Belton & Taylor, 2002).

4. Conclusion

Quinoa (Chenopodium quinoa Willd.) is an appealing food because of its nutritional characteristics, the high value of energy and therapeutic effects, as well as the absence of gluten. It is a good source of protein, carbohydrate, essential minerals and B vitamins. The protein quality of quinoa, mainly by its exceptional amino acid balance, makes it a more beneficial food than many common vegetables. The oil fraction of the seeds represents the high quality and high nutritional value (linoleic acid). It is also rich in iron and magnesium, phosphorus, potassium, and some B vitamins. All nutritional factors make it an attractive, novel protein source that could be used alone or combined with cereal grains.

Conflict of interest

The authors declare no conflict of interest. Besides, the funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

Acknowledgement

The authors thank Dr. Ebrahim Zare for his assistance during the research. This study did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

References

Abderrahim, F., Huanatico, E., Segura, R., Arribas, S., Gonzalez, M. C., & Condezo-Hoyos, L. (2015). Physical features, phenolic compounds, betalains and total antioxidant capacity of coloured quinoa seeds (Chenopodium quinoa Willd) from Peruvian Altiplano. Food Chemistry, 183, 83-90.

Alvarez-Jubete, L., Arendt, E., & Gallagher, E. (2009). Nutritive value and chemical composition of pseudocereals as gluten-free ingredients. International Journal of Food Sciences and Nutrition, 60(sup4),

ISSN-Internet 2197-411x OLCL 862804632

Table 3. Amino acids, vitamins and Free fatty acid profile in quinoa seeds present in quinoa seed

Amino acids (gr/100g)		Free fatty acid ($gr/100g_{fat}$)		Vitamin(mgr/100g)	
Aspartic acid	0.8141	Eicosenic acid	1.03	Thiamin	0.486
Glutamic acid	1.230	Linoleic acid	63.5	Riboflavin	0.572
Asparagine	0.4205	Oleic acid	18.46	Niacin	0.881
Serine	0.6612	Palmitic acid	11.24	Folic acid	0.097
Glutamine	0.0955	unknown	0.33		
Tyrosine	0.3981	Linolenic acid	5.32		
Arginine	0.6383	Σ Saturated fatty acid (SFA)	11.57		
Methionine	0.0878	Σ Unsaturated fatty acid (UFA)	88.31		
Tryptophan	0.2107	Σ Monounsaturated fatty acid (MUFA)	19.41		
Valine	0.2405	Σ Polyunsaturated fatty acid (PUFA)	68.82		
Isoleucine	0.5216				
Lysin	3.0829				

Table 4 Analysis of quinoa seed trace elements

Element	Measure (g/100g)	Element	Measure (g/100g)	Element	Measure (g/100g)	Element	Measure (g/100g)
Ag	>0.001	Al	0.005	As	>0.001	B	>0.001
Ba	>0.001	Bi	>0.001	Ca	0.07	Cd	>0.001
Co	>0.001	Cr	>0.001	Cu	>0.001	Fe	0.043
Ga	>0.001	In	>0.001	K	0.35	Li	>0.001
Mg	0.086	Mn	0.006	Mo	>0.001	Na	0.095
Ni	>0.001	P	0.12	Pb	>0.001	Sb	>0.001
Zn	>0.001	Sr	>0.001	Sn	>0.001	Ti	>0.001
Ti	>0.001	V	>0.001				

240-257.

Alvarez-Jubete, L., Arendt, E., & Gallagher, E. (2010). Nutritive value of pseudocereals and their increasing use as functional gluten-free ingredients. Trends in Food Science & Technology, 21(2), 106-113.

Anyakora, C., Afolami, I., Ehianeta, T., & Onwumere, F. (2008). HPLC analysis of nicotinamide, pyridoxine, riboflavin and thiamin in some selected food products in Nigeria. African Journal of Pharmacy and Pharmacology, 2(2), 029-036.

Bahmanzadegan, A., Rowshan, V., Zareiyan, F., & Hatami, A. (2019). Lagoecia cuminoides L., its antioxidant activity and polyphenolic constituents from Iran. Natural Product Research, 33(16), 2376-2378.

Bazile, D., Pulvento, C., Verniau, A., Al-Nusairi, M. S., Ba, D., Breidy, J., . . . Otambekova, M. (2016). Worldwide evaluations of quinoa: preliminary results from post international year of quinoa FAO projects in nine countries. Frontiers in Plant Science, 7, 850.

