Environment and Ecology 44 (3A) : 811—821, July—September 2026
Article DOI: https://doi.org/10.60151/envec/MWPF4809
ISSN: 0970-0420 (Print), ISSN: 3049-3625 (Online)

Development of Climate-Resilient Finger Millet-Based Beverage Premix for Sustainable Nutrition and Food Security

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Received 9 May 2026, Accepted 30 July 2026, Published on 18 September 2026

ABSTRACT

This study focuses on the development and evaluation of a climate-resilient finger millet-based premix as a nutritionally rich and functionally efficient food product. The research was conducted in the Department of Food and Nutrition, College of Community Science, Acharya Narendra Deva University of Agriculture and Technology (ANDUAT), Kumarganj, Ayodhya, Uttar Pradesh. The premix was formulated using roasted finger millet (*Eleusine coracana*) flour blended with roasted gram flour in different proportions (70:30, 80:20, 90:10 and 100:0), represented as T1, T2, T3, and T4, with wheat flour-based formulation serving as control (T0). Among all formulations, T3 (90:10) showed the most desirable physicochemical, nutritional, and sensory characteristics. This optimized sample recorded moisture content of 10.5%, water absorption capacity of 135 g/100 g, bulk density of 0.69 g/ml, swelling capacity of 150%, and pH of 6.40, indicating good functional and processing properties. Nutritional analysis revealed an energy value of 340 kcal/100 g, with 73 g carbohydrates, 11.5 g dietary fiber, 12.5 g protein, 1.4 g fat, 340 mg calcium, and 4.9 mg iron. Sensory evaluation using a 9-point hedonic scale indicated high consumer acceptability, with an overall acceptability score of 8.75, categorized as "like very much." The study confirms that incorporation of finger millet and roasted gram flour significantly enhances nutritional and functional quality without compromising sensory attributes. Furthermore, the use of finger millet, a climate-resilient and low-input crop, highlights its potential in promoting sustainable agriculture, resource conservation, and ecological stability. Overall, the developed premix represents a nutrient-dense, consumer-acceptable, and environmentally sustainable food product with strong potential to improve dietary quality and support food and nutritional security.

Keywords Finger millet, Climate-resilient crop, Sustainable agriculture, Functional food, Nutrient-dense premix, Food security.

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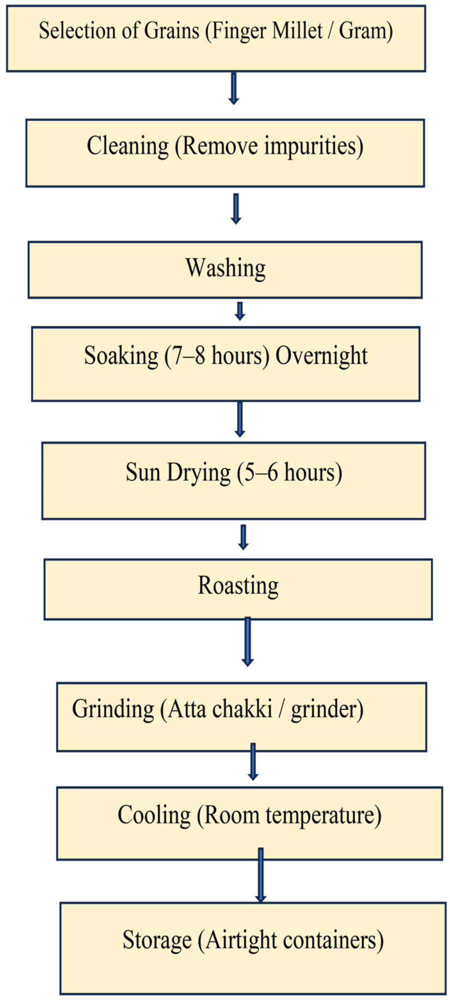
INTRODUCTION

Finger millet (*Eleusine coracana*) has emerged as an important nutri-cereal due to its exceptional nutritional profile and diverse health-promoting properties. In recent years, the growing prevalence of lifestyle-related disorders such as diabetes, obesity, cardiovascular diseases, and micronutrient deficiencies has led to an increased focus on nutrient-dense and functional foods. Millets, particularly finger millet, have gained considerable attention owing to their resilience, sustainability, and superior nutritional composition compared to major cereals. Finger millet is especially valued for its high calcium content, dietary fiber, essential amino acids, and polyphenolic compounds, which contribute significantly to its antioxidant and therapeutic potential (Kalsi *et al.* 2023). One of the most distinguishing features of finger millet is its exceptionally high calcium content, which is several times greater than that of commonly consumed cereals such as rice and wheat. This makes it particularly beneficial for bone health, especially among children, women, and elderly populations. Additionally, the presence of dietary fiber aids in digestion, promotes satiety, and helps regulate blood glucose levels, making finger millet an ideal food for diabetic individuals. The grain also contains important micronutrients such as iron, phosphorus, and magnesium, which play a crucial role in preventing anemia and supporting overall metabolic functions (Sharma *et al.* 2021).

