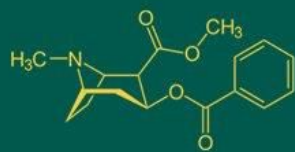


International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2026): 5.29
IJABR 2026; SP-10(2): 370-373
www.biochemjournal.com
Received: 15-11-2025
Accepted: 17-12-2025

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Biochemical and nutritional evaluation of a finger millet (*Eleusine coracana*)-based instant Laddu mix

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DOI: <https://www.doi.org/10.33545/26174693.2026.v10.i2Se.7614>

Abstract

Millets are increasingly recognized as climate-resilient and nutrient-dense cereals capable of addressing emerging nutritional and lifestyle-related health challenges. Finger millet (*Eleusine coracana* L.), popularly known as ragi, is distinguished by its exceptionally high calcium content, dietary fibre and rich in phenolic compounds. However, its utilization in modern diets has declined due to changing food habits and limited availability of convenient ready-to-use products. The present study aimed to develop and evaluate a finger millet-based instant laddu mix formulated with value-added ingredients. Two formulations were prepared using finger millet flour with either roasted groundnut or roasted sesame seed as the major fortifying ingredient. The mixes were analysed for proximate composition and selected mineral content, and sensory acceptability was assessed using a nine-point hedonic scale. The results indicated that both formulations possessed low moisture content (5.95-6.56 g/100 g), moderate fat (6.63-6.70 g/100 g) and appreciable levels of dietary fibre (3.14-5.44 g/100 g), protein (5.66-6.72 g/100 g) and iron (9.27-10.71 mg/100 g). The sesame-based formulation showed higher protein and mineral content, while the groundnut-based formulation exhibited superior dietary fibre. Sensory evaluation revealed good overall acceptability for both products, with a marginal preference for the sesame-based mix. From a functional perspective, the product offers potential benefits related to glycaemic moderation, mineral bioavailability and antioxidant intake. In addition, the simplicity of processing and use of locally available raw materials provide opportunities for rural entrepreneurship and women-led self-help groups. Thus, product can serve as a culturally acceptable functional food while contributing to nutritional security and livelihood generation.

Keywords: Finger millet, functional food, instant mix, nutritional quality, sensory evaluation, rural entrepreneurship

Introduction

Millets have traditionally served as staple cereals for millions of people inhabiting arid and semi-arid regions owing to their adaptability to marginal soils, low water requirement and tolerance to climatic stress. In recent years, renewed scientific and policy attention has positioned millets as “nutri-cereals” because of their superior nutrient density and health-promoting properties compared with major cereals such as rice and wheat (ICAR-IIMR, 2023; Saleh *et al.*, 2013) [8, 14]. Among the different millet species, finger millet (*Eleusine coracana* L.) is of particular nutritional significance. It contains exceptionally high levels of calcium (300-350 mg/100 g approximately), appreciable quantities of iron, zinc and magnesium and is rich in dietary fibre and polyphenolic compounds with antioxidant activity (Devi *et al.*, 2014; Gupta *et al.*, 2017) [5, 7]. The starch of finger millet is slowly digestible, contributing to a relatively low glycaemic index, which is beneficial for the dietary management of diabetes and metabolic disorders (Kumar *et al.*, 2018) [9]. Despite these advantages, consumption of millets has declined markedly over the past few decades. Urbanization, changing dietary preferences, convenience-driven food choices and the dominance of rice and wheat in public food distribution systems have collectively contributed to reduced millet intake, even in traditionally millet-growing regions (Pingali, 2015; Anitha *et al.*, 2021) [12, 1]. Consequently, populations that once relied on millets are increasingly vulnerable to micronutrient deficiencies and diet-related non-communicable diseases.

Recent evidence from Assam indicates a rapid transition in dietary behaviour, particularly among adolescents, characterised by increased consumption of energy-dense and nutrient-

poor processed foods, which may aggravate the risk of micronutrient deficiencies and future metabolic disorders (Borthakur and Borthakur, 2025) ^[4]. Such dietary transitions further underline the importance of developing culturally acceptable, nutrient-dense and convenient food formulations using locally available cereals such as finger millet.

