International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
www.chemijournal.com
IJCS 2021; 9(2): 1103-1107

Received: 04-01-2021
Accepted: 15-02-2021

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Physico-chemical, functional and anti-nutritional factors of the white bold quinoa (*Chenopodium quinoa* willd)

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DOI: https://doi.org/10.22271/chemi.2021.v9.i2p.11967

Abstract
Quinoa is a plant seed well known scientifically as *Chenopodium quinoa.* It is known as super food. In the present study the white bold quinoa variety was analyzed for physical, functional, cooking and nutritional properties. Thousand kernel weight (2.24g), length (2.2125mm), hydration capacity (0.16g/1000 kernel) and bulk density was 0.74g/ml. Lightness of the grains was 87.56 L*. Grains had 157.3 per cent of water holding capacity, 99 per cent of oil absorption capacity, 16.94 and 47.38 per cent of foaming capacity and foaming stability respectively. Cooking characteristics showed 235.29 per cent increase in weight, alkali spread ratio was zero which showed the highest 92.60˚C of gelatinization temperature. Quinoa has got 18.95 g of protein, fat (5.44 g), carbohydrate (57.88 g) and 356.81 Kcal of energy. Major anti-nutrient saponins were also present (616.82 mg/100g). Thus study concluded that quinoa is a rich source of protein with good functional properties.

Keywords: Dehulled quinoa grains, functional, nutritional composition, physical properties, saponins

Introduction

Quinoa is a pseudo cereal which belongs to Amaranthaceae family and genus Chenopodium and species quinoa. It is a annual herb that produces a panicle containing small seeds, flat and approximately 2-3mm in diameter with large array of color varied from white, yellow to red and black which vary from region to region (Schlick and Bubenheim, 1993).

This crop can be adopted in different agro-climatic conditions. It can be grown under conditions *viz.*, relative humidity from 40 to 88 per cent and withstands the temperature from -4 ℃ to 38˚C and a highly water efficient plant. (FAO, 2011). According to Jacobsen, 2003 quinoa is one of the oldest crops in the Andean region, and widely consumed and cultivated in Peru, Ecuador with higher altitudes (above 3500m). Peru and Bolivia accounted for 92 per cent of the quinoa produced in the world (FAO 2013). The United Nations General Assembly has therefore declared 2013 as the "International Year of Quinoa", in recognition of ancestral practices of the Andean people. With this background production has started all around the world. In India, Andhra Pradesh and Uttarakhand are emerging as the main cultivators of quinoa. In 2013, Uttarakhand reportedly signed a horticulture research agreement with Peru to grow quinoa in the state and research institutes in Andhra Pradesh have successfully developed local varieties of the crop (Mehra, 2016) [30].

Starch is the major component of quinoa mainly present in the perisperm. Perisperm, embryo and endosperm are the three areas containing food reserves in it. Protein and and lipids are the stored in the endosperm and embryo. The bran layer of quinoa seed comprise of most of the sapogenins, fat, fiber and ash.

It is a complete food with high nutritional value, mainly due to its high content of good quality protein. Protein content ranges from 13.8 to 16.5 per cent with an average 15 per cent (Koziol, 1992, Ogungbenle, 2003 and Kousalya, 2019) [25, 33]. Starch is the main carbohydrate and present between 52 to 68 per cent. The total dietary fibre ranges from 7 to 9.7 per cent. It is also being rich in essential fatty acids such as linoleic and alpha linolenic and contains high concentration of natural antioxidants such as alpha and gamma tocopherol (Filho, *et al.*, 2015) [17].

The ash content of quinoa (3.4%) is higher than that of rice and wheat, which is evident of high mineral content.
Saponins are the anti-nutrients present in the seed coat and responsible for the bitter tasteinquinoa but not toxic to humans (Zhu*et al*., 2002) [46]. Saponin content varies from 0.2 to 11.3g /kg (Mastebroek *et al*., 2000) [29].
According to Chavan, 2018 [11] reported that if the saponin content is 20-40mg/100g dry weight referred as sweet quinoa genotype and >450mg/100g refers to bitter quinoa genotype. Apart from this Saponins have their own role as nutraceuticals due to its anti-inflammatory effect, high dietary fibre which control the cholesterol and in turn helps in the management of diabetes and hypertension.
Hence the present study was undertaken to estimate the physico-chemical, functional and anti-nutritional factors of quinoa.

