Toxicology International, *31(3) : 409-416; 2024. DOI: 10.18311/ti/2024/v31i3/43419*

Online ISSN : 0976-5131; Print ISSN : 0971-6580

Toxicology International

Contents available at: www.informaticsjournals.com/index.php/toxi



Influence of Processing Techniques on the Saponin Content and Nutritional Quality of Quinoa (*Chenopodium quinoa*)

Priyanka R. Kale*, D. R. More, Ganesh P. Gaikwad, V. D. Surve and Aditi H. Bachate

Department of Food Business Management, College of Food Technology, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani – 431401, Maharashtra, India; priyankakale665@gmail.com

Abstract

Quinoa cultivated primarily for its edible seeds is renowned for its nutritional richness. The study highlights how each method affects quinoa's nutritional composition and saponin content by comparing different processing techniques. This information is valuable for food processors and manufacturers seeking to optimise their production processes to enhance their nutritional value. The soaking process involved immersing the seeds in sodium bicarbonate and citric acid solution (1% and 2%, respectively) for 6 hours at room temperature then roasting at 80^{0}C for 10 min. These pretreated quinoa grains were analyzed for their saponin content and nutritional composition. In raw quinoa grains, the saponin content was measured at 0.64%. After soaking the grains in a 2% citric acid solution, a significant reduction in saponin content to 0.09%. However, roasting the quinoa grains results in a decreased saponin content slightly to 0.62%. The results indicate that soaking in a 2% citric acid solution was particularly effective in reducing the saponin content of quinoa seeds to a desirable level while also eliminating bitterness. Consequently, quinoa seeds treated with a 2% citric acid solution were selected for further nutritional analysis. Significant alterations in the nutritional composition of quinoa were observed as a result of processing. In terms of proximate composition, soaking increased moisture, protein, and ash while decreasing other parameters. Soaking causes an increase in protein content from 15.6% to 16.2%. Conversely, roasting decreased moisture and protein levels while increasing other parameters. The moisture and protein content of roasted quinoa grains were reduced to 6.8% and 14.8%, respectively. Both soaking and roasting processes resulted in elevated mineral content in quinoa seeds. Consequently, soaked and roasted quinoa grains were found to be rich in nutrients, positioning them as valuable sources for enhancing food commercialization.

Keywords: Antinutritional, Bitterness, Nutrient, Pretreatment, Quinoa

1. Introduction

Quinoa (*Chenopodium quinoa willd.*) is classified as a pseudo-cereal crop, distinguished by its classification as a broadleaf plant with a starchy dicotyledonous seed. Unlike cereals, which are characterized as monocotyledonous, quinoa does not fall under the cereal category. This ancient crop originates from the Andean region and belongs to the dicotyledonous class, *Chenopodiaceae* family, *Chenopodium* genus and quinoa species. Beyond its botanical classification, quinoa serves as a cereal-like grain, playing a vital role in the functional food sector[1].

Quinoa's domestication traces back to approximately 5000 B.C. in the elevated plateaus of the Andean region

**Author for correspondence*

Article Received on: 30.03.2024 Revised on: 09.05.2024 Accepted on: 20.05.2024

near Lake Titicaca in South America. From this time, it has held significant importance as a staple food grain for the Incas, earning the revered title of the "mother grain" in their native Quechua language. As per the FAO, the primary quinoa-producing countries are Ecuador, Peru and Bolivia[2].

Quinoa is gaining popularity among consumers due to its status as a novel food source and its rich nutritional profile. Quinoa grains boast a protein content ranging from 13.9% to 17%. All nine essential amino acids required by humans namely, isoleucine, lysine, leucine, methionine, tryptophan, histidine, valine, phenylalanine and threonine are present in quinoa. This grain stands out for its elevated amylose levels and a well-balanced composition of carbohydrates, starch and sugars. In addition to protein content and amino acid profile, quinoa is a source of various vitamins, including those from the B complex, vitamins E, C and K. Furthermore, quinoa is a rich source of all essential minerals required for the body. The comprehensive nutritional makeup of quinoa contributes to its appeal as a wholesome and nutrient-rich food option[3].