Finger millet is also rich in bioactive compounds such as polyphenols, flavonoids, and tannins, which exhibit strong antioxidant properties. These compounds help in reducing oxidative stress and lowering the risk of chronic diseases such as cancer and cardiovascular disorders. Furthermore, the low glycemic index of finger millet contributes to better glycemic control, making it a suitable dietary component for individuals with diabetes and related metabolic disorders. The presence of essential amino acids such as methionine, which is often limited in other cereals, further enhances its nutritional quality (Navyashree *et al.* 2022). The preparation of finger millet flour involves a series of processing steps, including selection of grains, cleaning, washing, soaking, drying, grinding, cooling, roasting, and storage under suitable conditions. These steps are important for obtaining good-quality flour with improved processing characteristics and storage stability (Kalsi *et al.* 2023). The overall process of finger millet flour preparation is presented in Fig. 1. Despite its numerous health benefits, the utilization of finger millet in daily diets remains relatively low due to factors such as lack of awareness, limited product diversity, and inconvenience in preparation. Traditional methods of cooking finger millet are often time-consuming and may not align with the fast-paced lifestyle of modern consumers. Therefore, there is a growing need to develop convenient, ready-to-use, and nutritionally enhanced



Source: Adapted from Kalsi *et al.* (2023).

Fig. 1. Flow diagram for preparation of finger millet flour.

food products that can promote the consumption of this valuable grain (Saini *et al.* 2021).

In this context, premix formulations offer a promising solution. A premix is a blend of various ingredients that can be easily reconstituted or cooked to prepare a food product with minimal effort. Finger millet-based premixes can be designed to provide balanced nutrition, improved shelf life, and enhanced sensory acceptability. Such products cater to the increasing demand for convenience foods while maintaining high nutritional standards. Additionally, premixes can be fortified with other nutrient-rich ingredients such as pulses, nuts, and functional additives to further enhance their health benefits.

Processing techniques play a vital role in improving the nutritional and functional properties of finger millet. Methods such as germination, fermentation, roasting, and malting have been shown to enhance nutrient bio availability, reduce anti-nutritional factors like phytic acid, and improve digestibility. These processes also contribute to better flavor, texture, and overall acceptability of the final product. For instance, germination increases the levels of certain vitamins and enzymes, while fermentation enhances probiotic potential and mineral absorption (Navyashree *et al.* 2022). The development of innovative finger millet premixes also aligns with the global emphasis on sustainable and climate-resilient crops. Finger millet is a hardy crop that requires minimal water and can grow in poor soil conditions, making it an environmentally sustainable choice. Promoting its use through value-added products not only improves nutritional security but also supports sustainable agriculture and rural livelihoods. Furthermore, the incorporation of finger millet into functional foods has significant potential in addressing public health challenges, particularly in developing countries where malnutrition and micronutrient deficiencies are prevalent. By developing premixes that are both nutritious and easy to prepare, it is possible to enhance the accessibility and acceptability of finger millet among diverse population groups, including children, working adults, and elderly individuals. Therefore, the development and evaluation of a finger millet-based premix is important in the current nutritional scenario as it can improve dietary quality, support health benefits, and meet the demand for convenient functional foods. Finger millet is nutritionally superior due to its high calcium content, low glycemic response, and presence of phenolic compounds and flavonoids that help reduce oxidative stress and chronic disease risk (Onipe and Ramashia 2022, Rajkumar *et al*. 2024). Premix formulations based on finger millet also enhance shelf life, ease of preparation, and overall nutritional intake, making them effective in addressing malnutrition and obesity (Krishnan *et al.* 2024, Kokisi *et al.* 2026).

MATERIALS AND METHODS

Study Location: The study was conducted in the Department of Food and Nutrition, Skill Development Lab, College of Community Science, Acharya Narendra Deva University of Agriculture and Technology, (ANDUAT) Kumarganj Ayodhya (UP)

Preparation of Flours

Raw Materials including finger millet, whole gram, and other required ingredients, were procured from the local market in Kumarganj, Ayodhya. Finger millet (*Eleusine coracana*) grains were cleaned, washed, shade-dried, and milled into fine flour using a grinder. Similarly, gram was also milled into flour. The flours were stored in airtight, food-grade containers to prevent moisture absorption, rancidity, and insect infestation.

Table 1. Standardization of ingredients for finger millet premix beverage.