Material and Methods

Procurement of quinoa grains:
A local variety of Andhra Pradesh white bold quinoa (dehulled grains) were procured form Kilaru Naturals Private Limited, Hyderabad. Grains were cleaned for extraneous materials and stored in deep freezer and used for further processing**.** All the estimates were carried in triplicates.
Physical and functional properties of quinoa grains:
Quinoa samples were assessed for physical characteristics *viz*., kernel weight, length, thickness, bulk density, hydration capacity and color were analyzed using standard procedures. Functional properties *viz*., water holding capacity, tapped bulk density (Goula and Adamopoulos, 2008) [19] dispersibility (Kulkarni *et al*., 1991) [26], water absorption index and water solubility index (Sandoval et al., 2012) [39], oil absorption capacity, foaming capacity and foaming stability (Onwuka, 2005) [34] and emulsion capacity (Kaushal *et al*., 2012) [24]. Color estimation was carried by Ranganna (2005) method. Cooking characteristics of dehulled quinoa was estimated. characteristics *viz*., elongation ration (Sindh et al., 1975), gelatinization temperature (Juliano *et al*., 1964) [23], volume expansion (Sindh et al., 1975), cooking time, cooked weight and per cent increase cooked weight (Wani *et al*., 2013) [43] and alkali spread value (Bhattacharya and sowbhagya, 2007) [7].

Nutritional properties of quinoa grains

Macro nutrient analysis was estimated by following AOAC, 2005 [4] protocols. Moisture was determined by hot air drying method at 105˚ C for 4 hrs until the constant weight is obtained. Protein was estimated by micro kjeldhal method. Fat was estimated by solvent extraction method. Acid wash and alkali wash and difference in weight is taken as crude fiber content. Ash was estimated by charring the sample followed by muffle furnace charring. Carbohydrate and energy by difference method.
Anti-nutrient saponins estimation was measured by subjecting the mixture to spectrophotometer at wavelength of 544nm. Diosgenin was used as a reference standard (Hai *et al.*, 2003) [21]. Saponin concentration was obtained from the standard graph**.**

$$\text{Saponin content (mg/100g)} = \frac{\text{Absorbance of sample x dilution factor x gradient of graph}}{\text{weight of the sample}} \text{ X 100}$$

Results and discussion

The physical properties of dehulled grains was depicted in the Table 1. Mean thousand kernel weight, length, thickness, bulk density and hydration capacity were 2.24g, 2.12mm, 1.03mm, 0.74g/ml and 0.16 g/1000 kernals. The volumetric expansion of the seed and pore spaces that increased the absorption of moisture proportionately which corresponds to bulk density of grians.
Similar findings were observed for the physical characteristics of quinoa by Wu, 2016 [44, 45], estimated that the quinoa seeds ranged from 1.9 to 2.2 mm in diameter. In the Blanca variety, bulk densities ranged from 0.63kg/L to 0.63kg/L in the Japanese strain.
The weight of a thousand quinoa seeds varied from 1.8 to 4.1g. Vilche, *et al.*, 2003 [42] noted that with an increase in the moisture content of quinoa seeds, length and width proportionately increased and was found to be 2.045 mm and 2.015 mm respectively. Similarly, Abalone *et al.* (2004) [1] also showed an increase in volume as the moisture content increased in the amaranth seeds. Whereas, the bulk and true density decreased.
Color attributes includes L*, a* and b*, where L* value represents lightness and darkness, b* gives indication for yellowness and blueness while a* shows greenness and redness. Results revealed that lowest L* values was observed in dehulled sample 87.56 L* value and a* was 1.22 and b* was 14.28. These findings in the present study are comparable to the results reported by Patil *et al.* (2017) [35] and showed that rice flour possesses highest L values (93.65) depicts the lightness of the sample. b* values (yellowness).Present study results were on par with study carried by Gabrial *et al*., 2016 [18] showed color analysis of amaranth flour was L 89.68, a* was 1.54 and b* was 14.27.

Table 1: Physical properties of raw and dehulled quinoa grains

Parameters	Quantity (Mean ± SD)
Thousand kernel weight (g)	2.24± 0.26
Length (mm)	2.125±0.28
Thickness (mm)	1.03±0.02
Bulk density (g/ml)	0.74±0.03
Hydration capacity (g/1000 kernals)	0.16±0.06
Color	
L*	87.56±0.00
a*	1.22±0.03
b*	14.28±0.34

All values are mean ± standard deviation (n=3).