Value addition through development of convenient, ready-to-use and culturally familiar products is widely regarded as a practical strategy to improve millet utilization and market demand. Traditional products such as laddu are popular across different age groups in India and offer an ideal platform for incorporating nutritionally superior ingredients without compromising sensory acceptability (Rao and Reddy, 2022) ^[13]. Instant mixes, in particular, reduce preparation time and facilitate adoption among urban consumers, school feeding programmes and institutional catering systems. The inclusion of natural sweeteners and oil-rich seeds or nuts such as sesame and groundnut can further enhance the nutritional and functional quality of millet-based products. Sesame seeds are recognized for their high calcium content and lignan compounds such as sesamin and sesamol, which possess antioxidant and lipid-lowering properties (Pathak *et al.*, 2014) ^[11]. Groundnut contributes high-quality plant protein, monounsaturated fatty acids and bioactive phytochemicals associated with cardiovascular health (Arya *et al.*, 2016) ^[3].

The inclusion of dry fruits enhances the micronutrient profile, while the gluten-free nature of finger millet makes it suitable for individuals with celiac disease or gluten intolerance (Sharma *et al.*, 2023) ^[15]. Beyond nutritional considerations, millet-based value-added products also carry substantial socio-economic importance. Processing and marketing of such products can be effectively undertaken at the community level, creating livelihood opportunities for women-led self-help groups and small rural enterprises, thereby linking nutrition interventions with income generation (Rao and Reddy, 2022; Anitha *et al.*, 2021) ^[13, 1]. Against this background, the present study was undertaken in the context of India's national millet promotion initiatives and the United Nations declaration of the International Year of Millets. The objectives were (i) to develop finger millet-based instant laddu mixes using locally available fortifying ingredients, (ii) to evaluate their nutritional and sensory characteristics and (iii) to examine their functional and socio-economic relevance for extension and rural development programmes.

Materials and Methods

Raw materials: Finger millet grains, groundnut, sesame seeds, powdered sugar and cardamom were procured from the local market. Finger millet grains were cleaned manually to remove extraneous matter and subsequently milled into fine flour using a laboratory hammer mill. Groundnuts and sesame seeds were roasted separately and ground to a coarse powder.

Formulation of laddu mix: Two formulations were prepared to study the influence of different fortifying ingredients on nutritional and sensory properties.

Sample 1 (Groundnut-based mix): Finger millet flour (70 g), powdered sugar (20 g), roasted and crushed groundnut (9 g), cardamom powder (1 g).

Sample 2 (Sesame-based mix): Finger millet flour (70 g), powdered sugar (20 g), roasted and ground sesame seeds (9 g), cardamom powder (1 g).

The ingredients were blended thoroughly to obtain a uniform instant mix. The mixes were packed in airtight containers and stored at ambient conditions prior to analysis.

Proximate and mineral analysis

Moisture, ash, crude protein, crude fat, crude fibre and carbohydrate (by difference) contents were determined following standard AOAC procedures (AOAC, 2019) ^[2]. Iron and calcium contents were estimated using standard mineral analysis techniques after wet digestion of samples.

Sensory evaluation

Sensory acceptability of the formulated laddu mixes was evaluated by a panel of thirty semi-trained judges comprising faculty members and postgraduate students of the Department of Food Science. Samples were coded with random three-digit numbers and presented in randomized order to minimize positional bias. Reconstituted laddus prepared from the mixes were evaluated for colour, flavour, texture, taste and overall acceptability using a nine-point hedonic scale (1 = dislike extremely; 9 = like extremely).

Statistical analysis

Mean values were calculated for all analytical and sensory parameters. Descriptive statistics were used to compare the two formulations.

Results and Discussion

Nutritional composition

The proximate and mineral composition of the developed instant laddu mixes revealed from proximate analysis is presented in Table 1.

The moisture content of both formulations was low (6.56 g in Sample 1 and 5.95 g in Sample 2), indicating better shelf stability and reduced susceptibility to microbial spoilage. Low moisture is an important quality attribute for instant mixes, as it contributes to extended storage life under ambient conditions (Kumar *et al.*, 2018) ^[9]. The ash content reflects the presence of essential minerals and was marginally higher in the sesame-based formulation, which may be attributed to the naturally high mineral density of sesame seeds. Similar trends have been reported for millet products fortified with oilseeds (Pathak *et al.*, 2014) ^[11].