Ingredients	Control	Treatments				Replications
	T0 (100)	T1 (70:30)	T2 (80:20)	T3 (90:10)	T4 (100)	
Gram flour (%)	100	-	-	-	-	
Finger millet flour (%)	-	70	80	90	100	3 Times
Roasted gram flour (%)	-	30	20	10	-	

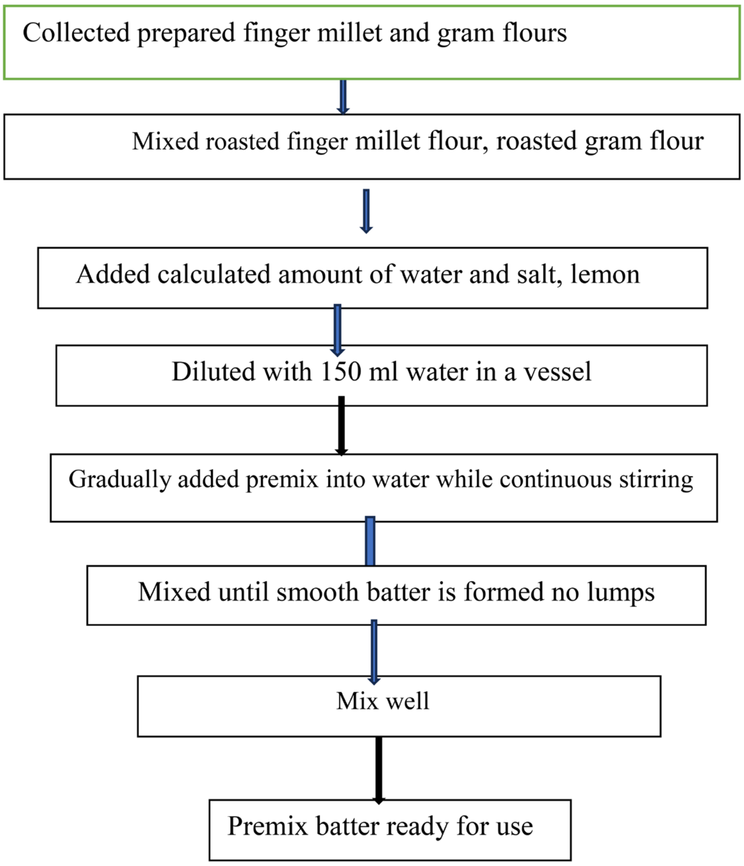


Fig. 2. The process of finger millet premix preparation.

Development of Finger Millets Premix

Premix were developed using finger millet flour blended with gram flour and the formulations were prepared (Table 1) using these blends with varying proportions of ingredients to optimize the final product. Finger millet premix preparation steps shown in Fig. 2.

The preparation of the finger millet premix involves a systematic sequential process starting with the soaking of finger millet grains, as shown in Plate 1, to soften them. Following this, the soaked grains are spread out on a clean cloth and sun-dried completely, as captured in Plate 2. After sun-drying, the grains are properly roasted to eliminate any residual moisture and to develop a pleasant aroma and flavor. Next, the roasted finger millet is combined with other required ingredients shown in Plate 3 to form the base mix. Finally, as displayed in Plate 4, this mixture is used to prepare five distinct treatment formulations, labeled

Plate 1. Soaking of finger millet.

Plate 2. Sun dry.

Plate 3. Ingredients mix.

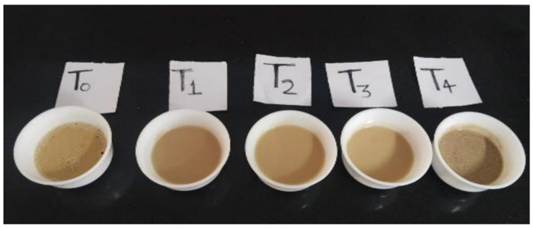


Plate 4. Different treatments prepared of finger millet premix.

from T_0 to T_4, varying in ingredient proportions for comparative analysis.

Sensory Evaluation of prepared (9-Point Hedonic Scale)

Panel Selection: A semi-trained sensory panel consisting of 20 members (faculty members specializing in food Science and Nutrition) and 50 consumers (Students, farmers) were selected. The sensory acceptability of the prepared premix was evaluated by selected panels of Semi- trained judges and consumers. Using a 9-point Hedonic Scale (Sri Lakshmi, 2007). Sensory evaluation of the prepared premix was carried out following the method described by Thangalakshmi *et al.* (2018).

Analysis of Physicochemical Properties of Prepared Finger Millet Premix

Moisture Content

Moisture content of the developed finger millet premix was determined using the standard hot air oven method. Approximately 5 g of the sample was accurately weighed into a pre-weighed moisture dish. The sample was then dried in a hot air oven maintained at 105°C for 4–6 hours or until a constant weight was obtained. After drying, the sample was cooled in a desiccator to prevent moisture absorption from the atmosphere and then reweighed. The loss in weight was recorded as moisture content and calculated using the formula (*AOAC International 2023*).

Moisture content (%) is calculated using the following formula:

$$\text{Moisture Percentage (\%)} = \frac{W2\text{-}W3\times100}{W2\text{-}W1}$$

Bulk Density

Bulk density was determined by filling a known weight of the premix into a graduated cylinder and recording the volume occupied. Bulk density was then calculated as weight per unit volume (g/ml). Measurements were carried out in triplicate and averaged (AOAC International 2023).

