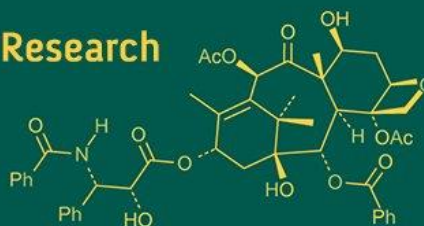


International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2026): 5.29
IJABR 2026; SP-10(8): 618-622
www.biochemjournal.com
Received: 15-05-2026
Accepted: 18-06-2026

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Development and nutrient evaluation of a millet-based calcium-enriched *Cheela* instant mix powder using dried drumstick (*Moringa oleifera*) leaves

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DOI: <https://www.doi.org/10.33545/26174693.2026.v10.i8Sh.9498>

Abstract

A major community health concern, calcium deficiency impacts people of all ages, but it particularly affects children, adolescents, pregnant women, nursing mothers, and older adults. Making affordable, nutrient-dense functional meals with locally available plant-based ingredients is a sustainable way to increase dietary calcium intake. The current study used dried drumstick (*Moringa oleifera*) leaf powder, Ragi (finger millet) flour, Rajgira (amaranth) flour, and oats powder to create and assess a millet-based calcium-enriched *cheela* instant mix powder. The resulting powder was subjected to sensory evaluation and proximate analysis using conventional analytical procedures to determine its moisture, protein, fat, ash, crude fiber, and carbohydrate content. Additionally, the levels of calcium and iron in the formulation were estimated to assess its mineral grade. Several methods were also used to determine the shelf life of the generated product. The study's goal was to evaluate the nutritional potential of the powder as a plant-based functional meal intended to promote calcium intake. The formulation's feasibility as an affordable and nutrient-dense dietary supplement will be supported by the findings of the nutrient analysis. The new calcium-enriched powder may help improve nutritional status and support bone health in groups at risk of calcium deficiency.

Keywords: Drumstick leaf powder, finger millet, amaranth, instant mixes, calcium enrichment, sensory evaluation, shelf life

1. Introduction

Calcium and vitamin D are vital minerals for strong bones. Over the past fifty years, the amount of calcium consumed by rural, tribal, and urban populations in India has declined. Over the past fifty years, both rural and urban populations' average 30-day grain intake has dropped by thirty percent [9].

Dietary changes that incorporate items that are naturally high in calcium, including dairy products, seem to be the most effective way to prevent calcium deficiencies. Furthermore, people may not have the money to buy animals or may simply keep cattle to supplement their income, depriving themselves of milk and milk products. Many populations in these areas, such as vegetarians and vegans, require other sources to meet their calcium needs [17].

Moringa oleifera is indigenous to India and grows well in tropical and subtropical regions of the world. It is commonly called "drumstick tree" or "horseradish tree". Because *Moringa* can withstand both severe drought and mild frost, it is grown all over the world. Because of the tree's exceptionally nourishing qualities, every part of it can be used for commercial or nutritional purposes. The leaves are rich in essential phytochemicals, minerals, and vitamins. Leaf extracts are used to treat malnutrition and boost breast milk production in nursing mothers. It could be used as an antibacterial, anti-inflammatory, anticancer, antidiabetic, and antioxidant [8].

Additionally, *M. oleifera* includes fat-soluble vitamins like vitamin-A (precursor to beta-carotene), vitamin-D, and vitamin-E, as well as water-soluble vitamin-B complexes like folic acid, pyridoxine, and nicotinic acid. Fresh leaves have 145 µg of vitamin C and 7564 IU of vitamin A, which are 252% and 235% of the daily needs, respectively [10]. Plant-based calcium, such as that present in conventional staple grains, is essential to diets in many countries. Finger millet has been shown to be consistently high in calcium (364±58 mg/100 g) and balanced with other minerals like zinc and magnesium [12, 1].

Finger millet is an excellent source of calcium as well as iron, slow-digesting starch, phytochemicals including polyphenols, and amino acids like methionine. It is a gluten-free, low-fat cereal that is non-allergic and easy to digest. It is often referred to be a "super cereal" due to these characteristics^[11]. In addition to its nutritional value, finger millet offers exceptional environmental sustainability advantages. It can withstand harsh weather and low soil fertility, has a short growing season, and requires minimal input to grow^[11]. According to^[14], it has a potential yield of up to 10 tons/ha under optimal watering conditions. Because of its higher storage quality attributes, it can be helpful in areas where farmers suffer losses due to poor post-harvest handling^[17].

