



Evaluation of Physical Characteristics and Impact of Germination on Functional Properties of Quinoa (*Chenopodium quinoa* Willd.)

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10.18805/ajdfr.DR-2148

ABSTRACT

Background: Quinoa is a nutrient-dense pseudocereal with remarkable nutritional quality. It is a gluten-free crop that provides a balanced set of essential amino acids and possesses hypoglycemic and free fatty acid-lowering properties. Quinoa has gained popularity in the current era due to its tolerance to extreme weather conditions, nutritional composition and other industrial applications.

Methods: The present study analyzed the physical and functional properties of quinoa using standard procedures and assessed the impact of germination on these properties. Germinated flour was developed by soaking quinoa seeds overnight and allowing for germination for 72 hours in an incubator at 20±2°C at 80-90% humidity. Germinated seeds were oven-dried at 60±2°C for 45 minutes, followed by grinding into flour and storing the flour in a dry and air-tight container for further analysis.

Result: The study findings showed that quinoa seeds had good physical properties. All functional properties viz water absorption capacity, oil absorption capacity, emulsion and foaming properties of quinoa flour improved on germination except flour solubility. It is concluded that germination is a cost-effective processing technique for enhancing the functional properties of quinoa flour, so as to increase its industrial use for product development. Germinated quinoa flour can be utilized in the development of various infant formulas.

Key words: Emulsification properties, Flour solubility, Germination, Pseudocereal.

INTRODUCTION

Quinoa (*Chenopodium quinoa* Willd.) is a pseudo-cereal/pseudo-grain belonging to the *Chenopodiaceae* family and class *Dicotyledoneae*. Quinoa has become popular in different parts of the world due to its broad genetic diversity, which allows quinoa to adapt to a variety of extreme environments.

Quinoa was first introduced in India in 1985. According to Indian Quinoa Association, out of a total production of 10,000 tonnes of quinoa in India in 2018, Rajasthan alone produced 6000 tonnes. Apart from Rajasthan andhra Pradesh, Telangana and Uttar Pradesh are the major quinoa producing states of India. Quinoa is a 1.5 m tall annual plant with an erect stem and alternate leaves (Bhargava *et al.*, 2006). It has remarkable nutritional qualities and provides a balanced set of important amino acids. Its protein is low in prolamins (0.5-7 per cent) which indicates that it is gluten free and, therefore, non-allergic. It is also classified as an oil crop since it has a high proportion of omega-6 fatty acids and a significant amount of vitamin E. Quinoa seeds contain 77.6 per cent carbohydrates, which have hypoglycemic and free fatty acid-lowering properties (Abugoch *et al.*, 2009). Its seeds contain vitamin B complex, vitamin C and minerals such as potassium, calcium, magnesium, iron, phosphorus, high-quality lipids and isoflavones (Pasko *et al.*, 2009). The fraction of dietary fiber varies from 12 to 14 per cent on dry basis in quinoa varieties (Nascimento *et al.*, 2014). Apart from their nutritional benefits, certain components of quinoa like protein isolates and saponin

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How to cite this article: Anuhya, Dobhal, N. (2024). Evaluation of Physical Characteristics and Impact of Germination on Functional Properties of Quinoa (*Chenopodium quinoa* Willd.). Asian Journal of Dairy and Food Research. doi: 10.18805/ajdfr.DR-2148.

Submitted: 26-07-2023 **Accepted:** 24-02-2024 **Online:** 26-04-2024

components are utilized in manufacturing various cosmetic and other industrial materials.

Quinoa has been identified as one of the most significant crops which can help in ensuring food security in future. The year 2013 was designated as "International year of Quinoa" by Food and Agricultural Organization in recognition of its contribution to the fight against malnutrition (Small, 2013).