Quinoa boasts significant nutritional value, characterized by high levels of proteins, unsaturated fats, dietary fibre, vitamins and minerals. It is a gluten-free grain and suitable for inclusion in the diets of individuals with celiac disease[4]. As a highly nutritious crop, quinoa surpasses many other plant foods in protein content, offering a light, tasty and easily digestible option[5].

Quinoa seeds, when boiled, serve as a rice alternative and are adaptable for various culinary applications. They can be used to thicken soups, create porridge and feature in hot breakfast cereals. In salad preparation, sprouted quinoa seeds offer a nutritious addition. Roasting quinoa seeds produces quinoa pops, while quinoa flour, known for its low gluten content due to minimal prolamines and glutamines, is incorporated into diverse recipes. Notably, it is blended with bread flour (10-13 %), used in noodles and pasta (30-40 %) and integrated into biscuits (up to 60%) for enhanced moisture retention and flavour infusion[6,7].

Along with its nutritional profile, quinoa contains certain antinutritional factors such as saponin, phytic acid, oxalates, tannins and trypsin inhibitors which are located in the outermost layer. Of all these antinutritional factors saponin is the major one which contributes bitter taste of quinoa and is removed by using various pretreatments such as soaking, roasting, abrasion and germination[8].

Saponins, natural detergents found in plants, are glycosylated secondary metabolites serving as a defence mechanism against predators. Quinoa harbours these compounds, which impart a bitter taste and may lead to gastric discomfort, with concentrations ranging from 0.1% to 5%. Quinoa can be categorized on its free saponin content, with varieties ranging from sweet to higher concentrations at 0.11%. Various methods have been explored to reduce saponin content without compromising nutritional integrity, such as thorough cold-water washing. Conversely, isolated saponins may offer health benefits, including anti-inflammatory properties. According to FSSAI standards, safe consumption levels for saponins are capped at 0.1%[9].

Quinoa saponins, the natural detergents are the major negative factor responsible for its bitter taste, lower palatability and lower consumer acceptability[10]. Saponins are present in the outer layer of quinoa grains i.e. the papillose cells of hulls[11]. Bitter varieties of quinoa contain saponin in the range of 0.1 to 5 g/100 g and sweet varieties in the range of 0.02 to 0.05 g/100 g[6]. The Saponin content of legumes is more than that of quinoa.

In addition to cross-hybridization as a possible solution to the production of sweet quinoa varieties for increasing their consumer acceptability, regulation of soil salinity and irrigation level is also known to greatly influence the saponin level in quinoa seed. They also revealed that high soil water deficit may also help in yielding quinoa crops with lower saponin content[12]. Saponins are known to engage in hemolytic activity of red blood cells and result in toxicity[13]. They also interfere in the absorption of minerals by forming tight saponin-mineral linkages. Although saponins adversely affect quinoa acceptability in the market they are to have a positive influence on crop protection against pests. In addition, saponins are reported to have antimicrobial and cholesterol-lowering potential[14]. Saponins are also known as "cell permeability modifiers" and are used as precursors which intensify the uptake of certain drugs by the small intestine which represents its pharmacological potential[15].

Quinoa seeds contain saponins, and triterpenoid glycosides primarily found in the seed coat, influencing the taste of quinoa and protein digestibility. To make quinoa suitable for consumption, the removal of saponins is essential. Traditionally, this process involves solid-liquid extraction, often carried out through domestic washing of the seeds under running water, creating foam due to saponin's presence. The washing is considered complete

when the foam formation diminishes. However, there remains ongoing discussion about the acceptable saponin content in quinoa concerning bitterness and potential adverse biological effects, as explored in the research[16]. Pretreatments were given to reduce the saponin content and to enhance the nutritional profile of quinoa seeds.

These processed forms of quinoa as valuable sources for enhancing food commercialization. This knowledge can inform future research and development efforts aimed at improving the processing techniques and nutritional value of other food crops. Overall, this study underscores the importance of considering processing methods in maximizing the nutritional value and commercial potential of quinoa, ultimately contributing to the promotion of healthier food choices and sustainable agricultural practices.