Functional properties of raw and dehulled quinoa flour

Functional properties of the flours that helps to reflect the complex interaction between the food components *viz*., molecular structure of proteins, fats associated with preparation, cooking and conditions in which they are measured. Also describes how they affect the finished food products in connection with taste, appearance and texture. Following functional properties of the food were analyzed and results expressed in the Table 2.
Water holding capacity or water binding capacity was defined as the ability to hold or absorb water even after the application of external forces *viz.*, centrifugation or other processing methods. dehulled quinoa grain flour (157.30%) ascribed to presoaking, cooking and fiber content. These results were in line with the study of Collar, 2016 [14] and the study reported that quinoa flour had WHC from 116 to 157

per cent. Abugoch *et al.*, 2009 [2] described as WHC of quinoa meal is higher than amaranth meal (1.8g/g of meal) (Mahajan and Dau, 2002) [28]. Thus, it can also be due to the high protein content, ash and hydration properties influenced by particle fraction composition (Cotovanu *et al.*, 2020) [15].

Bulk density reflects the capacity of the required packaging material, material handling, application in food preparation and food industries. Low bulk density foods are suitable for making high nutrient dense formulation food. Dehulled quinoa grain flour had bulk density of 0.72 g/ml. The present study results were supported by the study carried on different fractions of quinoa flour (Cotovanu *et al.*, 2020) [15]. It was found that small particles or fractions of quinoa with lowest moisture content (9.75%) contributed to their low bulk density due to the ability of water moisture to stick to flour particles, thus reducing their specific volume. Similar trend was observed in the Ratnawati *et al.*, 2019 [38] and Beniwal *et al.*, 2019 [5] study, where bulk density was positively correlated with carbohydrate content.

Dispersibility is the ability of the flour to disperse in water without forming lumps and disintegration of agglomerates, *i.e.*, it indicates the reconstitution ability. Results revealed that dispersibility of the dehulled grain flour was 34.91 per cent. Gamel *et al.* (2006) showed significant difference in amaranth cooked (7.0 cm^3), popped (10.0cm^3), germinated (6.0cm^3) sample compared to raw samples (5.6cm^3) This may be due to the difference in the particle size, nature of the starch, gelatinization temperaturein processing methods increased dispersibility of the amaranth flour.

Water absorption index (WAI) is a measurement of water absorbed by the flour and it can be used as gelatinization index. WAI of dehulled grains was 6.58 g/g. The degree of interaction within the amorphous and crystalline domains between starch chains affected in terms of molecular weight/distribution, degree of branching, duration of branching, conformation by the amylose/amylopectin ratio and by the characteristics of amylose and amylopectin. Sandoval *et al*., 2012 [39] reported that the potato starch had higher WAI was likely due to a higher amylopectin content of phosphate groups, resulting in repulsion between phosphate groups on adjacent chains, increasing hydration by weakening the degree of bonding within the crystalline domains.

Water solubility index (WSI) can be used as indicator of starch modification by thermo mechanical treatment. WSI was 4.17 per cent and oil absorption index (99.29%), WSI were higher in present study when compared to the study carried by Beniwal *et al.*(2019) [5] may be because of difference in the processing methods and experimental methods (centrifugation condition and sampling procedures) (Li and Zhu, 2017) [27, 46]. Since oil absorption capacity differs as it depends on the various conformational characteristics, lipophilic groups, surface hydrophobicity and nonprotein compounds in the protein concentrates. Quinoa flour OAC ranged from 1.53 to 2.73 ml/g (Beniwal *et al*., 2019) [5]. Elkhalifa and Bernhardt (2010) [16] results were similar to the present study.

Emulsion capacity (EC) of the dehulled quinoa grians was 100.46 per cent. Ogungbenle *et al.*, 2009 [33] reported that quinoa flour emulsion capacity was averaged to be 100.4 to 104 per cent which completely agree with the current results. Foaming capacity and foaming stability were 16.94 and 47.38 per cent respectively. The findings were collected from Ogungbenle*et al*., 2009 [33] were comparable to the present study for the foaming capacity of quinoa showed 66.66 per cent and foaming stability ranged from 35.56 to 9.63 per cent. Foaming capacity depends on the presence of the flexible protein molecules which may decrease the surface tension of water. On the other hand, low foaming capacity can be related to highly ordered globular protein which resists surface denaturation.

Table 2: Functional properties of dehulled quinoa grain flour

Functional properties	Percent/Quantity (Mean ± SD
Water holding capacity (%)	157.3 ±14.95
Tapped bulk density (g/ml)	0.72 ± 0.00
Dispersibility (%)	34.91 ±0.14
Water absorption index (g/g)	6.58±0.12
Water solubility index(%)	4.17±0.26
Oil absorption index (%)	99.29±0.97
Emulsion capacity (%)	100.46±1.41
Foaming capacity (%)	16.94±0.48
Foaming stability (%)	47.38±9.21

Cooking characteristics of dehulled quinoa grians.

