Research Article

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Nutritional insights: A comparative physico-chemical characterization of sprouted and native Finger Millet

Abstract

Millets, ancient grains cultivated for around 3,000 years, are an integral part of India's cultural and historical heritage. Due to its significant nutritional value they are sometimes known as "superfoods" or "nutricereals," Millets play a crucial role in addressing food and nutritional security, especially in regions prone to drought and food scarcity. Rich in essential nutrients like protein, fiber, vitamins, and minerals, millets are a valuable addition to diets aiming for better health outcomes. Recognizing their importance, the United Nations General Assembly declared 2023 as the International Year of Millets, aiming to raise awareness about their health benefits, promote their cultivation and consumption, and support efforts to improve their production and quality. These millets showed resilience to climatic changes, and reduced resource requirements as compared to other common grains. Finger millet (*Eleusine coracana L.*), also known as ragi or mandua, is a vital staple food in parts of eastern and central Africa and India. Its adaptability to diverse agro-climatic conditions results in the highest productivity among millets. Focusing on its adaptability, this study evaluates the comparative physico-chemical properties in term of parameters such as pH, moisture content, total solid content, and fat content of sprouted and native finger millets. Sprouted millets show altered pH levels, increased moisture content, and reduced fat content, indicating enhanced nutritional benefits compared to their native counterparts. These changes suggest that sprouted millets could offer improved dietary applications and food products, contributing to better nutritional security and can contribute to a more sustainable health-conscious food system.

Keywords: millet, nutritional benefits, superfood, finger millet, physico-chemical properties

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Introduction

Millets are among the oldest foods known to humans, possibly being the first cereal grain used for domestic purposes. These small-seeded cereals boast excellent nutritional attributes that surpass even staple cereals such as wheat and rice.[1] Ranking as the sixth most important cereal, millets feed one-third of the world's population.[2] They are non-glutinous, non-acid forming, and easy to digest,[3] and are packed with high levels of phytochemicals and antioxidants.[4] Recognized as the grain of the future, millets are drought-resistant and pest-tolerant, making them valuable in the context of climate change and global warming.[5] Millets are resilient C4 plants with a high photosynthetic efficiency and ability to create dry matter, making them well-suited for hot, dry climates and poor soils.[6] They adapt to acidic, salty, and aluminium-toxic conditions and withstand pests and diseases. Their brief growing season reduces susceptibility to unpredictable weather. Due to the green revolution and lifestyle disorders, the demand for millet-based products has increased. Millets are nutrient-dense, containing calcium, protein, iron, and crude fibre, and play a significant role in food security, especially in diverse climates like India.[7]

Millets are recognized as a superfood, being rich in essential nutrients and beneficial for those with diabetes due to their low carbohydrate content and absence of gluten. They contain high levels of lipids such as palmitic, oleic, and linoleic acids, and tocopherols, which support the immune system.[4] The protein content in millets like proso millet is high, and finger millet has a remarkably high calcium content. Millets, including little millet and foxtail millet, are superior in crude fiber content. Barnyard and small millet have a higher fat content and iron levels compared to other cereals.[3,8] Millets are considered a valuable crop for sustainable agriculture and addressing climate change and nutritional needs.[1]

Finger millet (*Eleusine coracana*), also known as ragi, nachani, or nagli, is a vital millet crop in India, extensively grown in hilly areas and the southern part of the country (Figure 1). It is widely consumed in the form of various traditional dishes. Finger millet is a rich source of calcium (300-350 mg%), phosphorus (283 mg%), and iron (3.9%).[9] It has a well-balanced amino acid profile, including methionine, cystine, and lysine, essential for those relying on plant-based protein. The grain contains about 72% carbohydrates, predominantly non-starchy polysaccharides and dietary fiber, beneficial for constipation and blood glucose management. Additionally, it is rich in vitamins such as thiamine, riboflavin, folic acid, and niacin.[10,11]

Figure 1 Seeds of native Finger millet seeds.

