

Effect of Germination on Nutritional, Antinutritional and Rheological Characteristics of *Chenopodium quinoa*

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ABSTRACT

White and red varieties of quinoa were germinated and studied for the changes in nutritional, anti-nutritional and rheological characteristics. Germination has significantly ($p \leq 0.05$) enhanced protein and crude fibre with the significant ($p \leq 0.05$) reduction in carbohydrate contents in both the varieties. Anti-nutritional factor like phytic acid was decreased by 8.56 and 18.80 unit in white and red varieties respectively. Total phenols, total flavonoids enhanced significantly ($p \leq 0.05$) in both the varieties, showing more in red variety exhibiting comparatively higher antioxidant activity. After 48 hr of germination, vitamin 'C' in both the varieties enhanced between the range of 10.56 mg/100g and 13.23 mg/100g. Linoleic acid was the major fatty acid identified in both the varieties constituting more than 50 per cent of total fatty acids. Germination has reduced linoleic, linolenic and palmitic acids with the increase in stearic and oleic acids. Germination also caused significant ($p \leq 0.05$) decrement in breakdown, set back and final viscosities in both the varieties without much affecting their pasting temperature.

Keywords: Quinoa; Variety; Germination; Nutritional; Antinutritional; Rheology

1. INTRODUCTION

Quinoa (*Chenopodium quinoa*) is a pseudocereal or a pseudograin, is a native of the Andean region of South America¹ and is one of the oldest crops of American continent². The crop belongs to Chenopodiaceae family, genus *Chenopodium* and its botanical name is *Chenopodium quinoa* wild³. Archeological findings of Northern Chile has demonstrated the use of crop prior to 3000 BC in Ayacocho and found extensively grown in whole Andean region, Bolivia, Peru, Chile, Equador, etc before the conquest of Spanish². Seed is considered as a complete food due to its excellent nutritional quality, especially in terms of protein quality, also an important source of vitamins and minerals⁴, thus attracting great interest during recent years. The seed grows at an altitude of 4000 m above the sea level⁵ and are flat, round, oval shaped and usually are pale yellow and can also range from pink to black⁴. Quinoa's aptitude to yield high protein grains under extreme ecological conditions has made the crop essentially important for the diversification of agriculture as in high altitude regions of Himalaya and North Indian plains⁶. The crop is environmental resistant, can be grown in different strenuous conditions such as drought, high altitude, poor sandy soils, extreme temperature and salinity⁷ and can be able to develop in the regions where annual rainfall falls between 200 mm - 400 mm³. Even though, it is a crop of South America, its high nutritional value and extraordinary adaptability has spread its cultivation to different

geographical areas of the world like USA, China, Europe, Canada and also India⁴. In India, Himalayan region and plains of North India have successfully produced the crop with high yield having good agricultural potential^{6,8}. Quinoa seeds were reported to have been cultivated in North East Regions of India⁹ and systematic trials were initiated by NBRI, Lucknow during 1990-2000¹⁰. Quinoa was successfully grown under the project "Ananta" both at Hyderabad and in Anantapur region in Andhra Pradesh. Though, quinoa is considered as a Super Food, majority of the population are still unaware about the dietary benefits of this food and its consumption is very limited in our country. Since, India has also started growing this crop in Anantapur and some parts of Himachal Pradesh and many drought resistant regions, the crop has started receiving some attention especially from the health conscious consumers due to its remarkable nutritional values.

Quinoa, was considered as a food of low social status and remained only as a staple food of Andean population for several years restricting its usage among European community¹¹. Traditionally, roasted and cooked seeds of quinoa were used in the preparation of soups, fermented into beer or chichi (traditional fermented drink of Andeans), and also consumed similar to rice¹². Leaves of quinoa were used similar to spinach¹³ and seeds were germinated and used in salads¹⁴. During recent years, the grain has started receiving popularity and attention in many countries like Europe, Australia, Japan, India etc¹⁵ due to its health, functional and nutritional benefits¹⁶. Flour of toasted and ground seeds were used in the preparation of various baked foods viz breads, noodles, cookies, biscuits,

pasta, tortillas etc^{12,6}.

Germination, a simple process can enhance the nutritive value of seeds by bringing the desirable changes in the availability of nutrients, texture and organoleptic properties¹⁷. Secondary metabolites viz phenolics, flavonoids, various vitamins etc also found to increase during germination, which are considered as biological antioxidants. Therefore, the present work was undertaken with an objective to study the nutritive, antinutritional factors and rheological characteristics in both ungerminated and germinated white and red varieties of quinoa collected from the growers of Andhra Pradesh.