2. Materials and Methods

2.1 Materials

The good quality raw material, i.e., quinoa was purchased from the local market.

2.2 Methods

2.2.1 Preparation of sample

2.2.1.1 Soaking of Quinoa

Good quality quinoa grains were selected and cleaned to remove the dirt, dust, stone, mud particles, leaves, chaff etc. The cleaned grains were soaked in sodium bicarbonate solution and citric acid solution (1% and 2%, respectively) for 6 hours at room temperature for the removal of saponin content which removes the bitterness of grains. Soaked grains were rinsed with running tap water and then dried in a dryer at 60°C for 2-3 hrs. After that convert the dried grains to flour by using the flour mill to grind it into a fine powder form.

2.2.1.2 Roasting of Quinoa

To remove dirt, dust and soil particles, quinoa grains were cleaned. The grains were washed under running tap water until foam formation stopped and then sundried. Next, the grains were roasted at 80°C for 10 minutes in a shallow pan, stirring continuously for uniform roasting. After roasting, the samples were cooled to room temperature and ground into a fine powder using a flour mill. The obtained flour was sieved using a 40-mesh sieve and packed in an airtight container until used for analysis and product preparation[17].

2.2.2 Analytical Methods

The grains were tested to investigate their chemical composition and mineral content. The analysis was performed following the procedure outlined by AOAC[18]. Nutrient analysis was conducted twice and the findings were noted based on dry weight.

2.2.3 Proximate Analysis

The grains were subjected to proximate analysis to explore their composition which encompassed moisture, protein, fat, ash, crude fibre and carbohydrate content. The analysis was performed following the procedure outlined by AOAC[18]. Each process was performed three times and the results represent the average of three determinations.

2.2.4 Determination of Minerals

Two grams of the defatted sample were weighed and burned at 550°C. The obtained ash was then treated with concentrated hydrochloric acid (HCl) on a hot plate. After digestion the material was filtered using Whatman No. 42 filter paper and the volume was made up to 100 ml with distilled water for mineral analysis by following the procedures given by AOAC[18].

2.2.5 Determination of Saponin Content

5 grams of quinoa seed flour was kept in a 250 ml conical flask and 100 ml of 20% aqueous ethanol was added to it. The mixture was heated in a hot water bath at 55°C for 4 hours and stirred continuously. The residue was re-extracted with another 100 ml of 20% aqueous ethanol after filtration and heated at the same temperature for 4 hours with constant stirring. The combined extract was concentrated to 40 ml in the water bath at 90°C. This concentrate was then transferred to a 250 ml separator funnel and 20 ml of diethyl ether was added and vigorously shaken. The aqueous layer was retained while the ether layer was discarded. This purification process was repeated twice. Subsequently, 60 ml of n-butanol was added and the butanol extract was washed twice with 10 ml of 5% sodium chloride. The sodium chloride layer was discarded and the remaining solution was heated over a water bath for 30 minutes. After that, the solution was taken in a crucible and dried in an oven until a constant weight was noted. The saponin content of both

samples was determined i.e. raw and pretreated quinoa by following the process of Obdoni and Ochuko[19].

$$\%Saponin = \frac{Weight\ of\ saponin}{Weight\ of\ sample} \times 100$$

3. Results and Discussion

3.1 Physical Properties of Quinoa Seeds

The physical properties play a very important role in the development of processing technology and the quality of final products.

The physical properties of quinoa seeds were determined and the results are depicted in Table 1. The results showed that the thousand kernel weight and thousand kernel volumes of quinoa seeds were 2.50 g and 16 ml respectively. The quinoa seeds exhibited a bulk density of 606 kg/m^3 and a true density of 882 kg/m^3 resulting in a porosity of 31.29%. The angle of repose of quinoa grains was 33.69°. Additionally, the geometric mean diameter and sphericity were noted to be 1.43 mm and 0.81, respectively. The results were matched with[7,20].