Finger millet serves as a staple food in the Konkan region, consumed in forms like unleavened bread and soup. In urban areas, where malnutrition issues like obesity, heart diseases, and diabetes mellitus are prevalent, ragi is considered a better staple cereal grain compared to refined cereals like rice or wheat. It is comparable to rice or wheat nutritionally and is suitable for preparing low-cost diets and ready-to-eat nutritious food products like ragi malt puffs, dumplings, bhakri, halwa, bread, biscuits, and cookies. Due to its abundant production, cost-effectiveness, and superior nutritional qualities, finger millet offers numerous opportunities for diversified product utilization.[12]

The grain varies in shape, size, and color, which is important for designing equipment for handling, harvesting, processing, and storing. These physical properties affect the conveying characteristics of solid materials and the cooling and heating loads of food materials. Finger millet's adaptability and nutritional value make it an essential crop for both rural and urban populations.[13]

However, finger millet production faces challenges from abiotic stresses like soil salinity, which negatively impacts crop quality and yield by causing osmotic stress, nutrient imbalances, and physiological disruptions. Excess sodium chloride (NaCl) in the soil leads to ion imbalances, affecting the plant's ability to absorb essential nutrients and resulting in reduced productivity and potential plant death.[14,15] Seed germination and seedling stages are particularly vulnerable to salinity stress, necessitating the development of advanced techniques to address these challenges and enhance finger millet production.[16] Salinity stress has been shown to significantly affect seedling and root growth, ion content levels, relative water content, photosynthetic pigments, proline content, membrane peroxidation levels, and the amounts of reducing sugars and total proteins.[17–20] Despite limited information on yield loss in large-scale production areas, pot studies have demonstrated genotypic variability in grain yield loss among different millet varieties.[21]

This current study undertakes a comparative analysis of various physico-chemical parameters of native and sprouted finger millet seeds. It focuses on analyzing pH, moisture content, fat content, and total solid content to understand the nutritional modifications that occur during sprouting. Additionally, the study conducts a salt stress analysis to evaluate the impact of different NaCl concentrations on the growth and development of finger millet seedlings.

Materials and Methods

Sample collection

Finger millets were purchased from the local market of Rakabganj, Galla Mandi Lucknow. The Proposed research was carried out in Department of Chemistry, Navyug Kanya Mahavidyalaya, Rajendra Nagar, Lucknow.

Soaking

The cleaned raw seeds were soaked in aerated fresh water (Figure 2) for 24 h at 28°C with 0.1% formaldehyde added to it to arrest mould growth. A portion of soaked seeds were then dried in hot air oven, set at 55°C overnight and milled to obtain flour.

Optimization of sprouting methods

Optimizing seed sprouting practices for finger millet can significantly enhance growth and yield. The methods for finger millet included the Muslin Cloth Method, Cotton Bed Method, and Pot System (Figure 3a–3c).

Figure 2 Soaking of seeds.

In the **Muslin Cloth Method**, the finger millet seeds were soaked in water for 6-8 hours. The soaked seeds were then spread evenly on a wet muslin cloth and covered with another layer of wet muslin cloth (Figure 3a). The cloth was kept moist by regularly sprinkling water, ensuring uniform moisture and good aeration, which promoted faster and more uniform germination. It was important to keep the cloth moist but not waterlogged to prevent fungal growth.

Figure 3a Seed germination in muslin cloth.

In the **Cotton Bed Method**, a layer of cotton was placed in a shallow tray and moistened. The soaked seeds were spread evenly on the cotton bed and covered with another layer of moist cotton (Figure 3b). The cotton bed provided a soft and moist environment, ideal for delicate seeds, and allowed easy observation of germination progress.

Figure 3b Seed germination by cotton bed method.