Belton, P. S., & Taylor, J. R. (Eds.). (2002). Pseudocereals and less common cereals: grain properties and utilisation potential.Verlag Berlin, Germany: Springer Science & Business Media.

Belury, M. A., Cole, R. M., Snoke, D. B., Banh, T., & Angelotti, A. (2018). Linoleic acid, glycemic control and Type 2 diabetes. Prostaglandins, Leukotrienes and Essential Fatty Acids, 132, 30-33.

Cardoso, R. V., Fernandes, Â., Heleno, S. A., Rodrigues, P., Gonzaléz-Paramás, A. M., Barros, L., & Ferreira, I. C. J. F. c. (2019). Physicochemical characterisation and microbiology of wheat and rye flours. Food Chemistry, 280, 123-129.

Eglezos, S. (2010). Microbiological quality of wheat grain and flour from two mills in Queensland, Australia. Journal of Food Protection, 73(8), 1533-1536.

Escudero, N., De Arellano, M., Luco, J., Giménez, M., & Mucciarelli, S. (2004). Comparison of the chemical composition and nutritional value of Amaranthus cruentus flour and its protein concentrate. Plant Foods for Human Nutrition, 59(1), 15-21.

Escuredo, O., Martín, M. I. G., Moncada, G. W., Fischer, S., & Hierro, J. M. H. (2014). Amino acid profile of the quinoa (Chenopodium quinoa Willd.) using near infrared spectroscopy and chemometric techniques. Journal of Cereal Science, 60(1), 67-74.

Farrahi, F., Hajseyedjavadi, S. A., Behfar, A., & Irani, V. (2001). Determination of thiamin, Riboflavin, Pyridoxin, niacin, and folic acid in dry vitamin supplements by high performance liquid chromatography (HPLC). Institute of Standards and Industrial Research of Iran, 1st ed. Retrieved from http://standard.isiri.gov.ir/StandardView.aspx?Id=89

González, J. A., Konishi, Y., Bruno, M., Valoy, M., & Prado, F. E. (2012). Interrelationships among seed yield, total protein and amino acid composition of ten quinoa (Chenopodium quinoa) cultivars from two different agroecological regions. Journal of the Science of Food and Agriculture, 92(6), 1222-1229.

Graf, B. L., Poulev, A., Kuhn, P., Grace, M. H., Lila, M. A., & Raskin, I. (2014). Quinoa seeds leach phytoecdysteroids and other compounds with anti-diabetic properties. Food Chemistry, 163, 178-185.

Graf, B. L., Rojas-Silva, P., Rojo, L. E., Delatorre-Herrera, J., Baldeón, M. E., & Raskin, I. (2015). Innovations in health value and functional food development of quinoa (Chenopodium quinoa Willd). Comprehensive Reviews in Food Science and Food Safety, 14(4), 431-445

Hădărugă, D. I., Costescu, C. I., Corpaş, L., Hădărugă, N. G., & Isengard, H.-D. (2016). Differentiation of rye and wheat flour as well as mixtures by using the kinetics of Karl Fischer water titration. Food Chemistry, 195, 49-55.

Hariadi, Y., Marandon, K., Tian, Y., Jacobsen, S.-E., & Shabala, S. (2010). Ionic and osmotic relations in quinoa (Chenopodium quinoa Willd.) plants grown at various salinity levels. Journal of Experimental Botany, 62(1), 185-193.

James, L. E. A. (2009). Quinoa (Chenopodium quinoa Willd): composition, chemistry, nutritional, and functional properties. Advances in Food and Nutrition Research, 58, 1-31.

Jancurová, M., Minarovičová, L., & Dandar, A. (2009). Quinoa–a rewiev. Czech Journal of Food Sciences, 27(2), 71-79

Konishi, Y. (2002). Nutritional characteristics of pseudocereal amaranth and quinoa: alternative foodstuff for patients with food allergy. Journal of Japan Society of Nutritionand Food Sciences, 55, 299-302.

Lin, M., Han, P., Li, Y., Wang, W., Lai, D., & Zhou, L. (2019). Quinoa secondary metabolites and their

ISSN-Internet 2197-411x OLCL 862804632

biological activities or functions. Molecules, 24(13), 2512.