3.2 Effect of Pretreatments on Saponin Content of Quinoa

Saponins are secondary metabolites known for their antinutritional properties such as their ability to cause hemolysis of red blood cells, bitter taste, foaming ability and enzyme inhibition. However, at lower concentrations, they can also act as a phytochemical with pharmacological benefits such as antioxidant, anti-inflammatory, cytotoxic, hypoglycemic and hypolipidemic effects[21]. Since saponins found in the outer layer of quinoa seeds impart a bitter taste saponin content was reduced to a safe level by using different pretreatments. The saponin content was determined and the findings were reported and displayed in Table 2.

The saponin content of raw quinoa was reported to be 0.64%. Different pretreatments such as soaking and roasting were given to the quinoa seeds to reduce the saponin content. The saponin content of roasted quinoa was found to be 0.62%. The soaking in sodium bicarbonate and citric acid results in a decrease in saponin content to an acceptable level. Soaking in 1% and 2% sodium bicarbonate solution reduced saponin content to 0.21% and 0.18%, respectively.

Soaked quinoa grains in 1% and 2% citric acid solution reduced saponin content to 0.12% and 0.09%, respectively. It is evident from the result that soaking in a 2% citric acid solution was found superior for reducing the saponin content of quinoa seed to a desirable level with the removal of bitterness. Soaking is essential for further processing of quinoa to eliminate saponin and increase nutritional quality. As saponin is located in the outer layer of quinoa seeds it may be decreased due to leaching of saponin into the soaked water during the soaking period[22]. Hence quinoa was treated with a 2% citric acid solution and then preceded for further research. The results are in close agreement with[23,24].

3.3 Effect of Pretreatments on Proximate Composition of Quinoa

Quinoa seeds underwent soaking and roasting processes both vital treatments aimed at adjusting moisture levels to prepare the seeds for milling into flour. Additionally, these treatments were effective in decreasing the saponin content and mitigating the bitter taste associated with quinoa. The approximate composition of soaked and roasted quinoa was determined and comparison of

Table 1. Physical properties of quinoa seeds

Properties	Values
1000 Kernel weight (g)	2.5±0.15
1000 Kernel volume (ml)	16±2.50
Bulk density (kg/m^3)	606±4.00
True density (kg/m^3)	882±2.00
Porosity (%)	31.29±0.04
The angle of repose (^{0})	33.69±1.01
Geometric mean diameter (mm)	1.43±0.10
Sphericity	0.81±0.06

*Each value is the average of three determinations

Table 2. Effect of pretreatments on saponin content of quinoa

Pretreatments	Saponin content (%)
Raw quinoa seed	0.64±0.008
Roasted quinoa seeds	0.62±0.005
Soaking in sodium bicarbonate solution (1%)	0.21±0.01
Soaking in sodium bicarbonate solution (2%)	0.18±0.003
Soaking in citric acid solution (1%)	0.12±0.02
Soaking in citric acid solution (2%)	0.09±0.005

*Each value is the average of three determinations

composition was analyzed and results were tabulated in Table 3. Each value in the provided data represents the average of three determinations, presented as means ± Standard Deviation (SD).

The moisture content of raw and soaked quinoa ranged from 9.60% to 10.40%. This rise in moisture content post-soaking likely occurred because the dry seeds absorbed water, causing hydration and cell multiplication within the seed[25].

The results indicate that during the roasting process, there was a gradual reduction in moisture content from 9.60% to 6.80%. This decrease in moisture content during roasting is likely attributed to the elevated temperature leading to the vaporization of water within the grains[26].

The soaked quinoa exhibited a fat content of 6.15%. Comparatively soaking resulted in a notable decrease in fat content compared to raw quinoa. The expansion of seeds due to water absorption during soaking consumes energy derived from fats which are a primary carbon source in seeds potentially leading to a reduction in fat content post-soaking[27]. Additionally, it was noted that the fat content slightly increased during roasting rising from 6.20% to 6.60%. This increase in fat content during roasting might be due to the breakdown of cell structures and membrane barriers within the seeds due to heat. As a result, the fat within the seeds melted and was released more readily potentially leading to the observed increase in fat content[28].