Quality of a food product is characterized by its structure, nutritional value and/or sensory acceptability. These quality parameters are greatly affected by the physical and functional properties of raw ingredients used in developing the food product. Physical properties of food grains play an important role in understanding their cooking

and processing properties. Functional properties give information on how foods behave in a system either as a processing aid or as a direct contributor of product attributes (Oyebode *et al.*, 2007). Seed weight, seed volume and seed density are fundamental attributes for determining seed quality, seedling development and plant performance. Hydration and swelling properties gives an idea of the consistency of the sample. Functional properties are those attributes that influence how proteins behave in the food system during preparation, storage, cooking and consumption (Kinsella and Melachouris, 1976). The functional properties of flour are determined to see how they affect the finished food product's appearance, taste and feel (IFST, 2017). Germination technique softens the kernel structure, increases the nutritional composition and improves the functional properties of grains (Dobhal and Raghuvanshi, 2023).

A lot of research has been carried out on nutritional quality of quinoa but scanty information is available on its physicochemical properties. Therefore, the present study was conducted to analyze the physical and functional properties of quinoa along with the analysis of impact of germination on these properties.

MATERIALS AND METHODS

The present study was carried out in the Department of Food Science and Nutrition, College of Home Science, G. B. Pant University of Agriculture and Technology, Pantnagar,

Uttarakhand, India w.e.f. January, 2021 to August, 2022. The quinoa seeds were procured from online retail store (Organic India). For estimation of physical characteristics, whole seeds of quinoa were used. For functional properties, flour was prepared using germination treatment. For preparation of germinated quinoa flour, quinoa seeds were sorted and manually cleaned to remove dust, grit and other impurities, followed by washing of seeds in clean water. The seeds were soaked overnight for 12 hours and drained next day. After draining, soaked seeds were kept for germination for next 72 hours at $20 \pm 2^\circ\text{C}$ in bacteriological incubator at 80-90% humidity. Germinated seeds were dried at $60 \pm 2^\circ\text{C}$ for 45 minutes in a tray drier oven, followed by grinding into flour using flour mill, Aata Master by Navdeep Pvt. Ltd. Flour was stored in a dry and air tight container for further analysis. Raw quinoa flour (non-germinated) was used as control in the study (Fig 1).

Physical characteristics

In order to assess the physical parameters, the seeds were sorted and cleaned to remove the dirt and grits. The physical parameters *i.e.* thousand seed weight, thousand seed volume, seed density, hydration capacity, hydration index, swelling capacity and swelling index were evaluated using the methods given by Williams *et al.* (1983). To ascertain the bulk density, method of Asoegwu *et al.* (2006) was applied. All the experiments were carried out in triplicates. The length of sprouts was measured at the intervals of 24, 48 and 72 hours and observations were taken in triplicates.