Despite not being grasses, the seeds referred to as pseudocereals, including amaranth (*Amaranthus spp.*), share a botanical pedigree with spinach. They are sometimes incorporated with grains because of their comparable culinary uses. Amaranth is becoming more and more well-known throughout the globe due to its high nutrient content and prospective use in functional meals and nutraceuticals. These are often referred to as "nutri-cereals" due to their nutritional significance, yet they are also sometimes dubbed coarse cereals^[13].

Grown and consumed worldwide, oats are among the ancient grains and food crops. It is growing in popularity due to its nutritional composition and the numerous benefits of particular bioactive compounds. Beta-glucan is an important component of the dietary fiber found in oat grains. It has been demonstrated to have antidiabetic and cholesterol-lowering qualities and is the primary active component of oats. They also contain high concentrations of other beneficial compounds like phenolic acids, tocopherols, sterols, avenacosides, and avenanthramides. Eating oats has been shown to enhance immunomodulation as well as improve gut flora, both of which are beneficial to human health^[15].

2. Materials and Methods

2.1 Procurement of Raw Materials

Drumstick leaves, finger millet flour, amaranth flour, and oats and other necessary raw materials were obtained from the Udaipur city local market.

2.2 Development and standardization of instant *cheela* mix

In order to create drumstick leaf powder, fresh drumstick leaves were collected and subjected to several steps of processing. The leaves were first thoroughly cleaned to remove any dust, debris, or other foreign substances. In order to deactivate enzymes, lower the microbial burden, and maintain the leaves color and nutritional value, the leaves were blanched in hot water for two to three minutes after cleaning. The leaves were equally spread out after blanching and sun-dried for 4 days to eliminate enough moisture. A grinder was then used to turn the dried leaves into a fine powder. The purchased finger millet flour and amaranth flour were sifted to ensure uniform particle size. The prepared constituent powders were weighed, properly blended, and stored in airtight containers for additional examination in order to produce a uniform calcium-enriched *cheela* instant mix.

Drumstick leaf powder was added to the instant mix at three different levels (Table 1) T₁ (5% drumstick leaf powder), T₂

(7% drumstick leaf powder), T₃ (10% drumstick leaf powder), and Control (0% drumstick leaf powder). This was done to standardize the ingredients and obtain the most suitable blend.

Table 1: Development and standardization of *cheela* instant mix

S. No.	Ingredients	T ₁	T ₂	T ₃	Control
1.	Drumstick leaf powder (g)	5	7	10	-
2.	Finger millet flour (g)	55	55	50	40
3.	Amaranth flour (g)	35	30	30	30
4.	Ground oats (g)	5	8	10	10
	Total amount (g)	100	100	100	100

2.3. Sensory evaluation

Using a nine-point hedonic rating scale developed by Swaminathan^[21], a panel of thirty semi-trained panelists evaluated the recommended formulations for sensory attributes. Appearance, color, texture, flavor, taste, and overall acceptance was evaluated. For additional nutritional and storage research, the formulation with the best sensory scores was selected.

2.4. Nutritional analysis

Using conventional methods, the proximate composition of the selected *cheela* instant mix and control sample was evaluated (AOAC 2000)^[4]. The moisture content was measured using the hot air oven method; the ash content was measured using the muffle furnace method; crude protein was measured using the Kjeldahl method; crude fat was measured using Soxhlet extraction, and crude fiber was measured using acid-alkali digestion. Atwater conversion factors were used to calculate the energy value, and the difference technique was used to estimate the carbohydrate amount. Iron and calcium were the minerals whose contents were analyzed. Calcium content was determined using a flame photometer in compliance with the protocol outlined by Chikhale and Chikhale^[6], while iron level was determined using Atomic Absorption Spectrophotometry in accordance with the method described by Bishnoi and Brar^[5].

2.5. Shelf life study

For thirty days, the most preferred *cheela* instant mix formulation was kept at room temperature in airtight plastic pouches. At regular intervals (0, 15, and 30 days), the samples were tested to evaluate changes in moisture content, microbial burden, and sensory quality. The Total Viable Count (TVC) was estimated using the conventional plate count method. The results were expressed in colony-forming units per gram (CFU/g), and the product's microbiological safety was assessed using recognized food quality guidelines.