The **Pot System** (Figure 3c) involved filling pots with a well-draining soil mix. The soaked seeds were sown at a shallow depth (about 0.5 cm) and lightly covered with soil. The soil was then gently watered to moisten it. Pots provided a controlled environment for seedling growth and could be easily moved to optimize light and temperature conditions. These methods ensured effective germination and subsequent growth of finger millet by providing suitable conditions for moisture, aeration, and observation.

Figure 3c Seed germination by Pot method

Physicochemical analysis

The samples were analysed for pH, Moisture content, total Fat content and total Solid content in accordance with official method of Association of official Analytical Chemists.[22,23]

pH measurement

The sample (flour of finger millet) were thoroughly stirred to homogenize the mixture and achieve uniformly. Then the pH paper strip was dipped into the sample and measurement was taken using a pH paper scale.

Moisture content determination

Briefly, sample moisture (native seed and sprouted seed flour) determined using hot air dry method for which samples were ground, weight and taken in previously weighed petridishes then the samples along with moisture dish were kept in a hot air oven at 100° C for 1 hour. Moisture dish was taken out after 1 hour and placed in a desiccator for cooling. Weight of moisture dish was recorded thereafter, this process repeated until a constant weight was attained. The loss in weight represents the moisture content of sample.

$$\textbf{Moisture (\%)} = \frac{Wt_1 - Wt_2}{Wt_2} \times 100$$

Where, Wt_1 = Weight of Initial dried sample

Wt_2= Weight of secondarily dried sample

Fat content analysis

Fat estimation was performed using the Soxhlet Extraction method in which moisture free samples were weighed and placed in thimbles for fat extraction these thimbles were kept in soxhlet apparatus with Petroleum Ether for 16-18 hour. The fat extract was filtered through a sintered funnel in a pre- weighed beaker.

Fat (%) = Amount of ether extract (g)/ Weight of sample(g) x100

Total solid content

Total solids content (TS) is the amount of solids in a sample relative to its original mass or volume. The Total Solids (TS) content of a sample is the mass of solids remaining after a sample has been dried in a 100°C Oven for 24 hours, divided by the original mass of the sample.

Salt stress analysis

As per the suggested method,[24] the remaining soaked millet seeds are allow to germinate at 28° C for 72 h till the growth of 4 to 5mm long rootlets. Seed germination studies were performed in seeds with treated with different concentration of NaCl (ie 100 mM, 200 mM, 300 mM), which is shown in Figure 6. Percentage germination and radicle, plumele growth were measured.

Sample preparation

The process began with ensuring that the germinated and dried finger millet grains were completely dry to avoid clumping. The grains were then ground using a mixer grinder to achieve a fine flour, carefully milling the grains multiple times to reach the desired fineness. The milled flour was then poured into a fine mesh sieve to separate the fine flour from any larger particles to attain finer flour. After sieving, the flour was stored in airtight zipper plastic bags that prevent moisture, ensuring that the flour remains dry and fresh. These bags were labelled with the date of milling and relevant information. Finally, the packaged flour was stored in a cool, dry place to maintain its quality and prevent any pest contamination, ensuring that the nutritional value and quality of the finger millet flour were preserved.

Statistical analysis and data representation

Physico-chemical parameters as well as Radicle and plumule lengths, were measured in triplicate for each sample and treatment. The values are presented as mean ± standard error (SE).

Results and discussion

Native and sprouted finger millet (*Eleusine coracana*) was investigated for their physico-chemical properties namely pH, moisture content, total solid content, fat content (Table 1).

Table 1 Comparative analysis of Physico-chemical parameters of Native & germinated seeds of finger millets

S.no.	Parameter	Sample	Values
1	Moisture Content (%)	Native Seed	10.2±0.06
		Germinated Seed	6.7±0.06
2	pH	Native Seed Flour	6.0±0.06
		Germinated Seed	5.6±0.06
3	Fat Content (%)	Native Seed	7.7±0.06
		Germinated Seed	11.2±0.12
4	Total Solid Content (%))	Native Seed	89.8±0.12
		Germinated Seed	93.3±0.06

Data are expressed as mean±standard error (SE). Standard error was calculated based on the variability among the three replicates