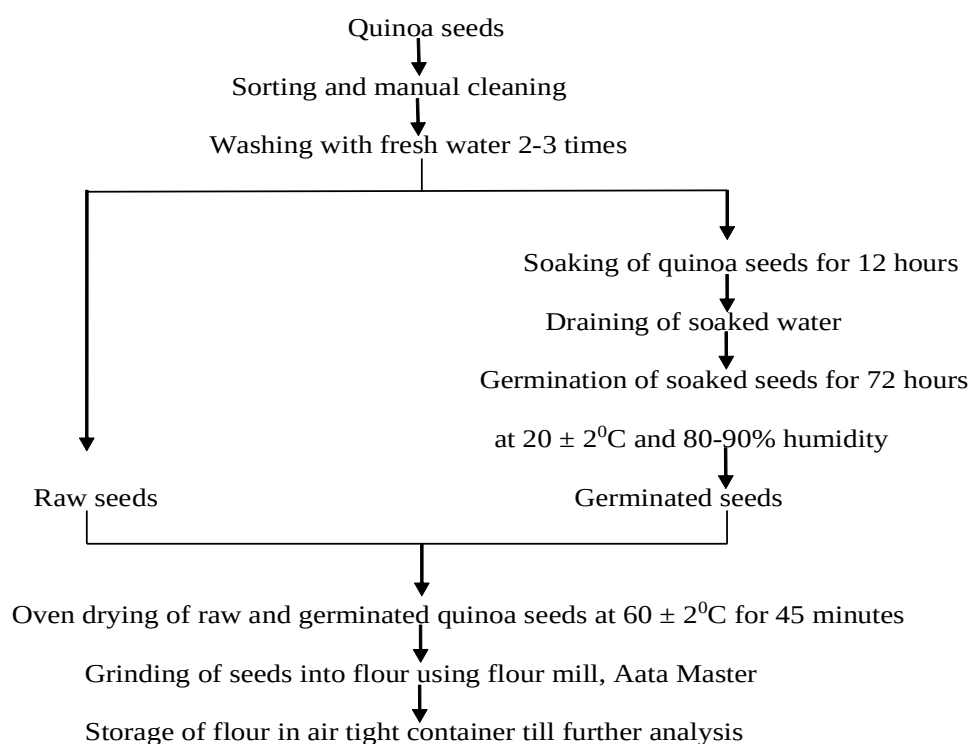


Fig 1: Flow chart for developing raw and germinated quinoa flour.

Functional properties of flours

Both the raw and germinated quinoa flours were studied for their functional properties. Water absorption capacity and oil absorption capacity were analyzed using centrifugation method given by Lin *et al.* (1974). Flour solubility was determined by the method of Subramanian *et al.* (1986). Emulsion capacity and emulsion stability were determined as emulsifying properties of quinoa flour using the method given by Yasumatsu *et al.* (1972). Determination of foaming properties included foaming capacity (Lawhon *et al.*, 1972) and foam stability (Shahidi *et al.*, 1995).

Statistical analysis

All the experiments were carried out in triplicates. The quantitative data was computed in terms of mean and standard deviation. To evaluate the effect of germination and to find out the significance of difference between data of raw and germinated quinoa flour, data was subjected to paired t-test (Snedecor and Cochran, 1967).

RESULTS AND DISCUSSION

Physical characteristics of quinoa seeds

Physical properties of seeds are important for the design of equipment necessary for harvesting and post-harvest handling, transportation and processing of agricultural produce into different consumable and marketable food items (Dobhal and Raghuvanshi, 2018). Knowledge of physical properties of grains is useful in farming, harvesting, storage and processing (Dobrzanski and Stepniewski, 2013). Seed weight is an ecologically important life history trait in plants as it influences both the dispersal ability and seedling establishment (Gross and Kromer, 1986). Table 1 shows that thousand seed weight of quinoa was 2.6 ± 0.01 g, which is comparable to the value of 2.57 g reported by Beniwal *et al.* (2019) and falls within the range of 1.1-3.6 g, as reported by Shahid and Thushar (2021). Thousand seed volume of quinoa seeds was 2.43 ± 0.03 ml which was less than the values of 4.49 and 2.86 ml, as reported by Badr and Eissa (2018) and Beniwal *et al.* (2019), respectively. The seed density of quinoa was 1.06 ± 0.11 g/ml which is lower than the value reported by Badr and Eissa (2018) as 1.27 g/ml but higher than the value of 0.9 g/ml reported by Beniwal *et al.* (2019). According to Kaur *et al.* (2005), the seed volume along with its weight positively correlates with hydration capacity, swelling capacity and cooking time.

Hydration parameters play a crucial role in various treatments of seeds like soaking, germination, dehulling and elimination of antinutritional components. Hydration capacity is defined as ability of food or its components to store water under particular conditions. Hydration capacity of quinoa seeds in present study was 0.07 ± 0.01 g/100 seeds, which lies between the range observed by Ghuman *et al.* (2021) as 0.02-0.07g/ 100 seeds. Hydration index of quinoa seeds was 0.26 ± 0.03 , which is lower than the value reported by Beniwal *et al.* (2019) as 0.879.

Swelling capacity gives an indication of increase in the volume upon absorption of water. It is a very important parameter as changes in volume during processing may change the acceptability of the final product (Ayodele and Beatrice, 2015). In the present study, swelling capacity of quinoa seeds was 0.4 ± 0.07 ml/g and swelling index was found to be 1.48 ± 0.15 . Singh and Punia (2020) reported the swelling capacity of amaranth seed flour as 2.54 ± 0.01 ml/g which is significantly higher than the findings of the present study. This might be due to the structural differences in the amaranth and quinoa seeds.