Water Absorption Capacity (WAC)

Water absorption capacity was determined by mixing a known weight of the premix (1 g) with distilled water (10 ml), followed by centrifugation. The supernatant was discarded, and the absorbed water was measured. WAC was expressed as the amount of water absorbed per gram of sample (%) (Singh and Immanuel 2022).

Swelling capacity

Swelling capacity was determined by adding a known weight of the premix (1 g) to a measured volume of distilled water and allowing it to stand for a fixed time.

The increase in volume was recorded, and swelling capacity was expressed as the percentage increase in volume of the sample (Mudau *et al.* 2021).

pH

The pH of the premix was measured by preparing a slurry containing 1 g of sample in 10 mL of distilled water and mixing thoroughly. The pH was then recorded using a calibrated digital pH meter. Measurements were performed in triplicate and averaged (Mudau *et al.* 2021).

Protein Content

Protein content was determined using the Kjeldahl method. The sample was digested with concentrated sulfuric acid, followed by distillation and titration to estimate nitrogen content. The protein content was calculated by multiplying the nitrogen value with a conversion factor (6.25). Measurements were carried out in triplicate and averaged (AOAC International 2023).

Mineral Content

Ash content was determined by incinerating a known weight of the premix (about 2–5 g) in a muffle furnace at 550°C until a light grey or white ash was obtained. The residue was cooled in a desiccator and weighed. Ash content was expressed as percentage of the original sample weight (AOAC International 2023).

RESULT AND DISCUSSION

The physicochemical properties of the developed premix as influenced by different treatments (T0–T4) are presented in Table 2. The parameters evaluated included moisture content, water absorption capacity (WAC), bulk density, swelling capacity, and pH. The results indicated significant differences ($p < 0.05$) among the treatments for all the physicochemical characteristics studied. The differences in superscript letters within each column indicate that the treatment means were significantly different according to Duncan's Multiple Range Test (DMRT).

The moisture content of the developed premix ranged from 10.23 ± 0.11% to 11.80 ± 0.12%. The highest moisture content was observed in T0 (11.80 ± 0.12%), while the lowest was recorded in T3 (10.23 ± 0.11%). Treatments T1, T2, and T4 showed moisture contents of 11.24 ± 0.08%, 10.80 ± 0.14%, and 10.50 ± 0.10%, respectively. A gradual reduction in moisture content was observed from T0 to T3, followed by a slight increase in T4. The lower moisture content of T3 is desirable from a storage perspective because reduced moisture may minimize the availability of water for microbial growth and undesirable chemical reactions, thereby potentially improving the keeping quality and stability of the dry premix.

The WAC of the premix varied significantly from 110.5 ± 1.24 to 141.6 ± 2.04 g/100 g. The lowest WAC was observed in T0 (110.5 ± 1.24 g/100 g), whereas the highest value was recorded in T3 (141.6 ± 2.04 g/100 g). The WAC increased progressively from T0 to T3, while T4 showed a slight decrease to 135.0 ± 1.50 g/100 g. The higher WAC of T3 indicates a greater ability of the premix to absorb and retain water. This may be associated with the presence and modification of hydrophilic constituents in the formulation. Higher water absorption can be beneficial

Table 2. Physicochemical Properties of Developed Premix.

Treatment	Moisture (dry premix) (%)	Water Absorption Capacity (WAC)(g/100g)	Bulk Density (g/mL)	Swelling capacity (%)	pH
T0	11.80 ± 0.12a	110.5 ± 1.24e	0.75 ± 0.02a	120.4 ± 2.10e	6.72±0.05a
T1	11.24 ± 0.08b	117.1 ±0.94d	0.71 ±0.01b	132.7 ±1.84d	6.63±0.03b
T2	10.80 ±0.14c	125.0 ±1.10c	0.70 ±0.03c	143.2 ±2.30c	6.50±0.04c
T3	10.23 ±0.11e	141.6 ±2.04a	0.66 ±0.01e	157.5 ±2.50a	6.31±0.05e
T4	10.5 ±0.10d	135 ± 1.50b	0.69 ± 0.02d	150.0 ±1.94b	6.40±0.02d

Values are expressed as Mean ± Standard Deviation of triplicates. Means in the same column followed by different superscript letters (a-e) are significantly different ($p < 0.05$) as per Duncan's Multiple Range Test.

Table 3. Average Sensory Score of Prepared Finger Millet Premix.

Trial	Color & Appearance	Body & Texture	Taste & Flavor	Overall Acceptability
T0	6.82 ± 0.34d	7.12 ± 0.30d	7.10 ± 0.29d	7.10 ± 0.15d
T1	7.31 ± 0.30c	7.51 ± 0.30c	7.45 ± 0.28c	7.30 ± 0.32c
T2	7.80 ±0.25b	7.80 ±0.21b	7.78 ±0.25b	7.60 ±0.29b
T3	8.51 ±0.20a	8.54 ±0.18a	8.53 ±0.20a	8.75 ±0. 18a
T4	8.34 ±0.21b	8.20 ±0.24b	8.14 ±0.27b	8.23 ±0.20b

Values are Mean ± SD of triplicate determinations. Means in the same column followed by different superscript letters (a-d) are significantly different ($p < 0.05$) according to Duncan's Multiple Range Test.

for premixes because it may improve hydration, consistency, and reconstitution characteristics of the final product.