Results of cooking quality characteristics of quinoa samples include elongation ratio, gelatinization temperature, volume expansion, cooking time and per cent increase in weight after cooking were presented in Table 5. Pressure cooking time was 6 min 36 sec. Per cent increase after pressure cooking was 235.29 g. Quinoa showed elongation ratio of 1.28, gelatinization temperature (92.60˚C). Alkali spread ratio was zero. Quinoa cooked doneness showed 20 min. and 18 sec with 13.5 ml of cooked volume. The similar results were indicated that the elongation ratio of commercial quinoa seeds (1.14 ± 0.02 mm) was lower than experimental quinoa seeds (2.10 ± 0.04 mm). As gelatinization temperatures (GT) was based on the alkali spreading score. Priyanka, 2018 [36] and Chamorro, 2003 [9] showed similar results that quinoa had high gelatinization temperature 96.33℃ and no effect on alkali degradation. Wu *et al.* (2016) [44, 45] showed higher gelatinization temperature for small granule starches and quinoa had (57 to 64 °C) gelatinization temperature, may be due to structure of the grains. The cooking time observed by Chukwuemeka *et al.* (2015) [12] and reported that it can be related to the grains' surface area and grains with high temperature requires more water and longer cooking time (Rasool *et al*., 2015**)** [37].

Table 3: Cooking Characteristics of quinoa grains

Parameters	Mean ± SD
Initial Weight (g)	15.06±0.65
After boiling (g)	50.50±0.46
Per cent increase	235.29±1.72
Pressure cooking time	6 min 36 sec
Elongation ratio	92.60±0.5
Gelatinization temperature (℃)	92.60±0.5
Cooked doneness	20 min 18 sec
Cooked volume (ml)	13.5
Alkali spread ratio	0

Nutrient composition of dehulled quinoa grians.

The composition of moisture content is dehulled (12.61%), protein content (18.95 g), fat (5.44 g), fiber (2.73 g), ash (2.25 g), carbohydrate (57.99 g) and energy (356.81 Kcal). These findings are comparable to the results reported by Chauhan and Sarita, 2018 [10] and Beniwal *et al.*, 2019 [5]. Valencia *et al.* (2010) [41] and Milovanovic (2014) [31] showed 11.52 per cent and 10.1 per cent of moisture content in quinoa grains. Quinoa protein quantity and consistency are usually superior to those of other cereal grains, thus providing high digestibility and gluten free properties. Dehulled grains represents the highest protein content as it was stored in embryo and also may be due to the removal of the saponins, other anti-nutrient. Chukwuma *et al.*, 2016 [13], and Bhathal *et al.*, 2017 [6] studies found that protein content of cooked quinoa ranged from 12.23 to 11.01 g/100g reduced from raw sample. Sade (2009) and Amaral *et al.* (2006) [3] consider quinoa as an oilseed due to its fat content ranged from 4.5 to 8.7 per cent. Valencia *et al*. (2010) [41] reported 88.7 g/kg of total dietary fiber, 78.5 g/kg of insoluble dietary fiber and 10.2 g/kg of soluble dietary fiber was present in quinoa grains. Chukwama *et al*., 2016 and Beniwal *et al*., 2019 [5] showed ash content of dehulled quinoa (3.46%) and reported that ash content depends on the varieties. Saponins is the major anti-nutrient present in the quinoa. Study results showed that it contains about 616.82 mg /100g. The presence of saponin content greater than 470mg/100g was generally established with the bitterness in quinoa (Chavan, 2018) [11]. Saponins are now considered as bioactive, health-promoting compounds with several interesting findings (Carlson *et al*., 2012; Miranda *et al*., 2010) [8, 32] showed that the total amount of saponins as alpha-hederin in the quinoa raw material was 557 mg/100 g DW (*i.e.* approximately 0.56 per cent).

Table 4: Nutrients and anti-nutrient composition of dehulled grains

Processing methods	Quantity (Mean ± SD)
Moisture (%)	12.61 ± 0.38
Protein (g)	18.95 ± 0.57
Fat (g)	5.44 ± 0.38
Fiber (g)	2.73 ± 0.16
Ash (g)	2.25 ± 0.05
CHO (g)	57.99 ± 1.11
Energy(Kcal)	356.81 ± 2.02
Anti-nutrient	
Saponins (mg/100g)	616.82 ± 4.02

Conclusion

Present study can be concluded that quinoa is a rich source of protein fat and fibre. Procured quinoa variety was found to be bitter variety and further processing is required for the reduction of bitterness. Thus, considering its physical, functional and nutrient composition, quinoa can be used for the product development, which contains stored nutrients and can be well packed in a suitable packaging materials.

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