Bulk density of seed flours is determined with two key factors *i.e.* particle size and packing density. This physical property is affected by polymer structure of starch of seed. Bulk density lowers with loosening of the polymer structure of starch (Manju and Dobhal, 2022). Bulk density of quinoa seeds in the present study was 0.76 ± 0.01 g/ml which is similar to the value reported by Beniwal *et al.* (2019) but lower than the value given by Singh and Punia (2020) as 6.06 ± 0.06 g/ml.

In the present study, sprout length was measured at different intervals. The average length of quinoa sprout was found to be 0.70 ± 0.02 mm, 1.03 ± 0.05 mm and 1.50 ± 0.03 mm on 24, 48 and 72 hours of germination, respectively. Pritham *et al.* (2021) reported the quinoa sprout length as 1.96 mm on 24 hours of germination. The finding of present study is lower than the sprout length of germinated quinoa seeds reported by Guardianelli *et al.* (2022) as 0.9 and 1.3 cm at 24 and 48 days of germination, respectively. Sprouting rate gives information about the age of seeds. With the ageing of seeds, sprouting rate and sprout length gets retarded.

Functional properties

Functional properties are the fundamental physicochemical properties that reflect the complex interaction between the composition, structure, molecular conformation and physicochemical properties of food components with the nature of environment in which these properties are associated and measured. Findings on water and oil absorption capacity of raw and 72-hours germinated quinoa flours are presented in Fig 2.

Water absorption capacity (WAC) is the amount of water taken up by the flours to attain the desired consistency and

Table 1: Physical characteristics of quinoa seeds.

Physical properties	Values*
Thousand seed weight (g)	2.6 ± 0.01
Thousand seed volume (ml)	2.43 ± 0.03
Seed density (g/ml)	1.06 ± 0.11
Hydration capacity (g)	0.07 ± 0.01
Hydration index	0.259 ± 0.03
Swelling capacity (ml)	0.4 ± 0.07
Swelling index	1.48 ± 0.15
Bulk density (g/ml)	0.76 ± 0.01

*values represent mean $\pm$ standard deviation for three replicates.

produce a high-quality food product. In the present study, water absorption capacity of germinated quinoa flour (144.7 ± 1.15 per cent) was non-significantly ($p < 0.05$) higher than raw quinoa flour (143.4 ± 0.44 per cent). WAC of both the quinoa flours was found higher than the value reported by El Sohaimy *et al.* (2018) as 141.5 ± 0.54 per cent. Singh and Punia (2020) and Jain and Agarwal (2015) reported a significantly higher WAC for amaranth seeds flour as 420 and 484 ml/100 g, respectively.

Beniwal *et al.* (2019) reported significantly high WAC in germinated quinoa flour (214 per cent) than the raw quinoa flour (125 per cent). The increase in the water absorption capacity of germinated quinoa flour might be due to the breakdown of polysaccharides and rise in the sugar content during germination which increased the sites for water molecules to interact. Kousala *et al.* (2019) didn't observe any increment in WAC of quinoa flour with germination. Water absorption capacity of product is directly related to the juiciness or moistness upon hydration, determining the texture of the product. Protein content of food is an important factor for affecting WAC. Food products with high protein content have higher WAC (Rehrah *et al.*, 2009).

The food's oil absorption capacity is determined by the physical entrapment of oils, which may be beneficial for their binding to foodstuffs in terms of preserving flavour, improving palatability and prolonging shelf life. In the present study, raw quinoa flour and germinated quinoa flours had the oil absorption capacity of 100 ± 0.36 and 106 ± 1.37 per cent,

respectively. Germination led to significant ($p < 0.05$) increase of 6 percent in OAC of raw quinoa flour. This finding is in accordance to the observation of Beniwal *et al.* (2019), where germinated quinoa flour had higher OAC (253 per cent) than raw quinoa flour (173 per cent). The increase in the oil absorption capacity can be positively related to the quality of protein, its surface hydrophobicity and ability to hold fat globules (Sibian *et al.*, 2017). Singh and Punia (2020) reported lower values for oil absorption capacity ($58.16 \pm 0.67\%$) in another pseudocereal *i.e.* amaranth seed flour.