2. MATERIALS AND METHODS

2.1 Materials

Good quality quinoa seeds (both white and red variety) were procured from Climate Growth solutions, Anathpur, Andhra Pradesh. Seeds were cleaned to remove dirt, stones and other impurities if any. Stored at ambient temperature conditions (15-34 °C) till further use.

2.1.1 Germination

One kg each of both white and red varieties of quinoa were cleaned to remove any impurities. Seeds were washed thoroughly and water was drained and spread on the trays by covering with a muslin cloth and stored at room temperature for 48 hr for the germination to take place. In between, water was sprinkled on the muslin cloth to maintain seed moisture to achieve good germination. After germination, quinoa seeds were dried in a cabinet drier at 50°C to obtain moisture content between 9-10 per cent. Dried seeds of both ungerminated and germinated quinoa were powdered and passed through 100 mesh sieve before use.

2.2 Methods

2.2.1 Chemical Analysis

The moisture, total ash, crude protein, crude fat, crude fiber of the germinated and ungerminated quinoa seeds were determined by the methods described by the Association of Official Analytical Chemists (AOAC, 1984)¹⁸. Antioxidant activity by DPPH was measured according to the method of Braca¹⁹, *et al.* Total phenolics were estimated by the method described by Singleton and Rossi (1965)²⁰. Total flavonoids were estimated using the method described by Zhishen²¹, *et al.* Total tannins were determined calorimetrically as described in AOAC²². Saponins were estimated according to the method suggested by Dorothy and Oakenfull²³. Phytate content was determined using the method described by Haugh and Lantzsch²⁴. Carbohydrate content was determined using the method described by Sadasivam and Manickam²⁵. Vitamin C content was determined using the method described by Ranganna²⁶.

2.2.2 Analysis of Pasting Property

A method reported by Yadav²⁷, *et al.* was used for measuring the pasting properties of ungerminated and germinated quinoa

flour using a Rapid Visco-Analyser 4D (Newport Scientific Pvt Ltd, Warie Wood, Australia). The programme was performed for 13 min with the rise in temperature at the rate of 12°C/ min from 50⁰ to 95⁰ C with a holding time of 2.5 min at 95⁰ C and cooling to 50⁰ C at the rate of 12⁰ C/ min with a holding time of 3 min. Pasting properties viz peak viscosity, breakdown viscosity, final viscosity and set back viscosities were measured by taking three independent determinations.

2.2.3 Statistical Analysis

All the values reported in the present study are the mean of three determinations and the one-way analysis of variance was carried out using statistical software (Statistica, Ver 7.1 Series 1205) for significance at p≤0.05 level using Duncan's multiple range tests.

Table1. Proximate composition in white and red varieties of ungerminated and germinated quinoa

Attributes (%)	White quinoa		Red quinoa	
	Ungerminated	Germinated	Ungerminated	Germinated
Moisture	9.26 ^a	9.60 ^a	10.07 ^b	10.25 ^b
Protein	15.50 ^a	16.60 ^b	17.30 ^c	18.76 ^d
Fat	6.98 ^c	6.90 ^c	5.50 ^b	5.13 ^a
T. Ash	1.94 ^c	1.69 ^b	2.04 ^c	1.45 ^a
C. Fiber	3.20 ^a	4.20 ^b	4.70 ^c	6.30 ^d
Carbohydrate	62.63 ^d	51.97 ^b	58.58 ^c	50.18 ^a
Starch	56.37 ^d	46.78 ^b	52.72 ^c	45.16 ^a
Energy (K cal)	375.34 ^c	336.38 ^a	353.02 ^b	335.93 ^a

Values are mean of three determinations ±SD

Values in each row with different superscripts are significantly (p≤0.05) different

3. RESULTS AND DISCUSSION

3.1 Changes in Proximate Composition

Table 1 illustrates the proximate composition of both the varieties of ungerminated and germinated quinoa seeds. Moisture varied slightly, while protein content varied significantly (p≤0.05) between both the varieties. Red variety showed higher protein content of 17.30 per cent while white variety showed 15.50 per cent of the same. Fat content was found less in red variety and white variety showed slightly more. Among the two varieties studied, carbohydrate and starch contents differed significantly (p≤0.05), with white variety containing 62.63 and 56.37 per cent carbohydrate and starch contents respectively and red variety containing 58.58 per cent and 52.72 per cent respectively.

