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Development of value-added ragi barfi by incorporating mudakathan (*Cardiospermum halicacabum*) and evaluation of its sensory, shelf life and nutrient analysis

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ABSTRACT

Introduction: Insufficient dietary calcium intake has resulted in calcium deficiency affecting half of the population, which has implications for bone strength and an increased risk of osteoporosis in post-menopausal women. Barfi made from ragi flour and mudakathan leaves powder provides various benefits, including antioxidants, anti-arthritic, anticancer, and anti-inflammatory properties. The present research aimed to develop ragi barfi incorporating mudakathan (*Cardiospermum halicacabum*) and to evaluate its sensory acceptability, as well as to analyse the micronutrient (calcium and vitamin D) and macronutrient contents of the developed products. **Methods:** Barfis were prepared using standard procedures, with one group made without mudakathan leaves powder (T0 Control) and three variations (T1, T2, and T3) made with mudakathan leaves powder in proportions of 5 grams, 10 grams, and 15 grams. These barfis were then evaluated by thirty panellists using a nine-point hedonic scale. The accepted product underwent nutrient analysis, microbial analysis for shelf life, and cost analysis. The samples were compared using one-way analysis of variance (ANOVA). **Results:** In the sensory evaluation, three variations (T1, T2, T3) were considered; T3 was ultimately selected based on sensory and nutritional analysis. The barfi prepared with 15 grams of mudakathan was found to be highly acceptable in all quality attributes and demonstrated good storage ability with a shelf life of one month. **Conclusion:** This indicated that the efficient combination of mudakathan and "poor man's millet" can be utilised to reach households and address public health by promoting bone strength.

Keywords: barfi, calcium, finger millet, mudakathan (*Cardiospermum halicacabum*), sensory evaluation

INTRODUCTION

Ragi, also known as finger millet and scientifically referred to as *Eleusine coracana L.,* is a cereal crop known for its abundance of nutrients. Millet, a group of crops from the grass family Graminae/Paniceae, is cultivated worldwide for food and feed due to their adaptability to poor irrigation and low rainfall conditions (ICAR, 1987). Finger millet is a significant contributor to human health and development, as well as an expansion of genetic potential (Dida & Kebero, 2023). In ancient Indian

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Sanskrit literature, ragi is one of India's earliest crops, also referred to as "rajika" or "markataka," which means "dancing grain." In the historic Indian Tamil text "Kuruntogai," it is referred to as "Kelvaragu". The drying, husking, and cooking of the grains are described in "Purananuru", a text from Sangam Tamil literature (600 BC–200 AD) (Vagdevi *et al.,* 2023).

Ragi is one of the functional millets since it is enriched with fibre, minerals, nutrients, macronutrients, amino acids, and fatty acids (Ashik Somarajan & Morya, 2022). It has high levels of calcium, dietary fibre, protein, carbohydrates, minerals, phytates, and certain phenolic compounds. Many advantageous qualities, including antibacterial, antioxidant, and anti-diabetic capabilities are added to this crop by the presence of polyphenols (Chamoli *et al.,* 2018). Finger millet grains are low in glycaemic index, non-acid-producing, gluten-free, and easy to digest. Additionally, finger millet grains contain linolenic and palmitic acids, which are crucial for brain and neural tissue development (Ramashia *et al.,* 2019). According to published estimates, almost half of the globe's population has insufficient access to dietary calcium, which is regarded as a worldwide problem (Shlisky *et al.,* 2022). Additionally, it offers various health benefits, including anti-diabetic, anti-tumorigenic, atherosclerogenic, antioxidant, and antimicrobial properties (Anitha, Bhavani & Malini, 2022).

When compared to other grains and millets, ragi has the highest calcium content. Household food processing techniques are applied in order to improve its nutritional value, increase its consumption, feed the general population, and aid in illness prevention and treatment (Singh & Sarita, 2016). It is a nutrient-dense food that can be consumed in several ways, including as weaning food products, health food products, pasta products, fermented food products, baked food products, fried food products, and household food products (Thomas & Karuna, 2019). Developing new food products with unique health-improving properties is becoming more difficult as a result of growing nutritional awareness in the public (Devi *et al.,* 2014).