Flour solubility is an important thermodynamic parameter affecting other properties of food such as emulsification, foaming and gelation. Solubility of raw quinoa flour (22.6 ± 0.75 per cent) was found to be significantly ($p < 0.05$) higher by 34 percent than germinated quinoa flour (14.75 ± 1.14 per cent) (Table 2). Beniwal *et al.* (2019) reported the solubility of raw and germinated quinoa flours as 17.63 and 10.29 percent, respectively. Ogungbenle (2003) and Oshodi *et al.* (1999) investigated solubility as a function of pH and reported solubility values of quinoa flour in the range of 15-52 per cent corresponding to a low solubility at pH 6 and a maximum solubility at pH 10. Shi *et al.* (2020) observed the lowest solubility of quinoa flour *i.e.* 17.7 percent at pH 3 and the highest solubility of 46.3 per cent at pH 7. Ghumman *et al.* (2021) reported the quinoa flour solubility between 30 to 53.3 per cent. High flour solubility shows high digestibility therefore, the flours with high solubility like quinoa flours can be used in developing infant feeds.

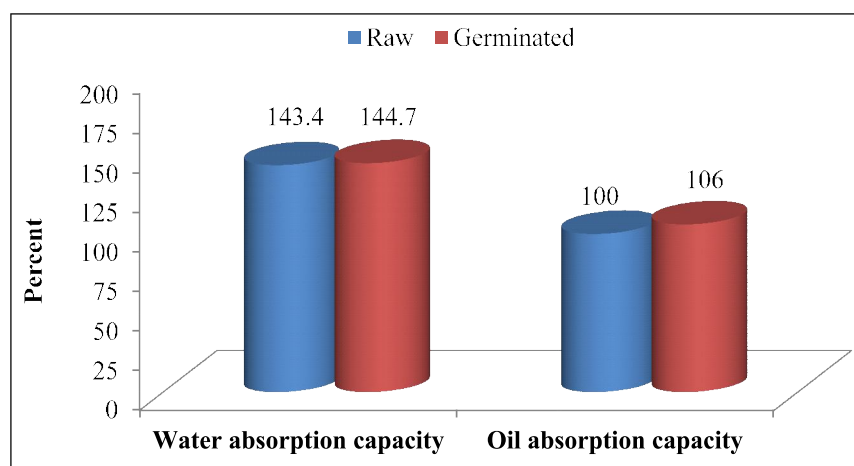


Fig 2: Water and oil absorption capacity of raw and 72-hours germinated quinoa flours.

Table 2: Functional properties of raw and germinated quinoa flour.

Functional properties (%)	Raw quinoa flour	Germinated quinoa flour	p value
Flour solubility	22.6±0.75	14.75±1.14	0.001*
Emulsion capacity	89.9±1.35	102.8±3.66	0.015*
Emulsion stability	41.3±0.60	46.2±1.17	0.016*
Foaming capacity	12.1±1.20	14.83±0.80	0.007*
Foaming stability	8.3±0.59	10.2±0.52	NS

*Values represent mean±standard deviation for three replicates.

p value at 5% level of significance, NS- Non Significant.

Emulsification properties including emulsion activity and stability are significantly related with polysaccharides and both soluble and insoluble proteins. Proteins help to emulsify oil droplets, regulate their surface tension and produce electrostatic repulsion on their surface. Emulsion capacity is defined as the ability of the solution to emulsify oil whereas the ability of the protein to withstand changes in its physicochemical qualities over a period of time is known as emulsion stability. In the present study, emulsion activity and stability of germinated quinoa flour (102.8% and 46.2%) was found significantly higher ($p < 0.05$) than raw quinoa flour (89.9% and 41.3%) (Table 2). The values for emulsification properties of raw quinoa flour in the present study were lower than the values reported by El Sohaimy *et al.* (2018). The increase in the emulsion capacity with germination may be due to high interaction of protein with fat and other components in the germinated flour. Emulsion stability might be increased due to the improvement in protein quantity and quality.