Table 1: Nutritional composition of finger millet-based instant laddu mixes (per 100 g)

Parameter	Sample 1 (Groundnut)	Sample 2 (Sesame)
Moisture (g)	6.56	5.95
Ash (g)	1.75	1.91
Fat (g)	6.63	6.70
Fiber (g)	5.44	3.14
Protein (g)	5.66	6.72
Carbohydrate (g)	79.40	78.90
Iron (mg)	9.27	10.71
Calcium (mg)	93.16	108.77

Moderate fat content observed in both samples (6.63 g and 6.70 g) contributes to palatability and energy density. The fat fraction derived from groundnut and sesame seeds is rich in unsaturated fatty acids, which are considered beneficial for cardiovascular health (Arya *et al.*, 2016) ^[3]. The

groundnut-based mix recorded higher dietary fibre content (5.44 g) than the sesame-based mix (3.14 g), possibly due to differences in the fibre composition of the fortifying ingredients and processing behaviour. Protein content ranged from 5.66 to 6.72 g/100 g, with the sesame-based formulation showing a relatively higher value. Although finger millet itself contains moderate protein, its amino acid profile is complemented by legumes and oilseeds, improving overall protein quality (Saleh *et al.*, 2013) ^[14].

High carbohydrate content reflects the dominance of finger millet flour in the formulation. However, unlike refined cereal-based products, finger millet starch is associated with slower digestibility and a lower post-prandial glycaemic response (Kumar *et al.*, 2018) ^[9]. This characteristic enhances the suitability of the developed mixes for individuals seeking better glycaemic control.

The iron content of both formulations (9.27 g and 10.71 g) was nutritionally significant, with the sesame-based mix providing higher iron. This is particularly relevant in the Indian context, where iron-deficiency anaemia remains a major public health concern. The calcium content of the mixes was also appreciable (93.16 mg and 108.77 mg) and the sesame-based mix exhibited higher calcium owing to the inherently high calcium concentration of sesame seeds. Adequate dietary calcium intake is critical for bone mineralization, particularly among children, pregnant women and elderly populations (Gupta *et al.*, 2017) ^[7].

From a functional perspective, finger millet is a rich source of polyphenols and dietary fibre that exert antioxidant, anti-inflammatory and cholesterol-lowering effects (Devi *et al.*, 2014) ^[5]. The incorporation of sesame further contributes lignans such as sesamin, which have been shown to improve lipid metabolism and oxidative stability (Pathak *et al.*, 2014) ^[11]. Therefore, the developed product can be positioned not only as a nutrient-dense food but also as a functional food capable of supporting metabolic health. Further, the inclusion of jaggery and dry fruits enriched the micronutrient profile, adding iron, potassium and essential fatty acids. These findings align with earlier studies on millet-based functional foods (Malleshi and Desikachar, 1986; Rao and Reddy, 2022) ^[10, 13].

Sensory evaluation

Both formulations received high scores for overall acceptability. The sesame-based formulation was rated marginally higher for flavour and texture. The roasted sesame imparted a pleasant nutty aroma and enhanced mouthfeel, which complemented the characteristic earthy flavour of finger millet. Similar consumer preferences for sesame-fortified millet products have been reported in earlier studies (Rao and Reddy, 2022) ^[13]. The high sensory acceptability suggests that traditional product formats such as laddu can effectively bridge the gap between nutritional superiority and consumer preference, which is often a major limitation in the promotion of millet-based foods.

Socio-economic and extension relevance

The developed instant laddu mix has considerable potential for adoption at the community and small-enterprise level. The processing steps involved are simple and require minimal capital investment, making the technology suitable for women-led self-help groups and farmer producer organizations. Local procurement of finger millet, sesame and groundnut can strengthen backward linkages with

smallholder farmers and promote diversified cropping systems. Incorporation of such products into school feeding programmes, anganwadi nutrition interventions and community-level health initiatives can simultaneously address nutritional deficiencies and create sustainable livelihood opportunities. This dual impact aligns with national strategies aimed at improving nutritional security while promoting millet-based agri-enterprises (Government of India, 2023; Anitha *et al.*, 2021) ^[6, 1].

Conclusion

The present study successfully developed and evaluated finger millet-based instant laddu mixes enriched with groundnut and sesame seeds. Both formulations exhibited favourable nutritional profiles, with appreciable levels of dietary fibre, protein, iron and calcium, along with good sensory acceptability. The sesame-based formulation demonstrated superior mineral content and consumer preference for flavour and texture. The functional attributes associated with finger millet polyphenols, low glycaemic response and oilseed-derived bioactive compounds enhance the health relevance of the product. In addition, the simplicity of production and reliance on locally available raw materials make the technology suitable for rural entrepreneurship and women-centred livelihood initiatives. Promotion of such value-added millet products through extension and nutrition programmes can contribute meaningfully to food and nutritional security as well as inclusive socio-economic development.

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