Bulk density showed a significant decreasing trend across the treatments, ranging from 0.66 ± 0.01 to 0.75 ± 0.02 g/mL. The highest bulk density was observed in T0 (0.75 ± 0.02 g/mL), whereas the lowest was found in T3 (0.66 ± 0.01 g/mL). The values for T1, T2, and T4 were 0.71 ± 0.01, 0.70 ± 0.03, and 0.69 ± 0.02 g/mL, respectively. The lower bulk density observed in T3 may indicate a relatively more porous and less compact powder structure. Such characteristics may be advantageous for handling, packaging, mixing, and dispersion of the premix. A significant increase in swelling capacity was observed among the treatments. The values ranged from 120.4 ± 2.10% in T0 to 157.5 ± 2.50% in T3. T0 exhibited the lowest swelling capacity, while T3 recorded the highest value. T1 and T2 showed swelling capacities of 132.7 ± 1.84% and 143.2 ± 2.30%, respectively, whereas T4 showed 150.0 ± 1.94%. The increased swelling capacity with treatment level up to T3 suggests an enhanced ability of the premix components to absorb water and expand. This property is important because greater swelling may contribute to improved body, consistency, and textural properties of the reconstituted product. The pH of the developed premix ranged from 6.31 ± 0.05 to 6.72 ± 0.05. The highest pH was recorded in T0 (6.72 ± 0.05), while the lowest was observed in T3 (6.31 ± 0.05). The pH decreased gradually from T0 to T3 and increased slightly in T4 (6.40 ± 0.02). The decrease in pH may be attributed to differences in the composition of the treatments and the contribution of acidic constituents present in the formulation. The relatively narrow pH range among the treatments indicates that the treatments produced only a moderate change in the acid–base characteristics of the premix. Similar findings were reported by Mane *et al.* (2022), who observed that millet flours generally possess low moisture content suitable for extended storage. A study by Rajkumar *et al.* (2024) reported bulk density values of finger millet flour around 0.65 g/cm³, supporting the present findings. The swelling capacity (42%) suggests moderate starch expansion behavior, which contributes to improved texture formation during processing and aligns with findings reported by Chandra *et al.* (2021). Similar pH reductions in treated finger millet flour were observed by Umar *et al.* (2024). Overall, these physicochemical properties demonstrate that the developed finger millet premix possesses good functional qualities required for efficient processing, reconstitution, and development of value-added food products.

The sensory profile of the developed finger millet and roasted gram flour premix was evaluated using a 9-point Hedonic scale, and the results are presented in Table 3. The sensory attributes evaluated included color and appearance, body and texture, taste and flavor, and overall acceptability. The results indicated considerable variation in sensory scores among the treatments, reflecting differences in the sensory quality and acceptability of the developed premix. For color and appearance, the sensory scores ranged from 6.82 ± 0.34 to 8.51 ± 0.20. The lowest score was recorded for T0 (6.82 ± 0.34), followed by T1 (7.31 ± 0.30) and T2 (7.80 ± 0.25). The score increased to 8.51 ± 0.20 in T3, which was the highest among all treatments, while T4 recorded 8.34 ± 0.21. The higher score obtained by T3 indicates that the color and appearance of this treatment were most preferred by the sensory panel. The slight decline in T4 compared with T3 suggests that further modification of the formulation did not result in additional improvement in visual acceptability. The body and texture scores

Table 4. Nutrient composition of finger millet premix (Per 100g).

Nutrients	Gram premix T0	Finger millet premix T1	Finger millet premix T2	Finger millet premix T3	Finger millet premix T4
Moisture (%)	10.70	10.64	11.66	12.14	10.53
Energy (Kcal)	369	350	352	343	340
Protein (g)	22.50	11.72	12.82	13.38	10.28
Fat (g)	5.20	1.56	2.56	2.86	1.32
Carbohydrate (g)	58.10	64.70	64.70	66.44	56.43
fiber (g)	1.00	1.28	1.48	2.56	1.20
Calcium (mg)	58.00	21.61	31.60	229.60	29.67
Iron (mg)	9.50	3.16	5.18	6.14	2.32

varied from 7.12 ± 0.30 in T0 to 8.54 ± 0.18 in T3. T1, T2, T3, and T4 recorded scores of 7.51 ± 0.30, 7.80 ± 0.21, 8.54 ± 0.18, and 8.20 ± 0.24, respectively. T3 received the highest score, indicating superior body and texture compared with the other treatments. The improvement in body and texture may be associated with the functional properties of the premix, particularly its water absorption and swelling characteristics. The relatively high score of T4 also indicates good textural acceptability, although it was lower than that of T3. Taste and flavor, the scores ranged from 7.10 ± 0.29 to 8.53 ± 0.20. T0 recorded the lowest score (7.10 ± 0.29), while T1 and T2 obtained scores of 7.45 ± 0.28 and 7.78 ± 0.25, respectively. The highest score was observed in T3 (8.53 ± 0.20), followed by T4 (8.14 ± 0.27). The higher taste and flavor score of T3 indicates greater preference by the sensory panel for its flavor characteristics. The decrease in score observed for T4 compared with T3 suggests that T3 may represent a more suitable formulation level for achieving desirable taste and flavor.