The capacity of proteins to enhance the formation and stabilization of emulsion is important for many applications in cakes, coffee whiteners and frozen desserts. In these products varying emulsifying and stabilizing capacities are required because of different compositions and stresses to which these products are subjected (Elkhalifa and Bernhardt, 2010).

Foaming properties are the functional properties, where aeration and overrun are required e.g. whipped toppings, baked foods and ice-cream mixes. Foaming capacity is defined as the amount of interfacial area formed by beating the food/flour. In the present study, foaming capacity of germinated quinoa flour (14.83 ± 0.80 per cent) was found to be significantly higher ($p < 0.05$) by 22 percent than raw quinoa flour (12.1 ± 1.20 per cent) (Table 2) which is comparable to 14.33 percent as reported by El Sohaimy *et al.* (2018). The increase in foaming capacity might be due to the decrease in surface tension of the air-water interface allowing soluble protein molecules to absorb and interact with hydrophobic compounds.

Foam stability is defined as the time taken to reduce 50 percent of its volume from foam. Foam stability of raw quinoa flour was found to be 8.3 ± 0.59 per cent which was non-significantly ($p < 0.05$) lower than that of germinated quinoa flour with 10.2 ± 0.52 per cent. Germination increased the foam stability by 23 per cent. El Sohaimy *et al.* (2018) reported the foam stability of quinoa flour as 9.63 percent. The increase in foam stability with germination might be due to the increased solubility of proteins.

CONCLUSION

Quinoa is one of the nutrient-dense pseudocereal with remarkable nutritional quality. The findings on the physical and functional properties showed that quinoa seeds had good physical properties. All functional properties viz water absorption capacity, oil absorption capacity, emulsion and foaming properties of quinoa flour improved on germination.

Therefore, it is concluded that germination is a cost-effective processing technique for enhancing the functional properties and nutritional quality of quinoa flour and thus can be utilized in the development of various infant formulas.

Conflict of interest

We, Anuhya and Dr. Neetu Dobhal, the authors of manuscript declare that we have no conflicts of interest.

REFERENCES

- Abugoch, L.E., Castro, E., Tapia, C., Anon, M.C., Gajardo, P. and Villarroel, A. (2009). Stability of quinoa flour proteins (*Chenopodium quinoa Willd.*) during storage. *International Journal of Food Science and Technology*. 44(10): 2013-2020.
- Asoegwu, S., Ohanyere, S., Kanu, O. and Iwueke, C. (2006). Physical properties of African oil bean seed (*Pentaclethra macrophylla*). *Agricultural Engineering International: CIGR EJournal*. Manuscript FP 05 006. Vol. 8.
- Ayodele, O.M. and Beatrice, A.I.O. (2015). Some functional and physical properties of selected underutilised hard-to-cook legumes in Nigeria. *American Journal of Food Science and Nutrition*. 2(5): 73-81.
- Badr, M.M. and Eissa, A.S. (2018). Some physical, mechanical and aerodynamic properties of quinoa seeds (*Chenopodium quinoa Willd.*). *Misr Journal of Agricultural Engineering*. 35(4): 1365-1382.
- Beniwal, S.K., Devi, A. and Sindhu, R. (2019). Effect of Grain Processing on Nutritional and Physico-chemical, Functional and Pasting Properties of Amaranth and Quinoa Flours. *Indian Journal of Traditional Knowledge*. 18(3): 500-507.
- Bhargava, A., Shukla, S. and Ohri, D. (2006). *Chenopodium quinoa* - An Indian perspective. *Industrial Crops and Products*. 23(1): 73-87.
- Dobhal, N. and Raghuvanshi, R.S. (2018). Physical characteristics and effect of germination on functional properties of black soybean (*Glycine max*). *Asian Journal of Dairy and Food Research*. 37(1): 6-60.
- Dobhal, N. and Raghuvanshi, R.S. (2023). Quality enhancement of black soybean (*Glycine max* L. Merrill) flour using germination technique. *Legume Research*. 46(1): 44-49.
- Dobrzański, B. and Stępniewski, A. (2013). Physical Properties of Seeds in Technological Processes. In: *Advances in Agrophysical Research* [S. Grundas and A. Stępniewski. (eds.)] IntechOpen, United Kingdom. Pp: 269-294.
- El Sohaimy, S.A., Mohamed, S.E., Shehata, M.G., Mehanyand, T. and Zaitoun, M.A. (2018). Compositional analysis and functional characteristics of quinoa flour. *Annual Research and Review in Biology*. 22(1): 1-11.
- Elkhalifa, A.E.O. and Bernhardt, R. (2010). Influence of grain germination on functional properties of sorghum flour. *Food Chemistry*. 121(2): 387-392.
- Ghumman, A., Mudgal, S., Singh, N., Ranjan, B., Kaur, A. and Rana, J.C. (2021). Physicochemical, functional and structural characteristics of grains, flour and protein isolates of Indian quinoa lines. *Food Research International*. 140: 109982.
- Gross, K.L. and Kromer, M.L. (1986). Seed weight effects on growth and reproduction in *Oenothera biennis* L. *Journal of the Torrey Botanical Society*. 113(3): 252-258.