Soaked quinoa was reported to have 16.20% protein content. Soaking led to an elevation in the protein content of quinoa seeds. The elevation in protein content of the soaked sample could be due to an increase in free amino acids and peptides contributed by the increment in non-protein nitrogenous constituents during soaking. The rise in protein content in the soaked sample could be attributed to an elevation in free amino acids and peptides resulting from the accumulation of non-protein nitrogenous constituents during soaking[29].

Table 3. Effect of different pretreatments on proximate composition of quinoa

Nutrients (%)	Pretreatments		
	Raw	Soaked	Roasted
Moisture	9.60±0.3	10.40±1.02	6.80±0.09
Fat	6.20±0.4	6.15±0.15	6.60±0.30
Protein	15.60±0.6	16.20±0.20	14.80±0.83
Crude fiber	3.60±0.5	3.40±0.40	3.80±0.46
Ash	3.40±0.2	3.80±0.80	3.60±0.80
Carbohydrate	61.60±0.1	60.35±0.25	64.40±0.13

*Each value is the average of three determinations

A slight decrease in protein content was observed in roasted quinoa seeds compared to raw ones with the protein content decreasing from 15.60% to 14.80%. This decrease in protein content could be attributed to protein denaturation occurring during the roasting process[30]. The maillard reaction which occurs between proteins and sugars involving the carbonyl group of reducing sugar and the free amino group from an amino acid or protein diminishes the nutritional value of the protein[31,32].

The crude fibre content of soaked quinoa decreased from 3.60% to 3.40% due to the reduction of soluble fibre content present in quinoa. A slight increase in the crude fibre content of quinoa was observed during roasting reaching 3.80%. This increase in fiber content could be attributed to the formation of protein-fiber complexes and the high temperature during roasting did not affect the fiber content. Similar findings were reported by Rajni *et al*[33].

The soaked quinoa seeds were reported to have an ash content of 3.80%. Soaking resulted in a 0.4% increase in ash content this may be due to a decrease in the carbohydrate and fat content of processed seeds which can be accounted for the increase in ash content. The soaked quinoa seeds exhibited an ash content of 3.80%. Soaking led to a 0.4% increase in ash content possibly due to a reduction in carbohydrate and fat content in the processed seeds which could account for the increase in ash content[34]. Roasting also causes an elevation in the ash content of quinoa. This increase in ash content could be attributed to the loss of moisture during roasting[35]. Ash content of roasted and raw quinoa were 3.60% and 3.40%, respectively. These results are similar to the findings of Jemima[26].

The carbohydrate content in raw, soaked and roasted quinoa seeds was 61.60%, 60.35% and 64.4%, respectively. The fluctuations in carbohydrate content among the grains from raw to soaked and roasted states could be attributed to variations in other constituents[36]. The decrease in carbohydrate content after soaking may be attributed to the activation of α-amylase in quinoa seeds. This activation leads to the breakdown of starch into simple sugars during hydration[37].

3.4 Effect of Pretreatments on Mineral Composition of Quinoa

The data on mineral composition viz. Ca, P, Mg, K, Fe and Zn of raw, soaked and roasted quinoa are given in Table 4.

Table 4. Effect of pretreatments on the mineral composition of quinoa

Minerals (mg/100g)	Pretreatments		
	Raw	Soaked	Roasted
Calcium	86±0.4	87±0.22	89±0.47
Phosphorus	412±0.1	416±0.18	418±0.08
Magnesium	430±0.9	228±0.13	232±0.28
Potassium	732±0.5	735±0.25	736±0.25
Iron	9.2±0.17	9.3±0.04	9.4±0.16
Zinc	3.8±0.25	3.2±0.08	3.9±0.18

*Each value is the average of three determinations

The results provided in Table 4 demonstrate that both soaking and roasting of quinoa seeds resulted in increased mineral content. Specifically soaking increased the levels of calcium (87 to 89 mg/100 g), phosphorus (416 to 418 mg/100 g), magnesium (228 to 232 mg/100 g), potassium (735 to 736 mg/100 g), iron (9.3 to 9.4 mg/100 g) and zinc (3.2 to 3.9 mg/100 g) in soaked quinoa seeds. Similarly roasting also led to elevated levels of these minerals in quinoa seeds.