Cardiospermum halicacabum, a member of the Sapindaceae family, is the scientific name for balloon vine plant (mudakathan). It is an accessible plant that is edible. The leaf has been found to have antibacterial, antifungal, antiparasitic, anxiolytic, memory-enhancing, hypoglycaemic, antipyretic, antioxidant, and antihyperlipidemic activities, as well as central nervous system depression, anti-rheumatic, antidiarrheal, and anti-inflammatory properties. Since antiquity, India has had a far higher rate of plant popularity than any other nation in the globe. In India, leaves are a great source of nourishment and are consumed as food (Suganya, 2018). Mudakathan's significance as a possible anticancer drug is made clear by its antioxidant activity, which is likewise highly significant. Its seeds, stem, roots, and leaves are all used in herbal medicine (Jenny & Baskar 2019). Considering its numerous health benefits and lack of toxicity, Indian traditional healers currently recommend its leaves to patients (Gaziano *et al.,* 2019).

Millet barfi that contains *Cardiospermum halicacabum* has an increased biological value with a wealth of nutrients, calcium, antioxidants, amino acids, vitamins, and minerals without irritating or burning the stomach (Ayyappadasan, Rubavathi & Ilakiya, 2022). Hence, incorporating mudakathan into a product formulation can help prevent calcium deficiency and boost overall immune health. From the available literature, there is a research

study that focused on the standardisation and optimisation of mudakathan use, utilising two millets and two herbs (Ayyappadasan *et al.,* 2022). In our current study, we focused on using ragi, the sole millet, and mudakathan, the sole herb, to create a product known as ragi barfi. Barfi, a popular sweet across India, is a khoa-based dessert with a texture akin to fudge; ragi barfi, on the other hand, incorporates millet ragi. This research hopes to address the gap in studies exploring mudakathan in product formulation. With that, our study aimed to develop ragi barfi with mudakathan leaves powder (*Cardiospermum halicacabum*) and evaluate its sensory attributes, shelf life, and nutrient content.

METHODOLOGY

The study design employed in this research was experimental, following the guidelines set by Kothari (2011). Approval from the Institutional Ethics Committee (CSP/23/JUL/132/662) at Sri Ramachandra Institute of Higher Education and Research (deemed to be a university) was obtained, along with registration under DHR/ICMR Registration No: EC/NEW/INST/2023/TN/0321. Informed consent was acquired from volunteers involved in the organoleptic evaluation of the product.

Description of the setting

Phase I

The product was formulated and standardised at the food science laboratory under the Department of Clinical Nutrition at Sri Ramachandra Institute of Higher Education and Research in Chennai, Tamil Nadu, India.

Phase II

The final developed product was evaluated by 30 individuals across different age groups, which included children, adolescents, adults, and professional nutritionists. Nutrient analysis and shelf life evaluation were conducted at a National Accreditation Board for Testing and Calibration Laboratories (NABL)-accredited laboratory after the sensory evaluation process.

Detailed methodology

Phase I: Formulation and standardisation of ragi barfi incorporated with mudakathan (Cardiospermum halicacabum)

The researcher prepared powdered mudakathan (*Cardiospermum halicacabum*) from the leaves of mudakathan in the lab for the formulation of ragi barfi. Following that, the main ingredient, ragi, was sourced in its pure form. Additional ingredients, such as jaggery powder, water, and ghee, were procured from the local market in Kundrathur, Kanchipuram district, Tamilnadu, India. The mudakathan powder was used in three different proportions: 5 grams (g) in trial I, 10 g in trial II, and 15 g in trial III for product formulation. Standardisation of a product involved repeated testing to ensure consistent volume and yield, often through a trial-and-error process. Multiple trials were conducted to establish an appropriate formula for manufacturing the product, with final amounts determined based on differences in appearance, colour, taste, texture, and flavour.

Preparation of barfi

Before grinding the mudakathan leaves into fine powder at room temperature, they were sun-dried for seven days. In a non-stick kadai, 10 ml of ghee was heated, then 30 g of ragi flour was added to it, followed by 5 g of Mudakathan powder; sauteed for 6 to 8 minutes on low flame. 100 ml of water was mixed with 40 g of powdered jaggery, heated until it reached thread consistency, then

Table 1. Average scores of organoleptic evaluations on products

Product	*Appearance (9)*	*Colour (9)*	*Taste (9)*	*Flavour (9)*	*Texture (9)*	*Overall acceptability (9)*
Trial I	8.1±0.7	8.1±0.7	7.7±0.7	7.5±0.6	7.7±0.6	7.7±0.7
Trial II	7.9±0.8	7.8±1.0	7.8±0.8	7.7±0.8	7.8±0.7	7.7±0.7
Trial III	8.1±0.8	8.0±1.0	8.0±1.0	8.0±1.0	8.0±0.6	8.1±0.7

strained. The roasted mixture was added and kept at a low flame to make sure that there were no lumps. The mixture was cooked on a low flame (121°C) for 15 minutes until it became non-sticky and started to hold its shape. An aluminium tray was greased with ghee and the mixture was spread evenly. The barfi was sliced into squares while it was still hot. After it cooled, the squares were taken apart and individually wrapped in silver foil.

