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Effect of grain processing on nutritional and physico-chemical, functional and pasting properties of amaranth and quinoa flours

Sushma Kumari Beniwal, Amita Devi & Ritu Sindhu*,+

Department of Food Technology, Guru Jambheshwar University of Science and Technology, Hisar 125 001, Haryana, India
E-mail: +ritu3400@gmail.com

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Amaranth and quinoa are the ancient crops known for their excellent nutritional profile. Impact of different processing treatments including cooking, germination and roasting of grains on their flour properties was investigated in present study. Flours of raw and treated grains were analyzed for their physicochemical, functional, pasting and anti-nutritional factors. Results revealed that amaranth and quinoa flours are good source of protein and minerals. Mineral content reduced while water and oil absorption capacities of flours increased following the grain treatments. Processing of grains resulted in reduction of saponin and tannin content of grains of both the crops that improved the overall eatable quality of flours. Raw amaranth flour was whiter in color exhibiting higher values of L* and lower values of b* than quinoa flour. Germination caused significant increase in protein and decrease in fat content of flours of amaranth and quinoa. RVA curves showed that peak viscosity, trough viscosity and final viscosity of amaranth and quinoa flours were higher than the raw quinoa flour. Peak viscosity and trough viscosity of amaranth and quinoa flours decreased after processing of grains.

Keywords: Amaranth, Cooking, Germination, Physicochemical properties, Quinoa, Roasting
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From the ancient time amaranth and quinoa flour are used as an alternate option of cereals. Grain amaranth and quinoa are dicotyledonous plants that belong to *Amaranth aceae* family. These crops come under the category of pseudo cereals because their seeds are eatable as cereal grains but these do not belong to grass family. Pseudo cereals have attracted much interest nowadays because of excellent nutrient profile. The most important feature of pseudo cereals is the absence of gluten that makes it applicable in therapeutic diets like gluten-free diet for celiac disease[1]. Pseudo cereals are consumed in the form of breakfast cereals, bread or cereal bars in developing countries. These are good source of saccharides especially starch and fibers. Appreciable amount of dietary fibers in pseudo cereals helps in enhancing lipid metabolism and prevent LDL-C oxidation. Pseudo cereals contain lipids having essential fatty acid, protein with high quality of amino acids, good content of vitamins and minerals.

Among 60 species of amaranth worldwide most cultivated three species are *A. caudatus*, *A. hypochondriacus* and *A. cruentus*. In India amaranth is grown in Himachal Pradesh, Jammu and Kashmir, Uttrakhand, Sikkim, Assam, Nagaland, Tripura, Jharkhand, Kerala, and Tamil Nadu at both hills and plains[3]. Amaranth has excellent nutritional potential having beneficial impact on human health. Amaranth grains are small in size, lenticular in shape and color varies from black to red, usually cream. For the production of flour, starch and protein, amaranth seeds are considered as a promising raw material containing 17% protein, 9-6% dietary fiber and admirable level of minerals and vitamin B[4].

Quinoa belongs to family *Amaranthaceae*, subfamily *Chenopodiaceae* and genus *Chenopodium*, native to the Andean regions in South America. Quinoa is cultivated in various regions of the world like, Europe, North America, Africa, and China. Quinoa grains are of disc-shaped and diameter ranges from 1.4 to 1.6 mm, color varies from white to black and grey, or can be yellow and red. Quinoa has good biological value due to its seed protein that is rich in lysine and sulphur amino acids. Quinoa protein is low in prolamines (0.5-0.7%) which make it gluten free and therefore non-allergenic. Quinoa contains 13.4% total dietary fiber content comprising 11.0% insoluble fiber and 2.4% soluble fiber. Fat content in quinoa grains varies from 4.4-8.8%

*Corresponding author

in which 55% of linoleic and 63% of linolenic acid accounting for the total fatty acids[5].