The overall acceptability scores ranged from 7.10 ± 0.15 to 8.75 ± 0.18. T0 showed the lowest overall acceptability score (7.10 ± 0.15), followed by T1 (7.30 ± 0.32) and T2 (7.60 ± 0.29). T4 received a higher score of 8.23 ± 0.20, whereas T3 recorded the highest overall acceptability score of 8.75 ± 0.18. Since overall acceptability represents the combined sensory perception of the product, the highest score obtained by T3 indicates that it was the most preferred treatment by the sensory panel.

Nutritional value of finger millet premix

Prepared premix contains highest amount of Dietary fiber, calcium, iron, phosphorous, and provided a balanced profile of protein, minerals, and overall nutritional value.

The nutrient composition of the developed finger millet and roasted gram flour premix on a per 100 g basis is presented in Table 4. The nutritional parameters evaluated included moisture, energy, protein, fat, carbohydrate, dietary fiber, calcium, and iron. The results showed considerable variation in the nutrient composition among the different treatments (T0–T4), which may be attributed to differences in the formulation and proportion of ingredients used in the respective treatments. The moisture content of the developed premix ranged from 10.53 to 12.14%. The control treatment T0 showed a moisture content of 10.70%, while T1, T2, T3, and T4 recorded values of 10.64, 11.66, 12.14, and 10.53%, respectively. The highest moisture content was observed in T3 (12.14%), whereas T4 had the lowest moisture content (10.53%). The variation in moisture content may be associated with differences in the composition and water-holding characteristics of the ingredients. The comparatively lower moisture content of T4 may be advantageous for storage stability of the dry premix. Similar variations in moisture content have been reported (Thakur *et al.* 2022). Lower moisture content in dry premixes is generally desirable for maintaining better storage stability. The energy content ranged from 340 to 369 kcal/100 g. The highest energy value was recorded in T0 (369 kcal/100 g), followed by T2 (352 kcal/100 g), T1 (350 kcal/100 g), T3 (343 kcal/100 g), and T4 (340 kcal/100 g). The relatively high energy value of T0 may be associated with its higher contribution from protein and fat. The gradual reduction in energy content across some treatments indicates changes in the macronutrient composition of the premix. This is similar to the findings by Navyashree *et al.* (2022). These changes in macronutrient composition can consequently influence the energy value of finger millet-based products. The protein content varied considerably among the treatments, ranging from 10.28 to 22.50 g/100 g. T0 recorded the highest protein content (22.50 g/100 g), while T1, T2, T3, and T4 contained 11.72, 12.82, 13.38, and 10.28 g/100 g, respectively. The relatively higher protein content of T0 can be attributed to the higher protein contribution of roasted gram flour. Among the finger millet premix treatments, T3 showed the highest protein content (13.38 g/100 g), indicating a comparatively favorable protein contribution among the developed premixes. The fat content ranged from 1.32 to 5.20 g/100 g. The highest fat content was observed in T0 (5.20 g/100 g), followed by T3 (2.86 g/100 g), T2 (2.56 g/100 g), T1 (1.56 g/100 g), and T4 (1.32 g/100 g). Similar findings reported by Navyashree *et al.* (2022). The higher fat content of T0 may contribute to its higher energy value. In the developed finger millet premixes, T3 showed a moderate fat content of 2.86 g/100 g, which may contribute to palatability and energy without resulting in an excessively high fat content. The carbohydrate content ranged from 56.43 to 66.44 g/100 g. T3 exhibited the highest carbohydrate content (66.44 g/100 g), followed by T1 and T2 (64.70 g/100 g each), T0 (58.10 g/100 g), and T4 (56.43 g/100 g). The higher carbohydrate content of T3 indicates that it can provide a substantial contribution to dietary energy. Carbohydrates are the major energy-providing macronutrients in cereal-based products, and the relatively high carbohydrate content of T3 contributes to its nutritional value. The dietary fiber content ranged from 1.00 to 2.56 g/100 g. The lowest fiber content was observed in T0 (1.00 g/100 g), whereas the highest value was recorded in T3 (2.56 g/100 g). T1, T2, and T4 showed fiber contents of 1.28, 1.48, and 1.20 g/100 g, respectively. The higher dietary fiber content of T3 is nutritionally desirable because dietary fiber contributes to digestive health and may improve the overall nutritional quality of the premix. The increased fiber content may be associated with the incorporation of finger millet, which contains appreciable amounts of dietary fiber. The calcium content showed marked variation among the treatments, ranging from 21.61 to 229.60 mg/100 g. T0 contained 58.00 mg/100 g, while T1, T2, T3, and T4 recorded 21.61, 31.60, 229.60, and 29.67 mg/100 g, respectively. The highest calcium content was observed in T3 (229.60 mg/100 g), which was substantially higher than the other treatments. This high calcium content enhances the nutritional significance of T3, particularly because calcium is essential for maintaining normal bone and teeth development and other physiological functions. The high calcium contribution may be associated with the greater incorporation of finger millet in this treatment.