Phase IIa: Sensory analysis of the product
The developed food products were represented as Trial I, Trial II, and Trial III. An organoleptic evaluation of these products – T_1 (30:15:40:10), T_2 (30:10:40:10), and T_3 (30:5:40:10) was carried out with thirty participants from various age groups, including children, teenagers, adults, and professional nutritionists. This assessment focused on sensory attributes such as appearance, aroma, taste, texture, and overall preference, utilising a nine-point hedonic scale. The scoring system ranged from 9 to 1, with 9 indicating "liked very much" and 1 indicating "disliked very much". The quality parameters for all samples were analysed and the average scores were computed.

Phase IIb: Nutrient value and shelf life analyses of the formulated products
The final product (i.e., T_3) and control barfi (without mudakathan, i.e., T_0) underwent a comprehensive analysis for its nutritional components, including energy (kcal), carbohydrates (g), protein (g), fat (g), fibre (g), calcium (mg), and vitamin D (mcg). This analysis was conducted using the methods outlined in (ALPL/FD/SOP/067), (ALPL/FD/SOP/065), (IS 7219:1973), (IS 12711:1989), (FSSAI LAB MANUAL), (IS: 5949:1990), and (AOAC 21st Edn. 2016, 982.29) at a NABL-accredited laboratory. A sample weighing 200 g of the final product was securely packed in an air-tight container and submitted for testing. Additionally, the shelf life of the product was evaluated in the same accredited laboratory through total plate count (IS: 5402: 2012), coliforms (IS: 5401 (Part 1): 2012), and yeast and mould (IS: 5403: 1999) analyses.

Statistical analysis
Data collected from organoleptic assessment were statistically analysed using mean and standard deviation (*SD*). One-way analysis of variance (ANOVA) was employed to compare the samples, with statistical significance set at $p \leq 0.05$, using IBM SPSS Statistics for Windows version 25.0 (IBM Corporation, Armonk, New York, USA).

RESULTS

Table 1 presents the average scores from the organoleptic evaluation, which considered attributes such as appearance, colour, taste, flavour, texture, and overall acceptability. Among the three product trials, Trial III, which featured ragi barfi with mudakathan, received the highest average score compared to Trial I and Trial II. The mean ± *SD* for the three trials were 7.82±0.06, 7.78±0.11, and 8.07±0.16, respectively.