Traditionally used methods of grain processing not only influence the changes in physical characteristics and flavor but also affect the chemical composition of the food produced. Heating and other processing treatments increase the nutritive value of the food and help in reduction of anti-nutrients that usually enhance the digestibility of foods. Popping and roasting of grains has been practiced since hundreds of years in different regions of world. In northern India roasted grain of amaranth were mixed with honey and jaggery to produce ladoos and these were consumed traditionally during fasting period. In southern part of India amaranth leaves are stir fried with red chillies and spices known as cheeratharan. In Europe and some part of northern America amaranth grain was popped and mixed with puffed rice to form different products. Boiled quinoa grains mixed with other foods such as in soup and other drinks to make them thick. From ancient years in the Andean region of Peru quinoa used in formation of beverage known as chicha. The present study was done to investigate the impact of different processing methods on the physical, chemical and functional properties of amaranth and quinoagrain flours.

Materials and methods

The grains of amaranth and quinoa (white) were procured from the local market, Hisar. Seeds were screened and washed to remove stones, dust, dirt and other impurities if presented and dried in hot air oven at 40-45°C for 6-8 h. Dried grains were stored in air tight plastic container for further analysis. All the chemicals used were of analytical reagent grade.

Cooking of amaranth and quinoa grains

Cleaned grains were placed in a closed water bath at normal pressure. The seeds were tested by teeth pressing after regular interval until a soft texture was obtained. The heated seeds were dried in hot air oven at 50°C for 16 h and milled by using kitchen grinder after cooling. The flour obtained was passed through 80-mesh sieve and stored in air tight container at 4°C.

Roasting of amaranth and quinoa grains

For roasting seeds were heated on a hot plate at 180°C for 10 s. The roasted seeds were cooled and milling was done by kitchen grinder at high speed to obtain flour of uniform particle size. The flour was passed through 80-mesh sieve and stored in air tight container at 4°C.

Germination of amaranth and quinoa grains

The germination of grains was done according to the method described by Ruiz and Bressani (1990)[6]. The seeds were washed and soaked in distilled water in the ratio of 1:5 w/v for seed to water for a period of 6-7 h at room temperature. The seeds were spread on moist sponge material and sterile paper towel were used to cover for keeping appropriate moisture constant. After that seeds were kept in incubator at 32°C for 48 h. Germination seeds were dried in hot air oven for 6-7 h and milled by using kitchen grinder. Flour obtained was passed through 80-mesh sieve and stored in air tight container at 4°C.

Analysis of grains and flours

Physical and hydration properties of grains were determined[7]. Proximate analysis of the raw and treated flours of the amaranth and quinoa were determined by the standard methods[8]. Chroma meter (CR-400) was used to measure color parameters of flour samples. Standardization of colorimeter was done by using white paper and black tiles supplied with instrument[9]. L*, a* and b* coordinates of the CIE scales were recorded. L* value indicated lightness where 0 is black, 100 is white. Value of a* shows (red-green) axis – positive values for red and negative values for green and 0 is neutral. Value of b* represents (yellow-blue) axis positive values are for yellow and negative values are for blue and 0 is neutral.

Rapid Visco Analyzer was used for analysis of pasting properties of flours. The suspensions prepared by mixing 3 g flour (14% moisture basis) in 25 mL distilled water were exposed to the time/temperature pattern: at 50°C for 1 min heating at 50°C to 95 °C in 3.5, hold at 95°C for 3 min then cooling was done from 95°C to 50°C in 3.5 min and holding at this temperature for 2 min. Peak viscosity, breakdown viscosity, final viscosity, trough viscosity, setback viscosity, peak time and pasting temperature were recorded.

Zinc and iron were measured using AAS after the digestion of flours sample in H_2SO_4, HNO_3 and $HClO_4$ mixture. Combine calcium and magnesium were estimated by titration method. Digested sample (1 m) was taken in crucible and 1-2 drops of EBTA and ammonium buffer solution were added step by step and titration was done by using EDTA (N/100). Changed in color from red to blue indicated the end point. For calcium estimation 1 mL of treated sample was taken and 4-5 drops of NaOH and ammonium perpurate were added. Changed in color from pink to purple indicated the end point of titration. Double

extraction gravimetric method was used to determine saponin content of the flour samples whereas tannin content of flours of amaranth and quinoa was determined by Vanillin-HCL Method[10,11].