The likely explanation for the elevation in calcium and iron content during soaking could be attributed to the reported decrease in phytic acid content as observed in this study. Phytic acid is recognized for its ability to bind with minerals, forming insoluble mineral-phytate complexes, which in turn reduces their bioavailability for proper utilization by the body[38].

Minerals are not destroyed they remain intact even when exposed to heat during roasting. So that elevation in mineral content could be attributed to the concentration of constituents during roasting facilitated by loss of moisture and reduction of certain antinutritional factors. Also found that thermal processing enhances the concentration of minerals[39].

The flour derived from roasted nuts retains more minerals than the flour obtained from boiled nuts. This is likely because roasting preserves minerals without leaching as observed in previous studies[34]. Moreover, the increased levels of potassium and phosphorus in roasted nut flour compared to raw nut flour are consistent with similar observations reported for roasted *Terminalia catappa* seeds[35].

4. Conclusion

The study demonstrated that soaking and roasting are effective methods for improving the nutritional value of quinoa, offering several advantages. These processes were found to enhance the nutritional quality of quinoa just before its incorporation into food products. Specifically, soaking and roasting significantly increased the bioavailability of minerals while decreasing the saponin content. The findings indicate that soaking quinoa seeds in a 2% citric acid solution was particularly effective in reducing the saponin content to a desirable level, thereby eliminating bitterness. Consequently, incorporating pretreated quinoa flour into food products could serve as a beneficial preventive measure against various disorders.

5. Acknowledgement

The author expresses sincere gratitude to the College of Food Technology, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani for providing facilities during research.

6. Funding Source

Author P. R. Kale is thankful to Chhatrapati Shahu Maharaj Research, Training and Human Development Institute (SARTHI), Pune (India) for financial support through Chhatrapati Shahu Maharaj National Research Fellowship (CSMNRF).

7. Conflict of Interest

The clinical studies with human subjects should be undertaken to investigate nutrient bioavability, biotoxicity and the positive effect on immune system.

8. References

1. Sharma V, Chandra S, Dwivedi P, Parturkar M. Quinoa: A nutritional health grain. Ind J Pure App Biosci. 2015; 3(9):725-36.
2. Arneja I, Tanwar B, Chauhan, A. Nutritional composition and health benefits of golden grain of 21st century, quinoa (*Chenopodium quinoa willd.*). Pak J Nutr. 2015; 14(12):1034-40. https://doi.org/10.3923/pjn.2015.1034.1040
3. Saeed MS, Saeed A, Iqbal M, Adnan M. Nutritional benefits of quinoa review. Ind J Pure App Biosci. 2020; 8(6):624-27. https://doi.org/10.18782/2582-2845.8493
4. Maradini-Filho AM, Pirozi MR, Borges JT, Santana HM, Chaves JB. Quinoa: Nutritional, functional and anti-nutritional aspects. Food Sci Nutr. 2017; 57(8):1618-30. https://doi.org/10.1080/10408398.2014.1001811 PMid:26114306