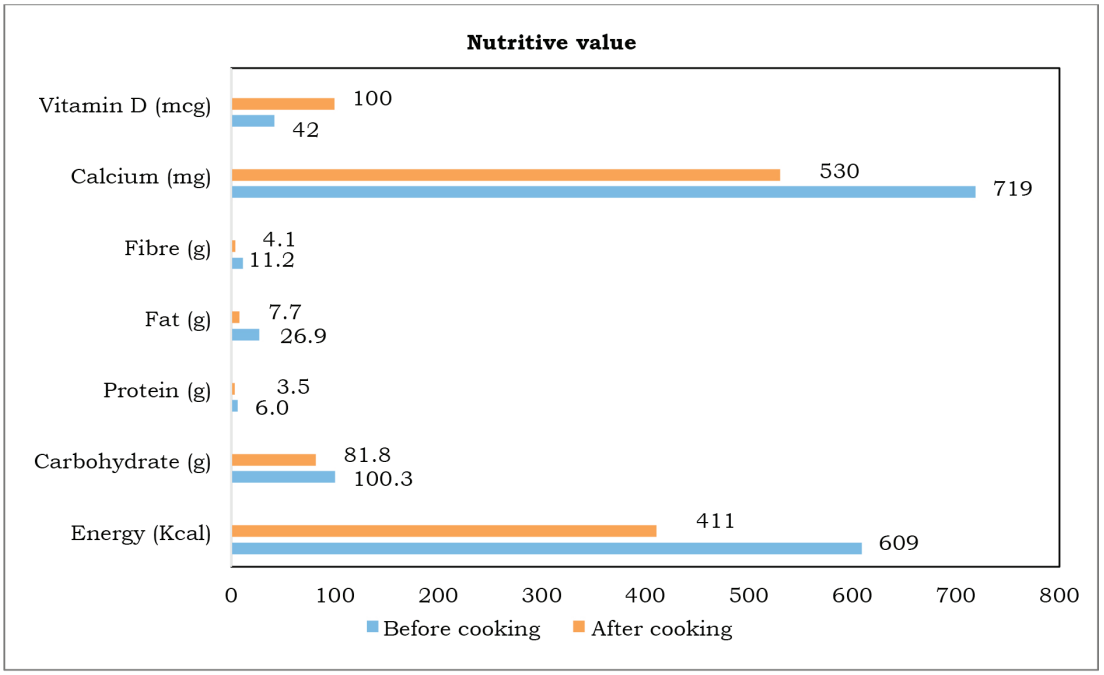

Figure 1: Nutritive values of ragi barfi incorporated with mudakathan before and after cooking - Trial III

The nutritional values of raw ingredients (before cooking) were referenced from the Indian Council of Medical Research (ICMR)-National Institute of Nutrition, while the developed products (after cooking) were analysed by the National Accreditation Board for Testing and Calibration Laboratories, as illustrated in Figure 1. The substantial enhancement in vitamin D levels may be ascribed to the cooking techniques employed in this research, particularly the combination method that featured both sauteeing and boiling processes. The analysis included macronutrients like energy, carbohydrates, protein, fat, and fibre, along with micronutrients such as calcium and vitamin D. Table 2 illustrates the comparative nutritive values of ragi barfi incorporated with mudakathan from Trial III against the control barfi (ragi barfi without mudakathan).

The nutrient analysis report indicated that control barfi contained 106 mg of calcium, 1 mcg of vitamin D, and 2.5 g of fibre per 100 g. In comparison, ragi barfi incorporated with mudakathan (T3 formulation of 30:5:40:10) exhibited markedly elevated levels of calcium, vitamin D, and fibre, measuring at 530 mg, 100 mcg, and 4.1 g per 100 g, respectively. The fat content in control barfi was noted to be 7.9 g, while ragi barfi with mudakathan exhibited a slightly reduced fat content of 7.7 g. This decrease can be attributed to the lower fat content inherent in millet flour combined with leaves. The protein content in ragi barfi with mudakathan was recorded as 3.5 g, in contrast to 4.8 g in the control sample. The elevated protein level in the control may be a result of the high protein content found in ragi millet. Additionally, the energy content of ragi barfi with mudakathan

Table 2. Comparison of nutritive values between control barfi and ragi barfi incorporated with mudakathan Trial III

Nutrients	*Control barfi (without mudakathan)*	*Ragi barfi incorporated with mudakathan trial III*
Energy (kcal)	419	411
Protein (g)	4.8	3.5
Carbohydrate (g)	82	82
Fat (g)	7.9	7.7
Fibre (g)	2.4	4.1
Calcium (mg)	106	530
Vitamin D (mcg)	1	100

was 411 kcal, whereas control barfi (without mudakathan) had an energy content of 419 kcal per 100 g.

The developed product had been meticulously formulated to meet the calcium requirements of various age groups and did not exceed the Recommended Dietary Allowance (RDA) 2020 guidelines (ICMR, 2020). Table 3 provides a summary of the ragi barfi incorporated with mudakathan, highlighting that this product meets 50% of the calcium RDA for children aged 4-6 years, 41% for those aged 7-9 years, 47% for children aged 10-12 years, 53% for adolescents aged 13-15 years, 50% for individuals aged 16-18 years, 53% for both adult men and women, and 44% for lactating women.

The Bureau of Indian Standards (BIS) (IS: 5550:2005) stated that the standard plate count for barfi should not exceed 30,000/g and the yeast and mould count should not exceed 10 CFU/g barfi. The microbial load of the sample on both the Nutrient Agar and Sabouraud's Agar plate was found to be less than 10 CFU/g within the BIS-recommended range. The shelf life of the product was determined to be four weeks, as shown in Table 4.

Prices of each ingredient from the local market were added up to estimate the cost, including overhead. For a 100 g serving, which is made up of four pieces of ragi barfi with mudakathan, currently it costs US Dollar 0.8. In comparison, other similar products are sold for around US Dollar 2.8 to US Dollar 3.4 (1 US Dollar = 87.2 Indian Rupees as of 12 March 2025). The developed product is definitely a more affordable and budget-friendly option.