Statistical Analysis

All the values in the present study were taken as mean of three replicates ± SD. Dunken Test was conducted to examine significant difference ($p<0.05$) among different treatments using SPSS software version 6.0.

Results and discussion

Physical and hydration properties of grains

Physical properties of grains of amaranth and quinoa are presented in Table 1. Thousand kernel seed weight indicates the size of the grain which has direct impact on the postharvest processing of the grains. Thousand kernel weight of grains varied crop to crop and also among the varieties of the same crop. Larger grain contain more edible portion because of large endosperm. Amaranth grain showed lesser weight of 1000 kernel than quinoa grains. Thousand kernel weights of various cultivars of *A. hypochondriacus* were reported in the range of 0.62 to 0.88 g which was comparable to the results of present study[12]. In present investigation thousand kernel volumes of amaranth and quinoa were recorded to be 0.76 and 2.86 mL respectively, which were in the range of 1.63 to 2.87 mL reported for quinoa grains[13]. Thousand kernel volumes for foxtail millet was 1.6 mL which was comparatively higher than amaranth while lower than quinoa grains[14]. Value of bulk density and true density of amaranth grain were higher than the quinoa grain.

According to the earlier findings bulk and true density for quinoa were 0.747 g/mL and 0.928 g/mL respectively, which are similar to present findings[15]. Density of grains plays considerable role in storage, packaging, transportation and helps in separating and grading of grains. True density and bulk density also helps in removal of undesirable materials, seed purity identification and grading as well as in design of silos and storage bins. Higher porosity of amaranth than that of quinoa grains might be due to the larger size of quinoa grains. Literature reported porosity of quinoa seeds varying from 6.94 to 15.04% which was comparable to the present findings[13]. Some investigations reported higher values of porosity ranged from 0.19 to 0.43% for quinoa seeds[16]. Porosity of seeds depends upon true density and bulk density and increases linearly with the increase in moisture content of the seed. Porosity data helps in making design of aeration system of the storing space and high porosity leads to better aeration and water vapors diffusion at the time of deep-bed drying. Hydration characteristics play an important role in different processing of seeds like Soaking, germination, dehusking and extraction of principle compound and elimination of antinutritional components. Values of hydration index of amaranth and quinoa grains were consistent with the earlier reports that found hydration index ranging from 0.83 to 1.05 for six varieties of lentil[17]. Higher values of swelling index were exhibited by amaranth grains as compared with quinoa grains. Properties of hydration capacity helps in examine the grain quality, cooking time and cooking quality of grains.

Properties of flours

Chemical compositions of flours

The proximate composition of flours of raw and processed grains of amaranth and quinoa is presented in Table 2. The results indicated that the moisture

Table 2 — Chemical compositions of flours of raw and processed amaranth and quinoa grains

Grain treatments	Moisture (%)	Ash (%)	Crude fat (%)	Protein (%)
Amaranth flour				
Raw	7.6±0.40^{d}	3.33±0.28^{c}	7.53±0.30^{e}	16.6±0.36^{d}
Cooked	6.26±1.60^{bc}	2.56±0.40^{b}	6.46±0.30^{d}	15.4±0.15^{c}
Roasted	3.2±0.40^{a}	2.1±0.40^{b}	5.66±0.30^{bc}	15.1±0.25^{c}
Germination	5.46±0.23^{b}	2.33±0.28^{b}	4.06±0.30^{a}	17.4±0.35^{e}
Quinoa flour				
Raw	7.93±0.30^{d}	3.46±0.05^{c}	8.1±0.26^{e}	14.5±0.30^{b}
Cooked	7.06±0.41^{bcd}	2.33±0.28^{b}	6.63±0.37^{d}	13.7±0.17^{a}
Roasted	3.46±0.83^{a}	1.16±0.76^{a}	6.06±0.23^{cd}	13.2±0.36^{a}
Germination	5.20±0.34^{b}	2.60±0.36^{b}	5.26±0.50^{b}	15.6±0.30^{c}

