ISSN Print: 2664-844X
ISSN Online: 2664-8458
NAAS Rating (2026): 4.97
IJAFS 2026; 8(8): 455-458
www.agriculturaljournals.com
Received: 02-06-2026
Accepted: 04-07-2026

Vishal P Raut
Department of Food Processing Technology, Institute of Biosciences and Technology, MGM University, Chhatrapati Sambhajinagar, Maharashtra, India

Manmath D Sontakke
Assistant Professor, Department of Food Processing Technology, Institute of Biosciences and Technology, MGM University, Chhatrapati Sambhajinagar, Maharashtra, India

Supriya M Kamble
Department of Food Processing Technology, Institute of Biosciences and Technology, MGM University, Chhatrapati Sambhajinagar, Maharashtra, India

Corresponding Author:
Manmath D Sontakke
Assistant Professor, Department of Food Processing Technology, Institute of Biosciences and Technology, MGM University, Chhatrapati Sambhajinagar, Maharashtra, India

Physicochemical characterization of quinoa, amaranth, foxnut and pumpkin seeds

Vishal P Raut, Manmath D Sontakke and Supriya M Kamble

DOI: https://www.doi.org/10.33545/2664844X.2026.v8.i8f.1798

Abstract
The present study evaluated the physicochemical, nutritional, mineral, and functional properties of quinoa (*Chenopodium quinoa*), amaranth (*Amaranthus spp*.), foxnut (*Euryale ferox*), and pumpkin seeds (*Cucurbita pepo*), which are widely recognized as nutrient-rich plant-based food ingredients. Standard analytical methods were employed to determine moisture, protein, fat, ash, crude fibre, carbohydrate, mineral composition, and selected physical properties. Considerable variation was observed among the four plant materials in their nutritional composition and functional characteristics. Pumpkin seeds exhibited the highest protein and fat contents, whereas foxnut was characterized by high carbohydrate content and low-fat levels. Quinoa and amaranth demonstrated balanced nutritional profiles with appreciable amounts of protein, dietary fibre, and essential minerals, highlighting their nutritional significance. Mineral analysis revealed that pumpkin seeds contained the highest concentrations of magnesium, phosphorus, potassium, and zinc, while amaranth showed comparatively higher calcium and iron contents. Physical characterization also demonstrated distinct differences in seed morphology, bulk density, true density, porosity, and angle of repose, reflecting their diverse structural and engineering properties. These findings provide a comprehensive understanding of the nutritional and functional characteristics of quinoa, amaranth, foxnut, and pumpkin seeds and support their potential utilization as valuable plant-based ingredients in the development of nutrient-rich food products.

Keywords: Quinoa, amaranth, foxnut, pumpkin seeds, physicochemical properties, functional properties, proximate composition, mineral composition, physical properties

Introduction

The increasing demand for nutrient-rich, plant-based foods has intensified research on pseudocereals and edible seeds because of their high nutritional value and functional properties. These ingredients are rich sources of proteins, dietary fibre, essential minerals, and bioactive compounds that contribute to human health and may help reduce the risk of chronic diseases (Kosicka-Gębska *et al*., 2022; Sharma *et al*., 2021) [11, 22]. Consequently, their utilization in food and nutrition research has gained considerable attention (Baraniak & Kania-Dobrowolska, 2022) [4].

Quinoa (*Chenopodium quinoa Willd*.) is a gluten-free pseudocereal recognized for its high-quality protein, balanced amino acid composition, dietary fibre, essential minerals, and antioxidant compounds. Its superior nutritional profile and adaptability to diverse agro-climatic conditions have made it an important functional food ingredient (Nowak *et al*., 2016; Repo-Carrasco-Valencia *et al*., 2010) [17, 20]. Similarly, amaranth (*Amaranthus spp*.) is valued for its excellent protein quality, dietary fibre, and significant concentrations of calcium, iron, and magnesium. The grain also contains several bioactive compounds with antioxidant potential, making it suitable for health-oriented food applications (Alvarez-Jubete *et al*., 2010; Baraniak & Kania-Dobrowolska, 2022) [2, 4].

Foxnut (*Euryale ferox*), commonly known as makhana, is an aquatic seed characterized by high carbohydrate content, low fat levels, moderate protein, and appreciable mineral composition. It also contains natural antioxidants and phenolic compounds that enhance its nutritional and functional value (Jha *et al*., 2019; Mishra *et al*., 2021) [9, 13]. Pumpkin seeds (*Cucurbita pepo*) are recognized as rich sources of protein, healthy lipids, dietary fibre, magnesium, phosphorus, zinc, and iron, together with several bioactive phytochemicals possessing antioxidant activity (Nawirska-Olszanska *et al*., 2013; Yadav *et al*., 2022) [16, 26].