2.6. Statistical Analysis

The collected data underwent the necessary statistical evaluations^[18]. The nutritional makeup of the developed food products was compared and accessed using one-way Analysis of Variance (ANOVA), which was also employed to find notable differences in the sensory attributes and general acceptance of the developed goods prepared with different treatments. Nested Completely Randomized Design (Nested CRD) was used to assess significant changes in the created products' sensory characteristics, moisture content, and microbial load after storage.

3. Results and Discussion

3.1. Sensory evaluation

The sensory evaluation of *cheela* produced with different integrations of drumstick leaf powder is illustrated in Figure 1. T₃, which had the greatest sensory scores and contained 10% drumstick leaf powder, was the panelists' favored treatment. T₁ (5% drumstick leaf powder) and T₂ (7% drumstick leaf powder) were both considered acceptable,

but having lower overall acceptance than T₃. The results showed that while reducing the amount to 5% had a negative impact on acceptance, adding drumstick leaf powder up to 10% enhanced the *cheela*'s sensory attributes. Based on these findings, T₃ (10% drumstick leaf powder) was identified as the optimal formulation and selected for further investigation.

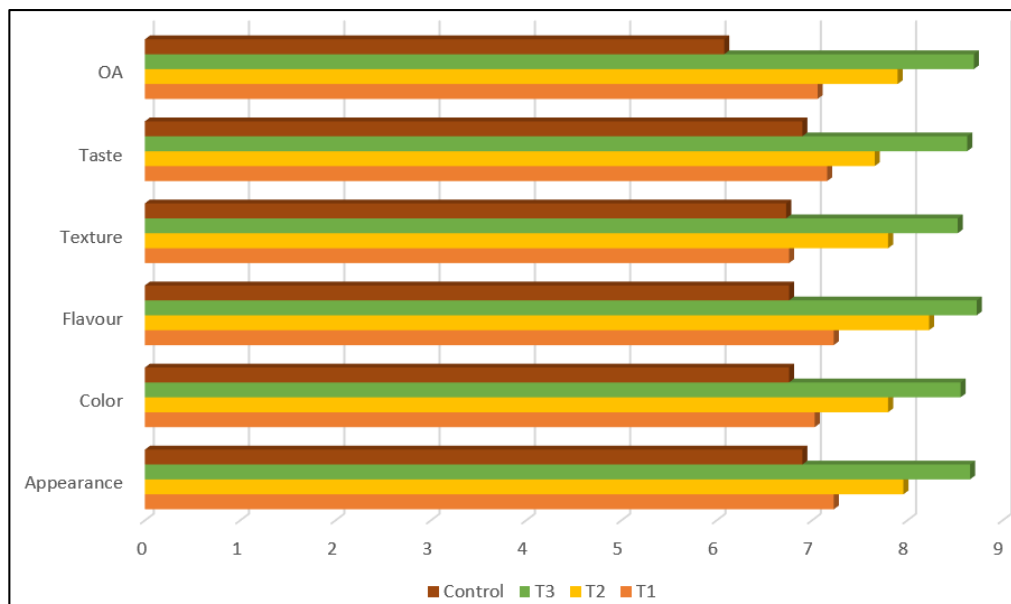


Fig 1: Mean acceptability score of calcium rich *cheela*

3.2. Nutritional composition

3.2.1 Proximate composition

The moisture content of the calcium-rich powder was 6.13 ± 0.81 g/100 g, whereas the control was 3.89 ± 0.38 g/100 g. This increase is consistent with research by Pawase *et al.* (2019) and Gopalakrishnan *et al.* (2016), which connected the higher moisture content to the hygroscopic properties and water-holding ability of leaf powders. Dehydrated green leaf powders had a moisture content of 6.2%, according to Saini *et al.* (2014). It is expected that this reduction will improve storage stability.

Crude protein increased from 9.95 ± 0.39 g/100 g in the control to 11.84 ± 0.83 g/100 g in the *cheela* instant mix after drumstick leaf powder was introduced. This increase is supported by the findings of Moyo *et al.* (2011) and Sengeev *et al.* (2013), who discovered that *Moringa oleifera* leaves are a rich source of protein and considerably raise the protein levels of fortified dietary products.