All values are mean ± standard deviation (n=3). Values with different superscript in the same column are significantly different ($p< 0.05$)

Table 1 — Physical and hydration properties of amaranth and quinoa grains

Grain	1000 kernel wt. (g)	1000 kernel vol. (mL)	Bulk density (g/mL)	True density (g/mL)	Porosity (%)	Hydration Capacity (%)	Hydration Index	Swelling Capacity (%)	Swelling Index
Amaranth	0.80±0.06	0.76±0.30	0.81±0.02	1.14±0.36	26.2±3.60	88.05±2.49	0.87±0.02	99.25±2.99	1.13±0.36
Quinoa	2.57±0.08	2.86±0.20	0.76±0.06	0.90±0.03	14.1±1.15	88.01±2.67	0.879±0.02	95.76±2.43	0.85±0.04

Value expressed as mean ± SD (n=3)

content decreased after the processing of grains. Similar trend of decreasing moisture content in fenugreek seed after processing was reported[18]. Low moisture content leads to less microbial activity and extends shelf life of flours. During roasting significant decrease in moisture content among the treated amaranth and quinoa flour was observed. Ash content of raw quinoa flour (3.5%) was close to the ash content value of quinoa flour reported in literature[19]. The decreased ash content in processed grains flours might be attributed to the diffusion of minerals into water during washing, soaking and other handlings.

The highest fat content (8.1%) was observed in raw quinoa flour followed by raw amaranth flour (7.53%). Lower values of fat content were recorded for processed grain flours of both the crops. Similar trend of decreasing fat content of chickpea flour during different cooking method was reported in earlier findings[20]. Highest decrement in fat content of germinated grain flours could be attributed to the increased lipolytic enzymes activity which hydrolyzed the fat and consequently used it as energy source during germination.

Protein content of amaranth and quinoa increased during germination while non significant decrement was noticed among the process of roasting and cooking of both seeds. The rise in protein content during the germination might be due to the metabolic activity of hydrolytic enzymes such as proteinase resulted in release of amino acids and peptides consequently formed new protein.

Functional and antinutritional properties of flours

Significantly increase in water absorption capacity of flours of processed amaranth and quinoa grains was observed. Maximum increase in water absorption capacity was noticed in roasted grain flour samples of amaranth and quinoa. Increase in water absorption capacity of flours following thermal processing might be due to gelatinization of starch and denaturation of protein. Increase in protein level and quality of protein providing hydrophilic part during germination could also be the reason for increased water absorption capacity of germinated grain flours[21]. Similar trend of increase in water absorption capacity during germination for cornstarch, tigernut and amaranth flour was reported in previous studies[21,22,23].

Oil absorption capacity is the interaction between lipid and non- polar side chain of amino acid and provides richness and flavor to the product. Amaranth and quinoa flours showed oil absorption capacity in the range from 1.53 to 2.73 (mL/g). Comparatively lower values of water absorption capacity and oil absorption capacity of raw amaranth flour were reported[35]. Processing of grains caused significant increase in oil absorption capacity of amaranth and quinoa grain flours. Similar results of increase in oil absorption capacity during germination were reported in literature[22,24]. Bulk density of raw amaranth and quinoa flours was 0.82 g/mL and 0.63 g/mL respectively and decreased significantly during different processing treatments. Maximum decrease in bulk density of flours was observed in roasted samples which could be due to loss of moisture and consequently reduction in grain size. Comparable values of bulk density of amaranth and quinoa grain flours were reported inliterature[13]. Flour of low bulk density is suitable for production of weaning foods because these flours provide low paste thickness and viscosity during reconstitution. Whereas, flours of high bulk density absorbs fat and these kinds of flours are used in baked and pastry products.