Mariotti, F., Tomé, D., & Mirand, P. P. (2008). Converting nitrogen into protein—beyond 6.25 and Jones' factors. Critical Reviews in Food Science and Nutrition, 48(2), 177-184.

Marmouzi, I., El Madani, N., Charrouf, Z., Cherrah, Y., & Faouzi, M. E. A. (2015). Proximate analysis, fatty acids and mineral composition of processed Moroccan Chenopodium quinoa Willd. and antioxidant properties according to the polarity. Phytothérapie, 13(2), 110-117.

Mišan, A. Č., Mimica-Dukić, N. M., Mandić, A. I., Sakač, M. B., Milovanović, I. L., & Sedej, I. J. (2011). Development of a rapid resolution HPLC method for the separation and determination of 17 phenolic compounds in crude plant extracts. Central European Journal of Chemistry, 9(1), 133-142.

Miranda, M., Vega-Gálvez, A., Uribe, E., López, J., Martínez, E., Rodríguez, M. J., . . . Di Scala, K. (2011). Physico-chemical analysis, antioxidant capacity and vitamins of six ecotypes of Chilean quinoa (Chenopodium quinoa Willd.). Procedia Food Science, 1, 1439-1446.

Miranda, M., Vega-Gálvez, A., Quispe-Fuentes, I., Rodríguez, M. J., Maureira, H., & Martínez, E. A. (2012). Nutritional aspects of six quinoa (Chenopodium quinoa Willd.) ecotypes from three geographical areas of Chile. Chilean Journal of Agricultural Research, 72(2), 175.

Mohyuddin, S. G., Riaz, A., Qamar, A., Ali, S. H., Hu, C., Wu, L., ... & Ju, X. H. (2019). Quinoa is beneficial to the comprehensive nutritional value of potential health. Pakistan Journal of Science, 71(2), 69-74.

Nanduri, K. R., Hirich, A., Salehi, M., Saadat, S., & Jacobsen, S. E. (2019). Quinoa: A New Crop for Harsh Environments (Eds., Gul,B., Böer, B., Khan, M.A., Clüsener-Godt, M and Hameed, A), Tasks for Vegetation Science (pp. 301-335). Cham, Switzerland: Springer Nature Switzerland.

Navruz-Varli, S., & Sanlier, N. (2016). Nutritional and health benefits of quinoa (Chenopodium quinoa Willd). Journal of Cereal Science, 69, 371-376.

Negewo, B. D. (2012). Renewable energy desalination: an emerging solution to close the water gap in the Middle East and North Africa: Washington, D.C, USA: World Bank Publications.

Nsimba, R. Y., Kikuzaki, H., & Konishi, Y. (2008). Antioxidant activity of various extracts and fractions of Chenopodium quinoa and Amaranthus spp. seeds. Food Chemistry, 106(2), 760-766. Olivera-Montenegro, L., Best, I., & Gil-Saldarriaga, A. (2021). Effect of pretreatment by supercritical fluids on antioxidant activity of protein hydrolyzate from quinoa (Chenopodium quinoa Willd.). Food Science & Nutrition, 9(1), 574-582.

Palombini, S. V., Claus, T., Maruyama, S. A., Gohara, A. K., Souza, A. H. P., Souza, N. E. D., . . . Matsushita, M. (2013). Evaluation of nutritional compounds in new amaranth and quinoa cultivars. Food Science and Technology, 33(2), 339-344.

Paśko, P., Bartoń, H., Zagrodzki, P., Gorinstein, S., Fołta, M., & Zachwieja, Z. (2009). Anthocyanins, total polyphenols and antioxidant activity in amaranth and quinoa seeds and sprouts during their growth. Food Chemistry, 115(3), 994-998.

Pastor, K., Ilić, M., Vujić, D., Jovanović, D., & Ačanski, M. (2020). Characterisation of fatty acids in cereals and oilseeds from the republic of Serbia by gas chromatography–mass spectrometry (GC/MS) with hemometrics. Analytical Letters, 53(8), 1177-1189.

Qureshi, Q., Jamil, M., & Mateen, A. (2005). Simultaneous determination of orotic acid and folic acid in pure forms and in pharmaceuticals formulations by HPLC. Pakistan Journal of Analytical & Environmental Chemistry, 6(1), 28-32.