The fat content significantly increased from 2.80 ± 0.40 g/100 g in the control to 3.96 ± 0.57 g/100 g in the *cheela* instant mix. Anwar *et al.* (2007) and Javed *et al.* (2021) demonstrated similar results and connected the increase to the inherent lipid composition of *Moringa oleifera*.

Ash levels in the *cheela* instant mix increased from 3.00 ± 1.17 g/100 g in the control to 6.86 ± 0.98 g/100 g, indicating effective mineral enrichment. Because of the significant mineral content of the leaves, Anwar *et al.* (2007) and Gopalakrishnan *et al.* (2016) found higher ash levels in *Moringa*-fortified products, which is in line with these findings.

Crude fiber content increased significantly after adding drumstick leaf powder, ranging from 2.02 ± 0.56 to 2.98 ± 0.56 g/100 g, because of the high dietary fiber

concentration of drumstick leaves. However, when the carbohydrate-rich cereal flour was replaced with nutrient-dense drumstick leaf powder, the carbohydrate content dropped from 80.47 ± 1.80 to 69.70 ± 0.61 g/100 g. Consequently, the energy value dropped from 386.34 ± 2.15 to 361.88 ± 3.95 kcal/100 g, mostly because of the decrease in carbohydrate content, even though the protein, fat, fiber, and mineral portions increased. This outcome is in line with the findings of Dessta *et al.* (2024), who found that changes in constituent composition particularly lower carbohydrate content and increased fiber and mineral fractions decrease the calorific value of composite formulations.

Table 2: Proximate analysis of instant *cheela* mix

S. No.	Nutrients	Control	T ₃	SE	CD 5%
1.	Moisture (g)	3.89 ± 0.38	6.13 ± 0.81	0.368	1.445*
2.	Crude Protein(g)	9.95 ± 0.39	11.84 ± 0.83	0.375	1.475*
3.	Fat (g)	2.80 ± 0.40	3.96 ± 0.57	0.165	0.647*
4.	Ash (g)	3.00 ± 1.17	6.86 ± 0.98	0.627	2.463*
5.	Crude fiber (g)	2.02 ± 0.56	2.95 ± 0.56	0.276	1.087*
6.	Carbohydrates (g)	80.47 ± 1.80	69.70 ± 0.61	0.179	3.061*
7.	Energy (kcal)	386.34 ± 2.15	361.88 ± 0.95	5.216	20.480*NS

All values are (Mean $\pm$ SD) of three observations

SE-Standard error, *-Significant at 5 per-cent level ($P \leq 0.05$), NS-Non Significant

3.2.2. Mineral composition

The calcium concentration increased from 214 ± 1.72 to 388 ± 0.80 mg/100 g, the most significant improvement among the minerals analyzed. This notable increase demonstrates the effectiveness of the fortification technique and confirms the formulation's superior calcium enrichment. Similar findings were noted by Gopalakrishnan *et al.*

(2016), who claimed that *Moringa oleifera* leaves are very high in calcium and have tremendous potential as a natural dietary fortifying agent.

The inclusion of powdered drumstick leaves increased the iron content from 6.30 ± 0.45 to 8.13 ± 0.50 mg/100 g. In *Moringa oleifera* leaf powder, Yun *et al.* (2020) observed 8.8 mg/100 g of iron, while Valdez-Solana *et al.* (2015) observed 7.07 mg/100 g.

Table 3: Mineral content (mg per 100 g on a dry weight basis)

S. No.	Nutrients	Control	T ₃	SE	CD 5%
1.	Iron	6.30 ± 0.45	8.13 ± 0.50	0.277	0.091*
2	Calcium	214 ± 1.72	388 ± 0.80	3.366	13.216*

All values are (Mean $\pm$ SD) of three observations
SE-Standard error, *-Significant at 5 per-cent level

3.3 Shelf-life assessment of the *cheela* instant mix

3.3.1 Effect of storage on Moisture content

The moisture level of the calcium-rich powder was 6.13 ± 0.81 percent on day one and 8.34 ± 0.45 percent on day thirty. The rise may be attributed to the absorption of moisture from the environment during storage, perhaps due to container porosity. The findings of this study are consistent with those of Ansari *et al.* (2020), who also observed that moisture absorption caused the moisture content of *Moringa*-fortified instant soup mixes to progressively rise during storage despite adequate drying and packaging.