Anti-nutritional factors in flours of raw and treated amaranth and quinoa grains are shown in Table 3. Saponins are identified by their bitter taste and their ability to form foams in water. Saponins are removed by washing and soaking prior to cooking. Saponins are toxic substance that can lead to vomiting and nausea and these can cause hypocholesterolemic effects in human being. Saponins were determined in the range from 0.46 to 2.6 g/100 g in flours of raw and treated grains. Earlier studies reported saponins in range from 0.47 to 1.13 g/100 g for raw quinoa flour which was consistent with the present findings[5]. Saponin content was significantly decreased following different processing treatments and the highest reduction was noted in germinated grains flours followed by roasting. Similar trend of reduction in saponins after having different processing treatments like germination, fermentation and blanching of amaranth grain flour was reported[26]. Tannin content of raw and treated amaranth and quinoa grain flours varied from 0.08 to 1.58 mg/100 g. Earlier studies found consistent values of tannin content of raw quinoa flour[27]. Similar results of reduction in tannins for chickpea were reported in the earlier studies[20]. The significant decrease in saponins and tannins during germination was due to the leaching of these substances in water during washing and soaking[28]. Decrease in tannins might also be the

Table 3 — Functional and antinutritional properties of flours of raw and processed amaranth and quinoa grains

Grain treatments	Solubility (%)	WAC (g/g)	OAC (mL/g)	Bulk density (g/mL)	Saponin content (g/100 g)	Tannin content (mg/100 g)
Amaranth flour						
Raw	37.87±2.89^{e}	1.53±0.15^{bc}	1.53±0.30^{a}	0.82±0.04^{e}	2.66±0.15^{g}	1.58±0.03^{g}
Cooked	35.25±1.77^{e}	1.63±0.07^{c}	2.26±0.23^{bc}	0.48±0.02^{c}	1.26±0.05^{e}	1.14±0.04^{f}
Roasted	12.39±1.03^{b}	5.22±0.01^{g}	2.66±0.23^{c}	0.14±0.02^{a}	1.12±0.04^{d}	0.84±0.04^{e}
Germinated	26.76±2.48^{d}	2.77±0.01^{e}	2.73±0.50^{c}	0.56±0.05^{d}	0.84±0.06^{c}	0.68±0.04^{d}
Quinoa flour						
Raw	17.63±1.64^{c}	1.25±0.03a	1.73±0.23^{ab}	0.63±0.04^{d}	1.42±0.04^{f}	0.57±0.03^{c}
Cooked	12.55±1.24^{b}	1.46±0.06^{b}	2.46±0.50^{bc}	0.42±0.04^{bc}	0.90±0.04^{c}	0.13±0.04^{b}
Roasted	7.53±0.66^{a}	4.22±0.04^{f}	2.60±0.52^{c}	0.11±0.03^{a}	0.64±0.03^{b}	0.08±0.03^{ab}
Germinated	10.29±1.07^{ab}	2.14±017^{d}	2.53±0.61^{c}	0.36±0.05^{b}	0.46±0.04^{a}	0.03±0.02^{a}

All values are mean ± standard deviation (n=3). Values with different superscript in the same column are significantly different ($p< 0.05$), OAC = Oil absorption capacity, WAC = Water absorption capacity

result of hydrophobic bonding between polyphenols with organic substance like carbohydrate or seed protein[29].

Color characteristics including lightness, redness and yellowness of flours of raw and processed amaranth and quinoa grains are presented in Table 4. Color is an important parameter for overall acceptance of the food product. Values of a* and b* for raw and processed amaranth grain flours were significantly different from each other. Positive value of a* in all the treated flour sample of amaranth and quinoa indicate red tint in flours. Value of b* indicates the yellowness in the flour. Roasted amaranth and quinoa flours showed increase in b* value among treated flour samples. Values of color parameters of flours from raw amaranth and quinoa grains were similar to the color values of amaranth flours reported earlier[30]. Values of color parameter for raw and processed quinoa grain flours were consistent with the earlier findings[13].