In addition to their nutritional composition, the physicochemical and engineering properties of these plant materials, including moisture content, bulk density, true density, porosity, angle of repose, and thousand-kernel weight, are important parameters influencing storage, handling, processing, and product quality (Mohsenin, 1986; Dutta *et al*., 1988) [15, 5]. Comprehensive evaluation of these characteristics provides valuable information regarding their nutritional quality and technological suitability for food applications (AOAC, 2019) [3].
Therefore, the present study aimed to evaluate the physicochemical, nutritional, mineral, and physical properties of quinoa, amaranth, foxnut, and pumpkin seeds using standard analytical methods. The findings provide comparative information on their nutritional composition and functional characteristics, supporting their potential application as nutrient-rich plant-based food ingredients.

Materials and methods
Collection and preparation of raw material
Quinoa, Amaranth grains, foxnuts Pumpkin seed were purchased from a local market in (Chhatrapati Sambhajinagar, Maharashtra) India. Grains were cleaned and stored in an airtight container till further used.

Proximate Analysis
The proximate composition of the samples was analysed for moisture using a hot air oven from Kamak India, crude fat with a hot air oven from Biotechics India and a Soxhlet apparatus model Soxtron SOX-2, crude protein with a Kjeltron KGIDB4M from India, and total ash using a muffle furnace from Biotechnics India. All analyses were performed in triplicates (n = 3). The total carbohydrate was determined using a different method (AOAC, 2019) [3].

Physical properties
Various physical properties of includes thousand kernel weight, true density, bulk density, porosity and angle of repose were determined to evaluate the quality of raw materials as per the methods given by Dutta *et al*., (1988) [5].

Thousand kernel weight
Count the 1000 kernels randomly and weigh a thousand grains in three replications using digital weighing balance and the mean value was noted.

Bulk-Density
Approximately 25 grams of sound grains were measured using the digital weighing balance and subsequently added to the measuring cylinder, which had previously been filled with a reference solution of hexane. The elevation of the liquid level was recorded following the addition of the grains. It is the bulk density expressed in kg/m^3.

$$\text{Bulk density } (\rho) = \frac{Weight\ of\ grains\ (g)}{Volume\ (mL)}$$

True density
True density is defined as the ratio of the mass of the seed sample to the solid volume it occupies. This was determined using an electronic balance with a precision of 0.0001 g and a pycnometer with a capacity of 50±0.1 ml, employing the liquid displacement method. Toluene was utilized in place of water due to its reduced absorption by grains. Given the limited timeframe of the experiment, the absorption of Toluene was deemed negligible, leading to the decision not to coat the seeds to prevent its absorption.

Porosity
Porosity is defined as the fraction of space within the bulk seed that remains unoccupied by the grain itself. The porosity was determined using a specific formula.

$$Porosity\ (\%) = \left(1 - \frac{True\ density}{Bulk\ density}\right) \times 100$$

Angle of repose
The steepest angle is established between the base and the slope of the cone created during the free vertical descent of a grain mass onto a horizontal surface, occurring when the material is either free falling or sliding. The determination was made by constructing a circular pile of the grains as they fell freely. The height of the pile was recorded (h), and its radius (r) was assessed. The angle of repose was established utilizing a technique outlined by Mohsenin N.N. in 1986 [15].

$$Angle\ of\ Repose\ (\theta) = tan^{-1}\left(\frac{h}{r}\right)$$

Where,
h = Height of grain hip (cm)
r = Radius of circle

Mineral analysis
Concentrations of calcium, iron, magnesium, zinc, and phosphorus were assessed in raw material samples employing the standard methods outlined by AOAC, 2019 [3]. The samples underwent dry ashing in a muffle furnace at 550°C, followed by dissolution in dilute hydrochloric acid and subsequent filtration. The minerals calcium, iron, magnesium, and zinc were analysed using Atomic Absorption Spectrophotometry (AAS), while phosphorus was quantified through calorimetric estimation. The findings were presented in milligrams per 100 grams of sample.