Physicochemical analysis

The **moisture content** of native finger millet seeds was found to be 10.2%, a relatively high level typical for seeds in their natural state, which helps maintain their viability. Upon germination, the moisture content decreased to 6.7%, likely due to the metabolic activities during germination where water is utilized for enzymatic reactions and seedling growth.[25] The pH of native seed flour and sprouted seed flour was recorded at 6 and 5.6 respectively (Figure 4), indicating a neutral to slightly acidic environment conducive to the stability of certain nutrients and enzymes within the seed.[25] The fat content (Figure 5) in native finger millet seeds was measured at 7.7%, essential for providing energy during seed germination and early seedling growth. Interestingly, the fat content in germinated seeds increased to 11.2%, which can be attributed to the mobilization and conversion of stored lipids into simpler forms used for the growth and development of the seedling.[26] The total solid content in native seeds was found to be 89.8%, reflecting the dense nutrient composition of the seeds. After germination, the total solid content increased to 93.35%, suggesting a concentration of solids as water content decreased and biochemical changes enhanced the nutrient density.

Figure 4 pH analysis.

Figure 5 Fat extraction by Soxhlet Extraction method.

Salt stress analysis

The salt stress experiment evaluated the impact of different NaCl concentrations on the growth of finger millet seedlings (Figure 6) over various time intervals, as shown in Table 2. The percent germination of seeds was recorded at 72 hours across different salt concentrations. A gradual decrease in percent germination was observed with increasing salt concentration (i.e., 100mM, 200mM, 300mM). However, 100% germination was recorded in seeds treated with 100mM, 200mM, and 300mM NaCl concentrations, as well as in the control group. Minimum germination was recorded in seeds treated with 300mM NaCl concentration, while maximum germination was observed at 100mM NaCl concentration, as shown in Figure 6. The radicle and plumule lengths were measured at 72 hours and 120 hours under 100mM, 200mM, and 300mM NaCl concentrations. A gradual decrease in length was observed with increasing salt concentration. Maximum lengths were recorded in seeds treated with 100mM NaCl concentration and in the control group, while the minimum lengths were recorded in seeds treated with 300mM NaCl concentrations

Figure 6 Seed germination at 72 hours under different NaCl conc.

Table 2 Salt stress analysis on germination of finger millets at different NaCl concentrations

NaCl (mM)	Sample	Radicle length (cm)	Plumule lengths (cm)	Plumule lengths
100	A1	8.67±1.05	3.0, 3.5, 4.0	3.50±0.15
200	B1	6.67±0.88	2.5, 3.0, 3.0	2.83±0.14
300	C1	5.33±0.88	1.5, 2.0, 2.0	1.83±0.14

Data are expressed as mean±standard error (SE). Standard error was calculated based on the variability among the three replicates

The reduction in moisture content during germination indicates the significant metabolic activities that utilize water for essential enzymatic reactions and seedling growth. The slight acidity in the native seed flour's pH level supports the stability of nutrients and enzymes, contributing to the seed's viability. The increase in fat content in germinated seeds reflects the mobilization of stored lipids, providing energy for the seedling's development.[27] The total solid content's increase post-germination suggests a concentration of nutrients as water content decreases, enhancing the seed's nutritional density. The salt stress analysis highlights the resilience of finger millet to varying salt concentrations, although higher salt levels negatively impacted germination rates and seedling growth.[28] These results emphasize the potential of finger millet as a nutritionally rich and resilient crop, suitable for diverse environmental conditions.

Conclusion

This study demonstrates that finger millet seeds show significant changes in their physicochemical properties upon germination, enhancing their nutritional value. The seeds also exhibit resilience to varying salt concentrations, making them a viable crop for diverse environmental conditions. Further research on optimizing germination conditions and salt stress tolerance can contribute to improving the nutritional quality and adaptability of finger millet.

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Conflicts of interest

The authors declare that they have no conflicts of interest.

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