Pasting properties of flours of raw and processed amaranth and quinoa grains are present in Table 5. During gelatinization of starch viscosity gets changed and this process is defined by the term "pasting"[31]. Higher viscosities were noticed for amaranth flour samples as compared to quinoa flours on every stage of heating cooling cycle. Viscosity of flour depends on flour composition and characterization of starch present in the flour. So the difference in viscosities of amaranth and quinoa flours could be due to different composition and amount of present starch with different ratio of amylose and amylopectin.

When the rate of swelling of starch granule is equal to the rate of breakdown of granules at this point peak viscosity is achieved. Peak viscosity of raw amaranth

Table 4 — Color characteristics of flours of raw and processed amaranth and quinoa grains

Grain treatments	L *	a*	b*
Amaranth flour			
Raw	78.35±1.29^{g}	1.31±0.02^{b}	13.95±0.32^{b}
Cooked	77.09±1.09^{fg}	1.63±0.07^{c}	14.61±0.19^{c}
Roasted	70.44±1.23^{a}	6.62±0.17^{e}	24.55±0.60^{f}
Germination	71.47±0.19^{ab}	1.41±0.08^{b}	12.34±0.07^{a}
Quinoa flour			
Raw	76.38±0.17^{ef}	0.62±0.04^{a}	15.28±0.13^{d}
Cooked	74.96±0.98^{de}	0.66±0.01^{a}	14.63±0.30^{c}
Roasted	72.47±1.15^{bc}	4.44±0.10^{d}	21.65±0.44^{e}
Germination	73.59±0.66^{cd}	0.63±0.07^{a}	13.46±0.10^{b}

All values are mean ± standard deviation (n=3). Values with different superscript in the same column are significantly different ($p< 0.05$). L: black to white; a*: green to red; b*: blue to yellow

flour (1372.3 cP) was consistent with the range from 1050 to 1459 cP with earlier investigation[30]. Breakdown viscosity of raw amaranth flour was consistent with the finding[32]. Ability of flour to form stable cooked paste is represented by final viscosity. Final viscosity of raw amaranth flour (1455.3 cP) was higher than the final viscosity reported[33] for raw *A. Cruentus L*. Setback viscosity indicates the retro gradation during cooling of cooking paste. All treatments showed reduced values of viscosities in quinoa grain flours. Roasted and germinated amaranth grain flours had decreased peak viscosity and final viscosity whereas, cooked amaranth grain flour exhibited significantly increase in final viscosity. Reduction in the viscosities of flours from germinated grains of amaranth and quinoa could be attributed to the decrement in starch content due to utilization of starch for germination. Disintegration of starch granules during roasting process produced starch

Table 5 — Pasting properties of flours of raw and processed amaranth and quinoa grains

Grain treatments	PV (cP)	TV (cP)	BV (cP)	FV (cP)	SBV (cP)	P_{Time} (min)	P_{Temp} (°C)
Amaranth flour							
Raw	1373.5 ±2.1^{e}	1314.0±5.6^{f}	57.0±7.0^{d}	1446.0±12.7^{e}	132.0±18.3^{c}	6.43±1.4^{a}	84.82±0.025
Cooked	1348±109^{e}	971.3±116^{e}	376.3±7.5^{g}	1704.3±100.5^{f}	733.0±16.00^{f}	7.00±0^{b}	92.2±0.60
Roasted	409±12.0^{c}	287±6.00^{c}	122.0±6.0^{f}	809.3±30.5^{d}	522.3±24.5^{e}	7.00±0^{b}	
Germinated	376.3±0.5^{c}	293±0.00^{c}	83.0±1.0^{e}	590±0.00^{c}	297±0.00^{d}	7.00±0^{b}	
Quinoa flour							
Raw	535.0±9.0^{d}	455.33±8.5^{d}	79.33±0.5^{e}	766±26.00^{d}	310.33±17.5^{d}	7.00±0^{b}	89.60±0.05
Cooked	212.3±19.5^{b}	183.3±16.5^{b}	29.00±3.0^{c}	282±25.00^{b}	98.5±8.50^{b}	7.00±0^{b}	
Roasted	50±0.00^{a}	44.3±0.5^{a}	5.33±0.5^{a}	69.33±0.57^{a}	25.0±0.00^{a}	7.00±0^{b}	
Germinated	121±0.00^{a}	108±1.00^{ab}	13.00±1.0^{b}	218.33±0.57^{b}	110.33±0.5^{bc}	7.00±0^{b}	