5. United Nations. Press Release. Secretary-general statements and messages. Launching international year of quinoa. New York; 2013 February 20. Secretary General SG/SM/14825 GA/11340 OBV/1184.
6. Valencia-Chamorro S. Quinoa: Encyclopedia of food sciences and nutrition. 2nd edn. Amsterdam: Academic Press; 2003. https://doi.org/10.1016/B0-12-227055-X/00995-0
7. Vilche C, Gely M, Santalla E. Physical properties of quinoa seeds. Biosyst Eng. 2003; 86(1):59-65. https://doi.org/10.1016/S1537-5110(03)00114-4
8. Valentina M, Francesca M. Functional components and anti-nutritional factors in gluten-free grains: A focus on quinoa seeds. Foods. 2021; 10(2):351. https://doi.org/10.3390/foods10020351 PMid:33562277 PMCid:PMC7915320
9. Miranda M, Vega-Galvez A, Quispe-Fuentes I, Rodríguez MJ, Maureira H, Martínez EA. Nutritional aspects of six quinoa (*Chenopodium quinoa willd.*) ecotypes from three geographical areas of Chile. Chil J Agric Res. 2012; 72(2):175-81. https://doi.org/10.4067/S0718-58392012000200002
10. Zhu N, Sheng S, Li D, Lavoie EJ, Karwe MV, Rosen RT, *et al.* Antioxidative flavonoid glycosides from quinoa seeds (*Chenopodium quinoa*). J Food Lipids. 2002; 8(1):37-44. https://doi.org/10.1111/j.1745-4522.2001.tb00182.x
11. Kuljanabhagavad T, Wink M. Biological activities and chemistry of saponins from *Chenopodium quinoa willd.* Phytochem Rev. 2009; 8(2):473-90. https://doi.org/10.1007/s11101-009-9121-0
12. Gomez-Caravaca AM, Iafelice G, Verardo V, Marconi E, Caboni, MF. Influence of pearling process on phenolic and saponin content in quinoa (*Chenopodium quinoa willd.*). Food Chem. 2014; 157:174-8. https://doi.org/10.1016/j.foodchem.2014.02.023 PMid:24679767
13. Araujo-Farro PC, Podadera G, Sobral PJ, Menegalli FC. Development of films based on quinoa (*Chenopodium quinoa willd.*) starch. Carbohydr Polym. 2010; 81(4):839-48. https://doi.org/10.1016/j.carbpol.2010.03.051
14. Afrose S, Tsujii H, Hossain MS, Salma U, Miah AG. Dietary karaya saponin and *Rhodobacter capsulatus* exert hypocholesterolemic effects by suppression of hepatic cholesterol synthesis and promotion of bile acid synthesis in laying hens. Cholesterol. 2010:1-7. https://doi.org/10.1155/2010/272731 PMid:21490913 PMCid:PMC3065839
15. Vega-Gálvez A, Miranda M, Vergara J, Uribe E, Puente L, Martínez E. Nutrition facts and functional potential of quinoa (*Chenopodium quinoa willd.*), an ancient Andean grain: A review. J Sci Food Agric. 2010; 90(15):2541-7. https://doi.org/10.1002/jsfa.4158 PMid:20814881
16. Irigoyen RM, Giner SA. Extraction kinetics of saponins from quinoa seed (*Chenopodium quinoa willd*). Int J Food Stud. 2018; 7(2):76-88. https://doi.org/10.7455/ijfs/7.2.2018.a7
17. Sandhya PS, Haripriya A. Effect of pre-treatment on selected nutrient profile and functional properties of quinoa (*Chenopodium quinoa*) flour and development of gluten free quinoa cookies. Indian J Nutr Diet. 2018; 55(2):197-208. https://doi.org/10.21048/ijnd.2018.55.2.18156
18. AOAC. Official methods of analysis. 16th ed. Association of Official Analytical Chemists, Washington, DC; 2005.
19. Obdoni BO, Ochuko PO. Phytochemical studies and comparative efficacy of the crude extracts of some Homostatic plants in Edo and Delta States of Nigeria. Global J Pure Appl Sci. 2001; 8(2):203-208. https://doi.org/10.4314/gjpas.v8i2.16033
20. Jan KN, Panesar PS, Singh S. Effect of moisture content on the physical and mechanical properties of quinoa seeds. Int Agrophys. 2019; 33:41-8. https://doi.org/10.31545/intagr/104374
21. Gemede HF, Ratta N. Antinutritional factors in plant foods: Potential health benefits and adverse effects. Int J Nutr Food Sci. 2014; 3:284-9. https://doi.org/10.11648/j.ijnfs.20140304.18
22. Chauhan GS, Eskin NA, Tkachuk R. Nutrients and antinutrients in quinoa seed. Cereal Chem. 1992; 69(1):85-8.
23. Mohammad NA. Studies on physico-chemical and nutritional properties of quinoa seed (*chenopodium quinoa willd.*) and its exploration in cookies. Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani; 2019
24. Ruales J, Nair BM. Effect of processing on the digestibility of protein and availability of starch in quinoa (*Chenopodium quinoa willd.*) seeds. Department of applied nutrition, university of Lund, Sweeden. Escuala Politecnica Nacional. Quito, Ecuador; 1993.
25. Nonogaki H, Bassel GW, Bewley JW. Germination-still a mystery. Plant Sci. 2010; 179:574- 81. https://doi.org/10.1016/j.plantsci.2010.02.010
26. Jemima B, Kumar M, Indu V.R. Nutrient and antioxidant analysis of raw and processed minor millets. Elixir Food Sci. 2012; 52A:1279-82.
27. Rumiyati A, James P, Jayasena V. Effect of germination on the nutritional and protein profile of Australian Sweet Lupin (*Lupinus angustifolius L.*). Food Nutr Sci. 2012; 3(5):621-6. https://doi.org/10.4236/fns.2012.35085
28. Adegunwa MO, Adebowale AA, Solano EO. Effect of thermal processing on the biochemical composition, anti-nutritional factors and functional properties of Beniseed (*Sesamum indicum*) flour. Am J Bio Mol Biol. 2012; 2(3):175-82. https://doi.org/10.3923/ajbmb.2012.175.182
29. Marmouzi I, El Madani N, Charrouf Z, Cherrah Y, Faouzi MYE. Proximate analysis, fatty acids and mineral composition of processed Moroccan *Chenopodium quinoa*