The iron content ranged from 2.32 to 9.50 mg/100 g. T0 showed the highest iron content (9.50 mg/100 g), followed by T3 (6.14 mg/100 g), T2 (5.18 mg/100 g), T1 (3.16 mg/100 g), and T4 (2.32 mg/100 g). Although T0 had the highest iron content, T3 also provided a considerable amount of iron (6.14 mg/100 g). Iron is an essential micronutrient involved in haemoglobin formation and oxygen transport; therefore, the presence of appreciable iron in the developed premix contributes to its nutritional value.

Findings

The study resulted in the development of a finger millet-based premix by combining finger millet flour and gram flour in a 90:10 ratio to improve nutritional quality and functional properties. Nutritional evaluation indicated that the developed premix exhibited higher protein content due to the incorporation of gram flour, along with significant amounts of dietary fiber and minerals, particularly calcium, contributed by finger millet. The premix formulation showed good hydration and mixing properties, making it suitable for preparation of batter and other food products. Overall, the developed premix demonstrated an improved nutritional profile and functional characteristics, suggesting its potential as a healthy alternative for value-added food applications. A similar study was reported by Sinha and Sharma (2015), who developed a nutritious ready-to-eat mix using finger millet, Bengal gram, quality protein maize and soybean in different proportions. The developed ready mixes were evaluated for sensory quality and nutritional composition. The study reported appreciable levels of protein, fat and dietary fiber in the developed products, demonstrating the nutritional potential of combining finger millet with pulse-based ingredients. These findings support the present study, where the incorporation of finger millet and gram flour resulted in a nutritionally improved premix with desirable functional and sensory characteristics.

Environmental and Sustainability Significance

Finger millet is widely recognized as a climate-resilient crop due to its ability to grow under conditions of low water availability, minimal fertilizer input, and limited agricultural resources compared to major cereals such as wheat and rice. Its adaptability to marginal, drought-prone, and low-fertility soils makes it highly suitable for sustainable agriculture and effective climate change adaptation strategies (Saini *et al.* 2021).

The promotion and utilization of finger millet-based value-added products, such as the developed premix, contribute to diversification of cropping systems and reduce dependency on resource.

Intensive cereal crops. This shift supports conservation of natural resources, particularly water and soil nutrients, thereby reducing environmental pressure and promoting ecological balance (Singh *et al.* 2021, Sukanya *et al.* 2024).

In addition, finger millet cultivation enhances agro-biodiversity and supports the livelihoods of small and marginal farmers by providing a low-input yet nutritionally rich crop option. The incorporation of finger millet into processed and convenient food forms further encourages its wider consumption, thereby improving dietary diversity, strengthening food security, and promoting nutritional sustainability (Rajkumar *et al.* 2024, Krishnan *et al.* 2024).

CONCLUSION

The present study demonstrates that finger millet can be effectively utilized for the development of a nutritionally rich and functionally acceptable premix. Among the evaluated formulations, the optimized sample (T3: 90:10) exhibited superior physicochemical characteristics, high sensory acceptability, and enhanced nutritional quality, particularly in terms of calcium, dietary fiber, and protein content. Beyond its nutritional advantages, the study also emphasizes the environmental significance of finger millet as a climate-resilient and low-input crop. Its utilization in value-added food products supports sustainable agriculture, reduces dependence on water- and input-intensive cereals, and contributes to the development of climate-smart food systems. The study further concludes that a highly nutritious, functional, and consumer-acceptable premix can be successfully developed through the incorporation of finger millet and roasted gram flour. The T3 formulation demonstrated balanced physicochemical properties, including optimal moisture content (10.5%) and water absorption capacity (1.35 g/g), along with the highest overall sensory acceptability score (8.75). Nutritionally, the developed premix was found to be rich in calcium (340 mg/100 g), dietary fiber (11.5 g/100 g), and protein (12.5 g/100 g), making it a healthier alternative to conventional cereal-based products. The present findings are supported by Patil *et al.* (2024), who developed a sattu premix using puffed finger millet flour and roasted bengal gram flour. Different proportions of finger millet and roasted Bengal gram flour were evaluated for their physicochemical and sensory characteristics. The study demonstrated that blending finger millet with roasted Bengal gram flour can be successfully utilized for the development of a value-added premix with desirable quality characteristics. These findings support the present study, where finger millet and roasted gram flour were combined to develop a nutritionally improved and sensory acceptable premix.