All values are mean ± standard deviation (n=3). Values with different superscript in the same column are significantly different ($p< 0.05$). PV: peak viscosity; TV: trough viscosity; BV: breakdown viscosity; FV: final viscosity; SV: setback viscosity; PT: pasting temperature; P_{time}: Pasting time; cP: centipoise

Table 6 — Mineral content of flours of raw and processed amaranth and quinoa grains

Grain treatments	Iron (mg/100 g)	Magnesium (mg/100 g)	Zinc (mg/100 g)	Calcium (mg/100 g)
Amaranth flour				
Raw	19.58±0.65^{g}	325.42±12.16^{d}	4.92±0.26^{f}	201.88±4.65^{e}
Cooked	13.27±0.60^{d}	295.74±6.61^{c}	3.46±0.16^{bc}	195.67±2.64^{d}
Roasted	16.92±1.83^{f}	306.86±7.66^{c}	3.88±0.23^{cd}	197.58±3.18^{de}
Germinated	14.82±0.19^{e}	302.46±4.51^{c}	4.25±0.24^{de}	196.27±2.44^{de}
Quinoa flour				
Raw	6.07±0.96^{c}	207.7±12.50^{b}	4.58±0.53^{ef}	69.18±2.81^{c}
Cooked	1.45±0.57a	157.31±4.74^{a}	1.87±0.15^{a}	55.05±3.94^{a}
Roasted	3.06±0.08^{b}	164.35±7.36^{a}	3.26±0.24^{b}	59.97±1.80^{ab}
Germinated	3.25±0.19^{b}	170.80±1.74^{a}	3.60±0.42^{bc}	60.97±2.41^{b}

All values are mean ± standard deviation (n=3). Values with different superscript in the same column are significantly different ($p< 0.05$)

granules with reduced swelling capacity that might be the reason for lower peak and final viscosity of roasted amaranth and quinoa grain flours. Among all the treated grain flours cooked grain flours showed maximum viscosities for both the crops that might be attributed to the pre gelatinization of starch during cooking. Pasting behavior of flours depends on various factors like particle size, size distribution, composition, ratio of different components and grain treatments and as well as conditions of heating and cooling process. Therefore, the variation in these factors and unique response of amaranth and quinoa grains for each treatment are the basic reasons for differences in pasting behavior of their flours.

The result of mineral contents of raw and processed grain of amaranth and quinoa are shown in Table 6. Amaranth and quinoa both are good source of minerals as compared to other staple foods such as rice, corn, oats, and barley. Amaranth have good amount of iron and calcium. Literature showed similar results for calcium, magnesium, zinc and iron for raw quinoa grains[15]. Amaranth and quinoa has higher iron content than rice and finger millet. Processing of grains significantly reduced the mineral content however statistically similar values were noticed for mineral contents of processed grain flours was noticed. Significant decrease in iron content of germinated grains flours of amaranth was observed but no significant change was noted in case of quinoa.

Similar trend of declination of mineral content during boiling, roasting and popping was observed for amaranth grains[34]. During wet processing most of the water soluble minerals get leached into the water that results in lower mineral content. The result of present finding for germinated amaranth grains was found consistent with the literature[4]. Mineral content of raw and processed grains was found corresponding with the ash content of grains in present investigation.

Conclusion

From the present study it was concluded that high protein and mineral content of amaranth and quinoa make them a good source of nutrients. All the treatments significantly decreased the non-nutritional components of amaranth and quinoa flours. Germination was found to be the best treatment among the studied treatments in improving nutritional profile of grains in term of protein content. White color of amaranth and quinoa flours indicated their suitability like major cereals flour for various food products. Increment in final viscosity of amaranth flour after cooking makes it applicable for products requiring high viscosity and low total solids.

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