Table 5: Sensory evaluation of *Cheela*

Day	Appearance	Colour	Flavour	Texture	Taste	Overall acceptability
0	8.60 ± 0.62	8.40 ± 0.62	8.76 ± 0.50	8.60 ± 0.49	8.70 ± 0.46	8.73 ± 0.52
15	8.53 ± 0.57	8.40 ± 0.72	8.63 ± 0.49	8.03 ± 0.66	8.60 ± 0.56	8.43 ± 0.56
30	7.96 ± 0.61	7.86 ± 0.77	8.33 ± 0.60	7.86 ± 0.68	8.13 ± 0.81	8.26 ± 0.78
SE	0.011	0.129	0.097	0.113	0.115	0.116
CD 5%	0.309*	0.364*	0.275*	0.319*	0.325*	0.326*

All values are (Mean $\pm$ SD) of thirty observations
SE-Standard error, *-Significant at 5 per-cent level

3.3.3. Microbial analysis

The Total Viable Count (TVC) of the calcium-rich flour was nil on day 0, indicating good microbiological quality. Although it climbed to 4.8×10^3 CFU/g on day 15 followed by 7.2×10^3 CFU/g on day 30, it remained within the permissible threshold, suggesting that the flour's microbiological state was acceptable during the course of the 30-day storage period.

The present findings are consistent with those of Zakaria *et al.* (2025), who discovered that changes in nutrient availability and storage circumstances led to a gradual increase in microbial load while storing instant supplemental food enriched with *Moringa*.

Table 6: Microbial analysis of *cheela* instant mix

<i>Cheela</i> mix	Day 0	Day 15	Day 30
Total Viable Count	Nil	4.8×10^3	7.2×10^3

4. Conclusion

The present study effectively used dried drumstick (*Moringa oleifera*) leaves as a natural source of minerals and nutrients to create a calcium-enriched *cheela* instant mix powder derived from millet. By increasing the amounts of calcium, protein, fat, ash, and crude fiber, drumstick leaf powder significantly enhanced the nutritional profile of the

Table 4: Effect of storage on moisture content of the instant *cheela* mix

Product	Day 0	Day 15	Day 30
T ₃	6.13 ± 0.81	7.85 ± 0.76	8.34 ± 0.45
SE	0.570*		
CD 5%	0.39*		

All values are (Mean $\pm$ SD) of three observations

SE-Standard error, *-Significant at 5 per-cent level ($p \leq 0.05$)

3.3.2 Effect of storage on Sensory parameters of *cheela* mix

The *Cheela*'s sensory attributes were evaluated on days 0, 15, and 30. On day 0, it showed high acceptability in terms of appearance (8.60 ± 0.62), taste (8.40 ± 0.62), flavor (8.76 ± 0.50), texture (8.60 ± 0.56), and overall acceptability (8.73 ± 0.52). By day 15, the scores remained satisfactory despite a slight decline (overall acceptability 8.43 ± 0.56). Despite being within acceptable norms, the sensory quality had significantly declined by day 30, with a overall acceptability of 8.26 ± 0.78 . The product did, however, remain satisfactory throughout, proving that it could retain an acceptable level of quality for up to 30 days with appropriate storage. Ansari *et al.* (2020) observed similar results, noting that while overall acceptance was maintained, the sensory scores of quick soup mixes enriched with *Moringa oleifera* gradually decreased over storage.

formulation. With relatively minor changes in moisture content and microbial load, the generated instant mix was found to be microbiologically safe and acceptable throughout the storage period. Thus, one potential strategy is to use drumstick leaves to create a convenient, nutrient-dense food product with higher calcium value and functional advantages.

5. Acknowledgment

The authors extend their heartfelt appreciation to the Department of Food Science and Nutrition, College of Community and Applied Sciences, Maharana Pratap University of Agriculture and Technology (MPUAT), Udaipur, for providing the essential infrastructure, resources, and institutional support that facilitated the successful completion of this research. The authors also gratefully acknowledge the faculty and laboratory personnel of the department for their continuous guidance, technical expertise, and valuable assistance throughout the course of the study.

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