- Guardianelli, L.M., Salinas, M.V. Brites, C. and Puppo, M.C. (2022). Germination of white and red quinoa seeds: Improvement of nutritional and functional quality of flours. *Foods*. 11: 3272.
- IFST, (2017). Functional properties of food. Retrieved on May 12, 2023 from <https://www.ifst.org/lovefoodlovescience/resources/functional-properties-food>.
- Jain, A. and Grewal, R.B. (2015). Development and quality evaluation of value added extruded snacks by supplementing amaranth and guar gum in mixed cereal flour formulation constituting maize, rice and wheat. *International Journal of Recent Scientific Research*. 6(9): 6221-6227.
- Kaur, S., Gupta, A.K. and Kaur, N. (2005). Seed priming increases crop yield possibly by modulating enzymes of sucrose metabolism in chickpea. *Journal of Agronomy and Crop Science*. 191(2): 81-87.
- Kinsella, J.E. and Melachouris, N. (1976). Functional properties of proteins in foods: A survey. *Critical Reviews in Food Science and Nutrition*. 7(3): 219-280.
- Kousalya, M.S., Sashidevi, G. and Kanchana, S. (2019). Physico-chemical and functional properties of quinoa (*Chenopodium quinoa*). *International Journal of Agricultural Science Research*. 9(3): 341-350.
- Lawhon, J.T., Carter, C.M. and Mattil, K.F. (1972). A comparative study of the whipping potential of an extract from several oilseed flours. *Cereal Science Today*. 17(9): 241.
- Lin, M.J.Y., Humbertand, E.S. and Sosulski, F.W. (1974). Certain functional properties of sunflower meal products. *Journal of Food Science*. 39(2): 368-370.
- Manju and Dobhal, N. (2022). Physical and functional properties of raw and roasted garden cress seeds (*Lepidium sativum* L.) Flour. *Asian Journal of Dairy and Food Research*. 42(2): 222-225.
- Nascimento, A.C., Mota, C., Coelho, I., Gueifão, S., Santos, M., Matos, A.S., Gimenez, A., Lobo, M., Samman, N. and Castanheira, I. (2014). Characterization of nutrient profile of quinoa (*Chenopodium quinoa*), amaranth (*Amaranthus caudatus*) and purple corn (*Zea mays* L.) consumed in the North of Argentina: Proximate, minerals and trace elements. *Food Chemistry*. 148: 420-426.
- Ogunbenle, H.N. (2003). Nutritional evaluation and functional properties of quinoa (*Chenopodium quinoa*) flour. *International Journal of Food Sciences and Nutrition*. 54(2): 153-158.
- Oshodi, A.A., Ogunbenle, H.N. and Oladimeji, M.O. (1999). Chemical composition, nutritionally valuable minerals and functional properties of benniseed (*Sesamum radiatum*), pearl millet (*Pennisetum typhoides*) and quinoa (*Chenopodium quinoa*) flours. *International Journal of Food Sciences and Nutrition*. 50: 325-331.
- Oyebode, E.T., Ojo, M.A. and Oshodi, A.A. (2007). Physico chemical properties and *in-vitro* protein digestibility of flours and protein isolate from *Adenopus breviflorus* Benth seed. *Science Focus*. 12(1): 28-34.