Results and Discussion

Table 1: Proximate composition of quinoa, amaranth, foxnut and pumpkin seed

Sample	Moisture (%)	Protein (%)	Fat (%)	Carbohydrate (%)	Ash (%)	Crude Fiber (%)
Quinoa	13.5 ± 1.5	14.1 ± 0.8	6.0 ± 0.7	64.2 ± 2.0	2.9 ± 0.3	5.1 ± 0.6
Amaranth	6.8 ± 0.4	14.8 ± 0.5	7.0 ± 1.0	65.0 ± 2.5	2.8 ± 0.2	4.9 ± 0.5
Foxnut	11.5 ± 1.2	9.8 ± 0.4	0.5 ± 0.2	77.0 ± 1.5	0.4 ± 0.1	0.9 ± 0.4
Pumpkin Seed	6.0 ± 0.5	30.2 ± 1.5	45.6 ± 2.0	12.0 ± 1.2	5.0 ± 0.6	6.5 ± 0.8

The proximate composition of quinoa, amaranth, foxnut and pumpkin seed exhibited significant variation in nutrient content, highlighting their potential applicability in functional food formulation. Quinoa exhibited a nutritional composition of 14.1 ± 0.8 g of protein, 6.0 ± 0.7 g of fat, and 64.2 ± 2.0 g of carbohydrate, indicating a well-rounded nutritional profile. Nowak *et al*. (2016) [17] reported comparable findings, noting that quinoa is abundant in protein, essential amino acids, and dietary fiber when contrasted with conventional cereals.

Amaranth showed elevated levels of protein (14.8 ± 0.5 g) and fat content (7.0 ± 1.0 g), alongside notable carbohydrate amounts (65.0 ± 2.5 g). Alvarez-Jubete *et al*. (2010) [2] indicated that amaranth has exceptional protein quality and mineral content, rendering it appropriate for functional and gluten-free food products.

Foxnut exhibited a significant carbohydrate content (77.0 ± 1.5 g), accompanied by minimal fat (0.5 ± 0.2 g) and protein (9.8 ± 0.4 g), suggesting its viability as a low-fat energy source. Comparable findings were reported by Jha *et al*. (2019) [9], indicating that foxnut is abundant in carbohydrates while exhibiting low lipid content.

Pumpkin seed demonstrated the highest levels of fat (45.6 ± 2.0 g) and protein content (30.2 ± 1.5 g) compared to all other samples, in addition to elevated crude fiber and ash values. Yadav *et al*. (2022) [26] noted that pumpkin seeds serve as outstanding sources of protein, beneficial lipids, essential minerals, and dietary fiber.

Overall, the proximate composition results indicated that the samples exhibit complementary nutritional characteristics, potentially enhancing the nutritional and functional quality of the developed food products.

Table 2: Mineral composition of quinoa, amaranth, foxnut and pumpkin seed

Sample	Calcium (mg)	Iron (mg)	Zinc (mg)	Magnesium (mg)	Phosphorus (mg)	Potassium (mg)
Quinoa	47 ± 3	4.6 ± 0.2	3.3 ± 0.2	197 ± 5	457 ± 10	563 ± 15
Amaranth	159 ± 6	7.6 ± 0.5	3.1 ± 0.3	248 ± 8	557 ± 12	508 ± 14
Foxnut	60 ± 4	1.4 ± 0.2	0.6 ± 0.1	210 ± 6	320 ± 9	350 ± 12
Pumpkin Seed	46 ± 3	8.8 ± 0.4	7.6 ± 0.5	550 ± 10	1174 ± 20	809 ± 25

The analysis of minerals in quinoa, amaranth, foxnut and pumpkin seed showed significant variations in their micronutrient profiles, underscoring their nutritional value in the development of functional foods. Quinoa is rich in magnesium (197 ± 5 mg), phosphorus (457 ± 10 mg), and potassium (563 ± 15 mg), highlighting its impressive mineral composition. Repo-Carrasco-Valencia *et al*. (2010) [20] reported comparable findings, noting that quinoa is abundant in essential minerals, especially magnesium and potassium.

Amaranth showed elevated levels of calcium (159 ± 6 mg), iron (7.6 ± 0.5 mg), magnesium (248 ± 8 mg), and phosphorus (557 ± 12 mg) when compared to quinoa and foxnut. Mlakar *et al*. (2009) [14] indicated that amaranth grains contain significant amounts of iron, calcium, and magnesium, which enhance their nutritional value.

Foxnut exhibited a moderate presence of calcium and magnesium, while displaying reduced levels of iron and zinc. The reduced mineral concentration could be linked to its composition, which is rich in starch. Comparable findings were reported by Mishra *et al*. (2021) [13], who noted that foxnut possesses moderate amounts of essential minerals in addition to a high carbohydrate content.