Germination of grains showed a significant effect on the protein, ash, crude fibre, starch and carbohydrate contents of both the varieties of quinoa. Germination increased protein content significantly (p≤0.05) from 15.50 to 16.60 per cent in white quinoa and 17.30 to 18.76 per cent in red quinoa. The increase may be due to the loss of dry matter especially carbohydrate through respiration during sprouting²⁸ and also attributed to the reawakening of protein synthesis upon imbibition²⁹ which might have lead to the increased protein content. The fat content in white variety found unaffected after germination, however slight decrease was shown by the red

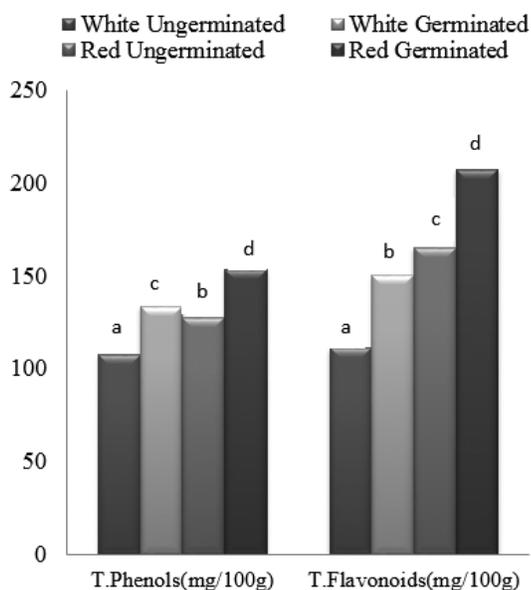
variety of quinoa and decrease may be due to the depletion of stored fat contributing to the catabolic activity of the seeds during germination³⁰. Germination process of quinoa also decreased both carbohydrate and starch contents significantly ($p \leq 0.05$) irrespective of the varieties used for the study. Carbohydrate and starch contents decreased from 62.63 per cent to 51.97 per cent and 56.37 per cent to 46.78 per cent and 58.58 per cent to 50.18 per cent and 52.72 per cent to 45.16 per cent in both white and red varieties respectively. The changes in carbohydrate content after germination may be due to its utilisation as a source of energy for the growth of embryo³¹. Breakdown of starch in cotyledon to simpler molecules such as glucose and fructose to provide energy for cell division attributed to the decrease in starch content²⁵ after germination of the seeds. Crude fiber also showed remarkable increase upon germination in both the varieties. Sood³², *et al.* also reported significant increase in crude fibre content of chickpea during germination.

Table 2. Anti-nutritional factors in white and red varieties of ungerminated and germinated quinoa

Attributes	White quinoa		Red quinoa	
	Ungerminated	Germinated	Ungerminated	Germinated
Phytic acid (mg/100g)	52.26 ^c	43.70 ^a	63.67 ^d	44.87 ^b
Saponins (g/100g)	0.22 ^a	0.14 ^a	0.65 ^c	0.45 ^b
Tannins (mg/100g)	2.56 ^a	2.33 ^a	3.42 ^c	2.98 ^b

Values are mean of three determinations \pm SD

Values in each row with different superscripts are significantly ($p \leq 0.05$) different



Values on each bar with different alphabets for the same analysis are significantly ($p \leq 0.05$) different

Figure 1. Total phenols and total flavonoids in white and red varieties of ungerminated and germinated quinoa.

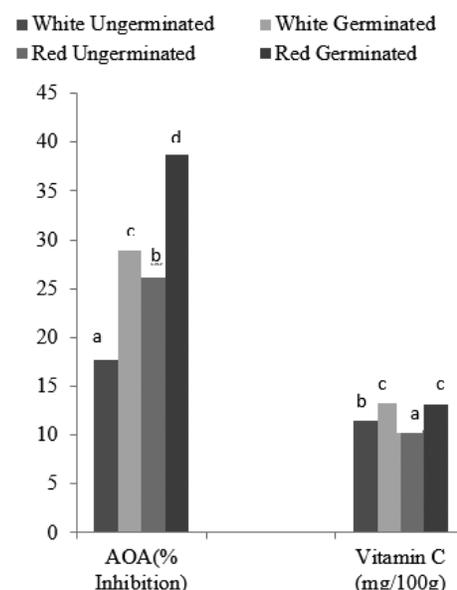
3.2 Changes in Anti-Nutritional Factors

Anti-nutritional factors like phytic acid, saponin and tannin also decreased significantly ($p \leq 0.05$) during germination of red and yellow quinoa (Table 2). Phytic acid might have broken

down for the utilisation of phosphorus during germination, as phytic acid is a source of phosphorus, thus showing decrease in their contents. In white variety, it decreased from 52.26 mg/100g to 43.70 mg/100g and a red variety has shown a decrease from 63.67 mg/100g to 44.87 mg/100g. Initial saponin contents showed by white and red varieties were 0.22 mg/100g and 0.65 mg/100g respectively and found to decrease on germination. Decrease in white variety was not found significant, while red variety showed a slight and significant ($p \leq 0.05$) decrease from 0.65 to 0.45 g/100g. Decrease in saponins may be due to the leaching of saponins from the seed during washing and soaking before germination, as soaking and washing of quinoa has been reported to reduce its high saponin contents³³. Germination also decreased tannin contents of red variety slightly and significantly ($p \leq 0.05$).