- Pasko, P., Barton, H., Zagrodzki, P., Gorinstein, S., Foltaand, M. and Zachwieja, Z. (2009). Anthocyanins, total polyphenols and antioxidant activity in amaranth and quinoa seeds and sprouts during their growth. *Food Chemistry*. 115(3): 994-998.
- Pritham, S.M., Revanna, M.L., Usha R., Kalpana, B., Niranjana M. and Madhusudan. (2021). Quinoa (*Chenopodium quinoa*) grains processing and its value added products. *International Journal of Current Microbiology and Applied Sciences*. 10(04): 681-691.
- Rehrah, D., Ahmedna, M., Goktepe, I. and Yu, J. (2009). Extrusion parameters and consumer acceptability of a peanut-based meat analogue. *International Journal of Food Science and Technology*. 44: 2075-2084.
- Shahidand, M. and Thushar, S. (2021). Response of Quinoa to High Salinity Under Arid Conditions. In: [Negacz, K., Vellinga, P., Barrett-Lennard, E., Choukr-Allah, R. and Elzenga, T. (Eds.)] *Future of Sustainable Agriculture in Saline Environments*. Boca Raton, Florida: CRC Press. Pp. 1-16.
- Shahidi, F., Han, X.Q. and Synowiecki, J. (1995). Production and characteristics of protein hydrolysates from capelin (*Mallotus villosus*). *Food Chemistry*. 53(3): 285-293.
- Shi, D., Fidelis, M., Ren, Y., Stone, A.K., Ai, Y. and Nickerson, M.T. (2020). The functional attributes of Peruvian (Kankolla and Blanca juli blend) and Northern quinoa (NQ94PT) flours and protein isolates and their protein quality. *Food Research International*. 128: 108799.
- Sibian, M.S., Saxena, D.C. and Riar, C.S. (2017). Effect of germination on chemical, functional and nutritional characteristics of wheat, brown rice and triticale: A comparative study. *Journal of the Science of Food and Agriculture*. 97(13): 4643-4651.
- Singh, A. and Punia, D. (2020). Characterization and nutritive values of amaranth seeds. *Current Journal of Applied Science*. 39(3): 27-33.
- Small, E. (2013). Quinoa - Is the United Nations' featured crop of 2013 bad for biodiversity? *Biodiversity*. 14(3): 169-179.
- Snedecor, G.W. and Cochran, W.G. (1967). *Statistical Methods*, Ed. 6th. Ames, Iowa, The Iowa State University Press. pp. 593.
- Subramanian, V., Jambunathan, R. and Ramaiah, C.D. (1986). Physical and chemical characteristics of pearl millet grains and their relationship to roti quality. *Journal of Food Science*. 51(4): 1005-1008.
- Williams, P.C., Nakouland, H. and Singh, K.B. (1983). Relationship between cooking time and some physical characteristics in chickpeas (*Cicer arietinum* L.). *Journal of the Science of Food and Agriculture*. 34(5): 492-496.
- Yasumatsu, K., Sawada, K., Moritaka, S., Misaki, M., Toda, J., Wada, T. and Ishii, K. (1972). Whipping and emulsifying properties of soybean products. *Agricultural and Biological Chemistry*. 36(5): 719-727.