Pumpkin seed demonstrated the highest concentration of minerals compared to all other samples, especially in magnesium (550 ± 10 mg), phosphorus (1174 ± 20 mg), potassium (809 ± 25 mg), iron (8.8 ± 0.4 mg), and zinc (7.6 ± 0.5 mg). Nawirska-Olszanska *et al*. (2013) [16] reported elevated levels of phosphorus, magnesium, zinc, and iron in pumpkin seeds, highlighting their significant nutritional potential.

Overall, the chosen raw materials exhibited a favourable mineral composition, particularly quinoa, amaranth, and pumpkin seed, which could play a crucial role in enhancing the nutritional quality of functional food products.

Table 3: Physical parameter of quinoa, amaranth, foxnut and pumpkin seed

Physical Parameters	Quinoa	Amaranth	Foxnut	Pumpkin seed
Colour	Cream white	Pale yellow	Milky white	Dark green
Shape	Circular	Spherical	Oval/Round	Flat oval
1000 kernel weight (g)	2.31±0.17	0.77 ± 0.41	420.8 ± 2.13	148.7 ± 1.25
Bulk density (kg/m^3)	602.3±0.32	791.5 ± 0.41	98.5 ± 0.37	512.5 ± 0.52
True density (kg/m^3)	872.6±0.59	1257.8 ± 0.66	214.5 ± 0.46	894.1 ± 0.73
Porosity (%)	31.09±0.55	37.13 ± 0.60	53.27 ± 0.76	42.65 ± 0.56
Angle of repose (θ)	31.9±0.31	28.6 ± 0.44	35.6 ± 0.26	30.7 ± 0.34

The physical properties of quinoa, amaranth, foxnut, and pumpkin seed exhibited notable differences attributed to variations in seed size, shape, and structure. The quinoa grains exhibited a cream white hue and a circular shape, whereas the amaranth seeds presented a pale-yellow color and a spherical form. Foxnut displayed a white oval form, while pumpkin seeds were characterized by a dark green, flat oval shape. Vilche *et al*. (2003) [25] reported similar observations concerning the physical characteristics of pseudocereals and seeds, noting that quinoa features small cream-coloured grains with favorable processing attributes.

The thousand kernel weight of quinoa was measured at 2.32 ± 0.16 g, suggesting a smaller grain size in comparison to pumpkin seed and foxnut. Abalone *et al*. (2004) [1] noted that the kernel weight of amaranth seeds is reduced due to their small seed structure.

Bulk density values varied from 98.4 ± 0.36 kg/m³ in foxnut to 790.5 ± 0.42 kg/m³ in amaranth. The reduced bulk density of foxnut could be attributed to its porous, puffed structure. Jha and Kumar (2018) [8] reported comparable findings, noting low density and high expansion characteristics in foxnut.

Porosity values suggested sufficient inter-particle air spaces, potentially enhancing aeration and storage stability. The angle of repose values indicated a satisfactory flowability of all samples, implying their appropriateness for mixing and processing operations. Madan and Prasad (2014) [12] reported that pumpkin seeds exhibit favourable handling and flow characteristics that are suitable for food processing applications.

Conclusion

The present study demonstrated that quinoa, amaranth, foxnut, and pumpkin seeds possess complementary nutritional, mineral, physicochemical, and functional properties, making them promising ingredients for value-added functional foods. Pumpkin seeds exhibited superior protein, lipid, and mineral contents, while foxnut was characterized by high carbohydrate and low-fat levels. Quinoa and amaranth provided balanced amounts of protein, dietary fibre, and essential minerals. Significant differences in bulk density, true density, porosity, thousand-kernel weight, and angle of repose further indicated their distinct processing and handling characteristics. Collectively, the complementary nutritional and technological attributes of these ingredients provide a strong scientific basis for developing protein- and mineral-rich functional food products.