3.3 Changes in Phenolics, Flavonoids and Antioxidant Activity

Figure 1 shows total phenolics and flavonoid contents of both the varieties of quinoa before and after germination. White and red varieties had 107.68 mg/100g and 111.0 mg/100g and 127.64 mg/100g and 165.00 mg/100g of total phenolics and flavonoid contents respectively, higher than the values reported by Carciochi⁵, *et al.* Germination enhanced significantly ($p \leq 0.05$) phenol and flavonoid contents of both the varieties. The values reported for phenols after germination was found to be 133.30 mg/100g and 153.44 mg/100g for white and red varieties respectively. Kim³⁴, *et al.* have reported considerable increase in the polyphenol content of germinated buckwheat



Values on each bar with different alphabets for the same analysis are significantly ($p \leq 0.05$) different

Figure 2. Antioxidant activity (AOA) and vitamin 'C' contents in white and red varieties of ungerminated and germinated quinoa.

(*Fagopyrum esculentum* Moench) seeds with the increase in sprouting. Germination of Lead tree seeds also reported a significant increase in polyphenolic contents¹¹.

Results of present study, also demonstrated increase in antioxidant activity as observed by DPPH methods after germination in both the varieties of quinoa as compared to the ungerminated one (Fig. 2). The increase in total phenolics and flavonoid contents has shown good correlation with the enhanced antioxidant activity during germination (Fig. 1). Antioxidant activity enhanced significantly ($p \leq 0.05$) from 17.64 to 28.83 per cent in white variety and 26.06 to 38.76 per cent in red variety. After 48 hr of germination, vitamin 'C' also recorded an increase from 11.47 to 13.23 mg/100g in white variety and 10.56 to 13.11 mg/100g in red variety. Orozco³⁵, *et al.* and Doblado³⁶, *et al.* also reported that germination increases vitamin 'C' and polyphenol contents with increase in

set back viscosity and pasting temperature as stated in Table 3. Significant ($p \leq 0.05$) decrease in pasting properties were observed in both ungerminated and germinated quinoa irrespective of the varieties studied. Break down viscosity, which measures the ability of starch to withstand shear and stress found to decrease significantly ($P \leq 0.05$) from 5.17 RVU to 2.67 RVU in white variety and 4.83 RVU to 2.42 RVU in red variety after 48 hr of germination.

Final viscosity showed a significant ($P \leq 0.05$) decrease from 197.33 RVU to 35.08 RVU and 156.92 RVU to 48.83 RVU in white and red varieties of quinoa respectively. Similarly, set back viscosity, an useful indicator of starch degradation, which measures the propensity of starch molecules to disperse in hot paste and re associate during cooling³⁷ also found to decrease significantly ($P \leq 0.05$) after germination in both the varieties and was found to be comparatively more in white variety. However, pasting temperature has shown a slight

increase in red quinoa, and found undetected in white variety after germination. Borenjindakul and Phimolsiripol³⁸ also reported a decrease in breakdown, set back and final viscosities during germination of *Dolichos lablab*.

Table 3. Pasting properties of white and red varieties of ungerminated and germinated quinoa

Attributes (RVU)	White quinoa		Red quinoa	
	Ungerminated	Germinated	Ungerminated	Germinated
Breakdown viscosity	5.17 ^b	2.67 ^a	4.83 ^b	2.42 ^a
Final viscosity	197.33 ^d	35.08 ^a	156.92 ^c	48.83 ^b
Set back viscosity	68.92 ^d	14.33 ^a	37.33 ^c	22.00 ^b
Pasting temperature	79.10 ^a	--	79.90 ^a	81.55 ^b

Values are mean of three determinations \pm SD

Values in each row with different superscripts are significantly ($p \leq 0.05$) different

Table 4. Fatty acid profile of white and red varieties of ungerminated and germinated quinoa