DISCUSSION

Ragi barfi made with mudakathan (*Cardiospermum halicacabum*) has a dark brown colour and weighs 25 g per piece.

Table 3. Recommendations of the product for different age groups according to Recommended Dietary Allowance (RDA) for calcium (ICMR, 2020).

Age group	*RDA (2023)*	*Quantity recommended*	*Calcium content in recommended quantity*	*% met of RDA*
Children (4-6years)	550mg	2 pieces	265mg	50%
Children (7-9years)	650mg	2 pieces	265mg	41%
Children (10-12years)	850mg	3 pieces	397mg	47%
Children (13-15years)	1000mg	4 pieces	530mg	53%
Children (16-18years)	1050mg	4 pieces	530mg	50%
Adult men and women	1000mg	4 pieces	530mg	53%
Lactating women	1200mg	4 pieces	530mg	44%

Table 4. Microbial analysis of the product

S. No	*Parameters*	*Test method*	*Results*			
			10^{th} day	*20^{th} day*	*30^{th} day*	*Unit*
1.	Total plate count	IS:5402:2012	<10	30	100	CFU/g
2.	Coliforms	IS:5401 (Part I): 2012	<10	<10	<10	CFU/g
3.	Yeast & mould	IS:5403:1999	<10	<10	<10	CFU/g

This finding is supported by research conducted by Ranjeet & Aparna (2021). The study indicated that ragi barfi is appropriate for people of all ages since it is packed with nutrients, especially calcium, and also provides vitamin D. Supporting this, a study by Sanjay *et al.* (2017) highlighted that finger millet is crucial for the diets of children, as well as for pregnant and lactating mothers. Ragi is often referred to as a staple for the less fortunate, as it combats malnutrition and is nutrient-dense with substantial amounts of calcium and vitamin D. With the addition of sun-dried mudakathan leaves powder, this further enhanced its nutritional profile by augmenting both vitamin D and calcium contents. This aligns with findings from Ayyappadasan *et al.* (2022), who revealed that millet barfi combined with extracts from *Cardiospermum halicacabum* and *Ocimum tenuiflorum* offers improved nutritional benefits. Even without mudakathan, ragi barfi still provides vital nutrients such as energy, carbohydrates, protein, fat, fibre, and calcium. Trial III of the ragi barfi made with mudakathan showed similar nutrients to the standard version, but with significantly higher levels of calcium and vitamin D due to the added ingredient. Moreover, the incorporation of mudakathan leaves powder with ragi flour also contributed to an increase in the fibre content of the final product, which is advantageous for digestive health. Thus, ragi barfi with mudakathan is more beneficial than the regular version, potentially aiding in the prevention of calcium deficiency and enhancing overall nutrition.

Strengths of the study

There was a noticeable gap in research regarding the formulation of products that utilise mudakathan. However, when mudakathan, known for its medicinal properties, was added to ragi flour, it significantly enhanced the nutritional content, especially calcium and vitamin D, yet was low in fat. According to the current research, calcium level in ragi barfi incorporated with mudakathan was five times greater, while vitamin D content was an incredible 100 times higher compared to the regular barfi.

Limitations of the study

Different consumer segments may react uniquely to a ragi barfi made with mudakathan, based on their experience with the ingredients and their taste inclinations. Although a shelf life of one month is generally acceptable, it may limit the possibilities for distribution and storage, especially when the product must be transported over long distances or stored in suboptimal conditions.

CONCLUSION

In this study, we formulated a health-orientated ragi barfi that incorporated mudakathan, which had a distinctive flavour and improved nutritional content. This product is meant to be a healthier choice compared to traditional sweets, which often provide too many empty calories. The ragi barfi incorporated with mudakathan is a good source of micronutrients, particularly calcium and vitamin D, which are vital for children, teenagers,

athletes, and pregnant or lactating women. The formulated product may assist in preventing calcium deficiency and boosting the overall nutrition of the community when combined with a healthy lifestyle. Future research may explore the supplementation of this product for various medical conditions such as osteoporosis.

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Authors' contributions

Saraswathi S, principal investigator, conceptualised and designed the study, prepared the draft of the manuscript, and carried out the research work such as product development, organoleptic evaluation, paper writing, and primary responsibility for final content under the guidance of Hema TH; Hema TH, performed plagiarism check; Hemamalini AJ; prepared and obtained the paper works for the research such as ethical clearance and permission letters.

Conflict of interest

The authors declare no conflict of interest.

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