References

1. Abalone R, Cassinera A, Gastón A, Lara MA. Some physical properties of amaranth seeds. Biosyst Eng. 2004;89(1):109-117.
2. Alvarez-Jubete L, Arendt EK, Gallagher E. Nutritive value and chemical composition of pseudocereals as gluten-free ingredients. Int J Food Sci Nutr. 2010;61(3):240-257.
3. AOAC International. Official methods of analysis of AOAC International. 21st ed. Gaithersburg (MD): AOAC International; 2019.
4. Baraniak J, Kania-Dobrowolska M. The dual nature of amaranth—Functional food and potential medicine. Foods. 2022;11:618. DOI:10.3390/foods11040618.
5. Dutta SK, Nema VK, Bhardwaj RK. Physical properties of grain. J Agric Eng Res. 1988;39(1):259-268.
6. Giménez-Bastida JA, Hamdi S, Llopis JML. Nutritional and health implications of pseudocereal intake. In: Pseudocereals. Hoboken (NJ): Wiley; 2017. p. 217-232. DOI:10.1002/9781118938256.ch10.
7. James CS, editor. Analytical chemistry of foods. New York: Springer Science & Business Media; 2013.
8. Jha SN, Kumar A. Engineering and functional properties of foxnut (*Euryale ferox*). J Food Process Preserv. 2018;42(3):1-8.
9. Jha SN, Singh AK, Kumar A. Nutritional and functional properties of foxnut (*Euryale ferox*). J Food Sci Technol. 2019;56(11):5068-5075.
10. Joye I. Gluten as a unique protein building cereal product structure, is there an alternative? J Am Oil Chem Soc. 2022;99:155. DOI:10.21748/nszg5126.
11. Kosicka-Gębska M, Jeżewska-Zychowicz M, Gębski J, Sajdakowska M, Niewiadomska K, Nicewicz R. Consumer motives for choosing fruit and cereal bars—Differences due to consumer lifestyles, attitudes toward the product, and expectations. Nutrients. 2022;14(13):2710.
12. Madan S, Prasad S. Physical and mechanical properties of pumpkin seeds. Int J Eng Res Technol. 2014;3(5):1254-1258.
13. Mishra N, Singh P, Kumar R. Nutritional and functional characterization of foxnut (*Euryale ferox*). Curr Res Nutr Food Sci. 2021;9(2):512-520.
14. Mlakar SG, Turinek M, Jakop M, Bavec M, Bavec F. Nutrition value and use of grain amaranth: Potential future application in bread making. Agricultura. 2009;6(1):43-53.
15. Mohsenin NN. Physical properties of plant and animal materials. 2nd ed. New York: Gordon and Breach Science Publishers; 1986. p. 63-107.
16. Nawirska-Olszanska A, Kita A, Biesiada A, Sokół-Łętowska A, Kucharska AZ. Characteristics of antioxidant activity and composition of pumpkin seed oils. Food Chem. 2013;139(1-4):155-161.
17. Nowak V, Du J, Charrondière UR. Assessment of the nutritional composition of quinoa (*Chenopodium quinoa* Willd.). Food Chem. 2016;193:47-54.
18. Olagunju AI, Arigbede TI, Makanjuola SA, Oyebode ET. Nutritional compositions, bioactive properties, and in-vivo glycemic indices of amaranth-based optimized multigrain snack bar products. Measurement: Food. 2022;7:100039.
19. Reddy MVK, Dubey PK, Mishra AA, Sabeel VA. Potential processing techniques for safe utilisation of pseudocereals in the food system. J Food Compos Anal. 2024;106609. DOI:10.1016/j.jfca.2024.106609.
20. Repo-Carrasco-Valencia R, Espinoza C, Jacobsen SE. Nutritional value and use of the Andean crops quinoa (*Chenopodium quinoa*) and kaniwa (*Chenopodium pallidicaule*). Food Rev Int. 2010;26(3):263-275.
21. Sabeel VA, Wani KM, Dubey PK, Reddy MVK, Kumar S. Pseudocereals and dates as potential ingredients in nutrition bars: A review. Nutrire. 2024;49:38. DOI:10.1186/s41110-024-00281-8.
22. Sharma D, Sood S, Verma R, Thakur A. Development and storage stability of multi seed energy bars for sports persons. Himachal J Agric Res. 2021;47(1):66-76.
23. Smithers GW. Whey and whey proteins: From 'gutter-to-gold'. Int Dairy J. 2015;18(7):695-704.
24. Sudarmadji S, Haryono B, Suhardi. Prosedur analisa untuk bahan makanan dan pertanian [Analytical procedures for food and agricultural materials]. 4th ed. Yogyakarta: Liberty Publishers; 1997.
25. Vilche C, Gely M, Santalla E. Physical properties of quinoa seeds. Biosyst Eng. 2003;86(1):59-65.
26. Yadav M, Jain S, Tomar R. Nutritional and therapeutic potential of pumpkin seeds: A review. J Food Meas Charact. 2022;16(2):1234-1245.