Fatty acids (%)	White quinoa		Red quinoa	
	Ungerminated	Germinated	Ungerminated	Germinated
Myristic C _{14:0}	0.54 ^b	0.62 ^c	0.40 ^a	0.76 ^d
Palmitic C _{16:0}	13.79 ^d	12.30 ^b	12.82 ^c	12.02 ^a
Stearic C _{18:0}	0.51 ^a	0.79 ^c	0.50 ^a	0.62 ^b
Oleic C _{18:1}	19.16 ^a	19.87 ^b	20.14 ^{bc}	21.26 ^c
Linoleic C _{18:2}	56.32 ^c	55.13 ^b	54.93 ^b	53.97 ^a
Linolenic C _{18:3}	6.43 ^c	6.21 ^b	5.95 ^a	5.81 ^a

Values are mean of three determinations \pm SD

Values in each row with different superscripts are significantly ($p \leq 0.05$) different

antioxidant activity.

3.4 Changes in Pasting Properties

The pasting property of both white and red varieties of ungerminated and germinated quinoa grains were depicted in terms of changes in breakdown viscosity, final viscosity,

3.5 Changes in Fatty Acid Profile

Linoleic acid was the most predominant acid identified in both ungerminated and germinated quinoa seeds followed by oleic and palmitic acids in both white and red varieties (Table 4). Red variety showed slightly lower amounts of palmitic, linoleic and linolenic acids than the yellow variety.

Germination process has significantly ($p \leq 0.05$) lowered the polyunsaturated fatty acids containing linoleic and linolenic acids in both the varieties. Linoleic and linolenic acids decreased from 56.32 per cent to 55.13 per cent and 6.43 per cent to 6.21 per cent in white variety and 54.93 per cent to 53.97 per cent and 5.95 to 5.81 per cent in red variety. MUFA containing oleic acid showed a significant ($p \leq 0.05$) increase from 19.16 per cent to 19.87 per cent and 20.14 to 21.26 per cent in yellow and red varieties of quinoa respectively. Halm³⁹, *et al.* also stated, increased oleic and reduced linoleic, linolenic and palmitic acids upon germination. In the present study, palmitic acid showed decrease in its content from 13.79 per cent to 12.30 per cent in white variety and 12.82 per cent to 12.02 per cent in red variety.

4. CONCLUSIONS

Germination of both white and red varieties of quinoa has undoubtedly enhanced their nutritive value. Between white and red varieties, red variety exhibited slightly higher amounts of protein and fibre, while white variety showing slightly higher amounts of fat. During germination, anti-nutritional factors, particularly phytic acid decreased significantly ($p \leq 0.05$) in both the varieties of quinoa. Results

of the study also indicated that, antioxidant activity was found to increase significantly ($p \leq 0.05$) with the significant increase in phenolics, flavonoids and vitamin 'C' upon germination. Germination enhanced oleic and stearic acids and reduced palmitic, linoleic and linolenic acids. Study undertaken on quinoa revealed that, an underutilised super food can act as a powerful source of nutrients, in both germinated and ungerminated form, to nourish silent hunger of the poor population who suffer from the little access to the nutrient rich food, if it is made available at a cheaper rate by cultivating in a larger area and also creating awareness about its health benefits to larger section of population.

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Her contribution includes preparation and processing of the raw material and correction of the manuscript.

Ms Sheetal Handu, worked as a project assistant in DRDO-Defence Food Research Laboratory, Mysuru. She was involved in the analysis of proximate composition of different varieties of the produce.

Mr MA Khan, obtained MSc (Food Sciences) from the University of Mysore. Currently working as a Scientist ‘D’ in DRDO-Defence Food Research Laboratory, Mysuru. Significantly contributed in the improvement of texture and extension of shelf life of chapatias as well as extrusion technology. His contribution includes analysis of rheological characteristics in quinoa.

Dr AD Semwal, Scientist ‘G’ obtained Ph.D. in Chemistry from University of Mysore. Currently he is an Associate Director DRDO-Defence Food Research Laboratory, Mysuru. He has significantly contributed in the development of convenience foods, extrusion technology and extensively worked on the factors affecting the stability of various precooked dehydrated foods.

His contribution includes supervision of the work and correction of the manuscript.

Dr G.K. Sharma, Scientist ‘G’ obtained PhD in Chemistry from Lucknow University. Currently he is an Associate Director DRDO-Defence Food Research Laboratory, Mysuru. He has significantly contributed in separation and identification of various flavour and off flavour compounds in processed foods, development of convenience foods and indigenisation of low cost processing equipment.

His contribution includes the planning and guiding of the work.