REFERENCES

Anitha, S., Givens, D. I., Botha, R., Kane Potaka, J., Sulaiman, N. L. B., Tsusaka, T. W., & Bhandari, R. K. (2021). Calcium from finger millet a systematic review and meta-analysis on calcium retention, bone resorption, and in vitro bioavailability. *Sustainability,* 13(16), 8677.

AOAC International. (2023). *Official methods of analysis of AOAC International* (22nd ed.). Oxford University Press.

Chandra, D., Chandra, S., Pallavi, & Sharma, A. K. (2021). Finger millet processing and functional properties: A review. *Food Reviews International,* 37(3), 253–273.

Kalsi, R., Bhasin, J., Goksen, G., & Kashyap, P. (2023). Exploration of nutritional, pharmacological, and processing trends for valorization of finger millet (Eleusine coracana). *Food Science and Nutrition,* 11(11), 6802–6819.

Krishnan, H., Kaushik, D., Kumar, M., Öz, E., Brennan, C., Öz, F.,

& Abd Allah, E. F. (2024). Assessing the efficacy of pearl millet and finger millet enriched breakfast cereals to combat obesity. *Scientific Reports,* 14(1), 27752.

Kokisi, P., Nchu, F., Kambizi, L,. & Bvenura, C. (2026). Finger millet and soybean as functional ingredients in next-generation fermented foods: a review of nutritional, technological, and health-promoting perspectives. *Frontiers in Nutrition,* 13, 1718090.

Navyashree, N., Sengar, A. S., Sunil, C. K., & Venkatachalapathy, N. (2022). White finger millet (KMR-340): A comparative study to determine the effect of processing and their characterization. *Food Chemistry,* 374, 131665. https://doi.org/10.1016/j.foodchem.2021.131665

Onipe, O. O., & Ramashia, S. E. (2022). Finger millet seed coat: A functional nutrient-rich cereal by-product. *Molecules,* 27(22), 7837.

Patil, V. V., Pardeshi, I. L., Swami, S. B., Waikar, G. A., & Ranveer, R. C. (2024). Development of sattu and idli premixes from puffed finger millet. *International Journal of Advanced Biochemistry Research,* 8(11), 1004–1008. https://doi.org/10.33545/26174693.2024.v8.i11m.3006

Rajkumar, H., Muthu, I., James, P., Baskaran, S., Lakshmanan, K., Vellaichamy, M., & Pandi, P. (2024). Enhancing nutritional profile, functional properties, and therapeutic attributes of finger millet (Eleusine coracana) by germination: A com prehensive exploration. *Natural Product Communications,* 19(12), 1934578X241293027.

Saini, S., Saxena, S., Samtiya, M. Puniya, M., & Dhewa, T. (2021). Potential of underutilized millets as nutri-cereal: An overview. *Journal of Food Science and Technology,* 58(12), 4465–4477.

Singh, K., & Immanuel, G. (2022). Evaluation of physical and functional properties of composite flour from finger millet, rice and guar gum. *International Journal of Plant & Soil Science,* 34(23), 270–277.

Sri Lakshmi, B. (2007). *Food science* (4th ed.). New Age International Publishers.

Sinha, R., & Sharma, B. (2015). Sensory and nutritional evaluation of ready mix prepared from QPM, Bengal gram and soybean. *Asian Journal of Dairy and Food Research,* 34(2), 160-163.

Thangalakshmi, S., Pandey, V., Kamble, D. B., & Singh, R. (2018). Standardization and quality evaluation of instant tea premix. *The Pharma Innovation Journal,* 7(9), 154–157.

Thakur, A., Pandey, P., Dalbhagat, C. G., & Mishra, H. N. (2022). Development of grain-based carbonated beverage premix using maize (*Zea mays*), Bengal gram (*Cicer arietinum*), and finger millet (*Eleusine coracana*). *Journal of Food Science and Technology,* 59(4), 1637–1648. https://doi.org/10.1007/s13197-021-05175-5

Umar, M., Hassan, M., & Rungraeng, N. (2024). *In vitro* digestibility and physicochemical analysis of heat-moisture treated finger millet flour and starch. *Sustainable Food Technology,* 3(1), 215–226.

Sukanya, T. S., Sneha, M. A., Chaithra, C., & Ragimasalawada, M. (2024). Optimizing productivity and resource use efficiency under a finger millet-based cropping system. *Sustainability,* 16(24), 11046.

Singh, D., Mathimaran, N., Sekar, J., Ramalingam, P. V., Perisamy, Y., Raju, K., & Kahmen, A. (2021). Spatial arrangement and biofertilizers enhance the performance of legume Millet intercropping system in rainfed areas of southern India. *Frontiers in Sustainable Food Systems,* 5, 711284.