willd. and antioxidant properties according to the polarity. Phytotherapie. 2015; 13(2):110-17. https://doi.org/10.1007/s10298-015-0931-5

30. Sahni CK, Khurdiya DS, Dalal MA, Maini SB. Microwave processing of foods-potential and prospects. Ind Food Pack. 1997; 5:32-41.
31. Beltagi HS. Effect of roasting on protein fraction profiles and enzyme activities of Egyptian peanut. Int J Food Sci Nutr. 2011; 62(5):453-6. https://doi.org/10.3109/09637486.2010.544642 PMid:21338250
32. Adeyeye EI. Effect of cooking and roasting on the amino acid composition of raw groundnut (*Arachis hypogaea*) seeds. Acta Sci Pol Technol. 2010; 9(2):201-16.
33. Rajni M, Nagi HP, Sharma P, Sharma S. Effect of processing on chemical composition and antinutritional factors in chickpea flour. J Food Sci Eng. 2012; 2:180-6. https://doi.org/10.17265/2159-5828/2012.03.008
34. Chaudhary N, Vyas S. Effect of germination on proximate composition and anti-nutritional factor of millet (ragi) based premixes. Int J Food Nutr Sci. 2014; 3(4):72-9.
35. Ezeokonkwo CA. Effect of roasting on the nutrient composition of *Terminallia catappal* seed. New Jersey Nurs Stud, Inc. 2005; 26(1):19-24.
36. Inyang UE, Akpan EO, Bello FA. Effect of boiling and roasting on the nutrient and anti-nutrient contents in conophor nut flour. Int J Inf Res Rev. 2015; 2(6):769-72.
37. Rosa M, Hilal M, Gonzalez JA, Prado FE. Low-temperature effect on enzyme activities involved in sucrose–starch partitioning in salt-stressed and saltacclimated cotyledons of quinoa (*Chenopodium quinoa willd*.) seedlings. Plant Physiol Biochem. 2009; 47:300-7. https://doi.org/10.1016/j.plaphy.2008.12.001 PMid:19124255
38. Coulibaly A, Kouakou B, Chen J. Extruded adult breakfast based on millet and soybean: Nutritional and functional qualities, source of low glycemic food. J Nutr Food Sci. 2012; 2:151-60. https://doi.org/10.4172/2155-9600.1000151
39. Gunashree BS, Selva KR, Roobini R, Venkateswaran G. Nutrients and antinutrients of ragi and wheat as influenced by traditional processes. Int J Curr Microbiol Appl Sci. 2014; 3(7):720-36.