Rahamifard, N., Fayazi, A. S., Amirahmadi, S. S., Jabari, M., Delavari, H., Zamani, S., Saadati, S., Sharafi, G., Keshavarz, R. & Mohammadi, A. (2019). Microbiological of grains cereal and pulses specifications and test method. National Standard No. 11603.

Ranjbar, G. H., Dehghani, F., Banakar, M. H.,

Hasheminejad, Y., & Rahimian, M. H. (2019). Instructions of the Salinity Institute, Edited by National Salinity Research Center, Yazd, Iran. Retrieved from : ttp://www.areeo.ac.ir/_DouranPortal/Documents/%D8%B4%D9%88%D8%B1%DB%8C%20%D9%86%D9%87%D8%A7%DB%8C%DB%8C%20%DA%86%D8%A7%D9%BE_20200502_124124_20200512_102317.pdf

Repo-Carrasco, R., Espinoza, C., & Jacobsen, S.-E. (2003). Nutritional value and use of the Andean crops quinoa (Chenopodium quinoa) and kañiwa (Chenopodium pallidicaule). Food Reviews International, 19(1-2), 179-189.

Sezgin, A. C., & Sanlier, N. (2019). A New Generation Plant For The Conventional Cuisine: Quinoa (Chenopodium Quinoa Willd). Trends in Food Science & Technology.

Simopoulos, A. P. (2006). Evolutionary aspects of diet, the omega-6/omega-3 ratio and genetic variation: nutritional implications for chronic diseases. Biomedicine & Pharmacotherapy, 60(9), 502-507.

Souza, J. M. L. d., Álvares, V. d. S., Leite, F. M. N., Reis, F. S., & Felisberto, F. Á. V. (2008). Physicochemical characteristics of flours deriving of cassava varieties used in the Vale do Juruá, Acre. Acta Amazonica, 38(4), 761-766.

Tan, M. (2020). Macro-and micromineral contents of different quinoa (Chenopodium quinoa Willd.) varieties used as forage by cattle. Turkish Journal of Agriculture and Forestry, 44(1), 46-53.

Tang, Y., Li, X., Chen, P. X., Zhang, B., Hernandez, M., Zhang, H., . . . Tsao, R. (2015). Characterisation of fatty acid, carotenoid, tocopherol/tocotrienol compositions and antioxidant activities in seeds of three Chenopodium quinoa Willdgenotypes. Food Chemistry, 174, 502-508.

Tang, Y., Zhang, B., Li, X., Chen, P. X., Zhang, H., Liu, R., & Tsao, R. (2016). Bound phenolics of quinoa seeds released by acid, alkaline, and enzymatic treatments and their antioxidant and α-glucosidase and pancreatic lipase inhibitory effects. Journal of Agricultural and Food Chemistry, 64(8), 1712-1719.

United States Pharmacopeia. (2017). The United States Pharmacopeial Convention, 1052 Rockville Biotechnology-Derived Articles—Amino Acid Analysis.

Vega-Gálvez, A., Miranda, M., Vergara, J., Uribe, E., Puente, L., & Martínez, E. A. (2010). Nutrition facts and functional potential of quinoa (Chenopodium quinoa Willd), an ancient Andean grain: a review. Journal of the Science of Food and Agriculture, 90(15), 2541-2547.

Verdier, F. (2011). MENA regional water outlook part II desalination using renewable Energy task 1–desalination potential. Fichtner Stuttgart.

Wang, S., Opassathavorn, A., & Zhu, F. (2015). Influence of quinoa flour on quality characteristics of cookie, bread and Chinese steamed bread. Journal of Texture Studies, 46(4), 281-292.

Woomer, J. S., & Adedeji, A. A. (2021). Current applications of gluten-free grains–a review. Critical Reviews in Food Science and Nutrition, 61(1), 14-24.

Wright, K., Pike, O., Fairbanks, D., & Huber, C. (2002). Composition of Atriplex hortensis, sweet and bitter Chenopodium quinoa seeds. Journal of Food Science, 67(4), 1383-1385.

Zhang, W. J., & Lin, M. F. (2020). Influence of redox potential on leaching behavior of a solidified chromium contaminated soil. Science of the Total Environment, 733, 139410.

ISSN-Internet 2197-411x OLCL 862804632

UniKassel & VDW, Germany- May 2021