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Research Article

Formulation of paneer spread incorporated with malted ragi (*Eleusine coracana*) flour

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Abstract

This investigation focused on the development of a functional paneer spread supplemented with malted ragi (*Eleusine coracana*) flour, aiming to enhance its nutritional and functional profile while maintaining desirable sensory attributes. The product was formulated using paneer prepared from premium buffalo milk, combined with malted ragi flour, unsalted butter, and citric acid as the coagulating agent. Lecithin serves as an emulsifier, while rosemary extract acts as a natural antioxidant, with salt and water completing the formulation. The specific ingredient composition was optimized using Response Surface Methodology (RSM) to ensure structural stability and product uniformity. A control sample was prepared with the same formulation but without the malted ragi flour to enable a comparative assessment. Sensory testing indicated positive acceptance for the paneer spread containing ragi. There was no significant difference in moisture, protein, ash, titratable acidity, viscosity and spreadability between the ragi-enriched spread and the control. However, the ragi-enriched spread exhibited higher fiber content and a lower fat level compared to the control. The product also maintained desirable physicochemical and microbiological standards, ensuring both quality and safety. The integration of malted ragi flour not only enhanced the functional value of the product but also aligned with current consumer trends toward health-oriented, clean-label dairy innovations. Ragi, as a nutrient rich millet, plays a vital role in the human diet by providing essential nutrients, supporting overall health, and promoting sustainable food practices.

Keywords: Dairy spread, Malted ragi, Paneer spread, Spreadability, Viscosity

Highlights

- Incorporation of malted ragi flour significantly enhanced the nutritional profile of the paneer spread.
- The formulated spread is a cost-effective, nutritious alternative to butter and cheese.
- Optimization of the formulation was achieved through RSM, enhanced spreadability and overall quality.
- Ragi flour increased fiber, addressing a common nutritional deficiency in dairy spreads
- The developed paneer spread exhibited outstanding sensory qualities

INTRODUCTION

The increasing consumer demand for health-oriented and functional food products has driven innovation in the dairy and spread segments. Spreads are typically soft food products that can be applied in a thin layer onto bread, pizza bases, chapatis, and other items. Common examples include margarine, butter, and various fat-based mixtures. Among dairy spreads, fresh butter is a popular choice due to its rich flavour and creamy texture; however, it is often more expensive and has limitations such as poor spreadability, high cholesterol, and saturated fat content. Consequently, there is a growing interest in alternative, healthier spread options.

India remains a leading producer of paneer (cottage cheese), with key contributions from states like Punjab, Haryana, Uttar Pradesh, and Maharashtra. The domestic demand for paneer has been steadily increasing, driven by rising consumer awareness of vegetarian, protein-rich diets and the expanding foodservice industry. According to the Department of Animal Husbandry and Dairying, Government of India, the paneer market was valued at INR 648.05 billion in 2024 and is projected to grow to INR 2.03 trillion by 2033, with a compound annual growth rate (CAGR) of 12.85% from 2025 to 2033. This growth is supported by the increasing vegetarian demographic, expanding retail channels, and ongoing product innovations.

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Paneer offers broad culinary versatility, serving as a nutritious base for developing value-added products by incorporating dietary fiber, whey protein, or components derived from non-dairy sources.

Paneer spreads offer notable advantages over other dairy or vegetable spreads, including their high-quality protein content, essential nutrients, and natural ingredients, making them a healthier alternative. Their creamy, smooth mouthfeel and subtle flavour make them suitable for a wide range of uses, from sandwiches to dips. Paneer is rich in calcium, supporting healthy bones and teeth, and its natural makeup reduces the need for artificial additives or preservatives. Combined with these nutritional benefits, paneer spreads appeal to consumers seeking wholesome, tasty choices.

In addition to dairy-based spreads, millets particularly finger millet or ragi has gained recognition for its nutritional and cultural significance. Ragi is among the oldest domesticated grains and is highly valued for its impressive nutritional content. It provides essential nutrients such as vitamins A and B, proteins, phosphorus, dietary fiber, and key amino acids. Finger millet is particularly noted for its high levels of protein, carbohydrates, and fiber. On average, 100 g of raw ragi contains about 3.3 g of protein, 79.1 g of carbohydrates, 1.8 g of fat, 3.7 g of dietary fiber, and 1.7 g of ash. It is also a good source of important minerals like calcium and iron, along with several B-complex vitamins (Longvah et al., 2017). Its polyphenolic compounds underpin a variety of health advantages, including hypoglycemic, antibacterial, anticancer, and antioxidant effects, as noted in studies by Pradhan et al. (2010), Kuruburu et al. (2022), Jha et al. (2025), and Kumari et al. (2025). Despite its nutritional advantages, millet has often been overlooked in favor of staple cereals like wheat, rice, and maize. Considering millet's potential to improve global nutrition and bolster climate resilience, the United Nations proclaimed 2023 the International Year of millets.

From a nutritional perspective, finger millet surpasses many other cereals in calcium and potassium content and provides higher levels of dietary fiber, essential amino acids, and minerals compared to common cereals (Onipe & Ramashia, 2022). This positions millet as a valuable ingredient in developing functional foods aimed at promoting wellness and combating nutritional deficiencies. This research seeks to create a health-focused, nutrient-rich paneer spread enriched with malted ragi flour. Leveraging paneer's protein and calcium along with the fiber, minerals, and advantages of malted ragi flour, the formulation targets the rising market for functional foods that promote well-being, especially in populations with restricted access to diverse diets.

MATERIALS AND METHODS

Materials

Paneer was prepared using buffalo milk (7% fat and 9.5% solids-not-fat) procured from the Instructional Livestock Farm at Kerala Veterinary and Animal Sciences University, Pookode. Food-grade citric acid, obtained from the local market and compliant with food safety norms, served as the primary milk coagulant. Carefully selected ragi grains, chosen based on physical attributes such as uniformity in size and colour and free from visible defects or foreign matter, were used in the formulation. Unsalted butter of the Amul brand (Gujarat Co-operative Milk Marketing Federation Ltd.) containing a minimum of 80% milk fat, was incorporated as the lipid phase. Lecithin, an emulsifier from the Urban Platter, Mumbai, and rosemary extract, used as a natural antioxidant and procured from Plant Lipids Pvt Ltd., Kochi, Kerala, were also included. The study utilized analytical-grade chemicals sourced from Himedia Biosciences (Mumbai, India) and Sigma-Aldrich (St. Louis, MO).

Methods

Preparation of paneer: The paneer was prepared following the method described by Sachdeva et al. (1985), with slight modifications. Buffalo milk was heated to 90°C and then cooled to 70°C. A 70°C preheated 2% citric acid solution was added to the milk, causing it to coagulate, and the mixture was left for about 5 minutes. The curd was then strained through muslin cloth, pressed at 230 kg/m² for 15 minutes to remove excess whey, and chilled with cold water for 10 minutes to improve texture. The resulting paneer was stored under refrigeration for spread preparation.

Malted ragi flour (MRF) preparation: The process of malting ragi (*Eleusine coracana*) was slightly modified from the method by Nirmala and Muralikrishna (2002) to improve flour quality. First, the ragi seeds were washed five times with clean water to remove dirt. Then, they were soaked in drinking water for 12 hours at room temperature to start germination. After soaking, the seeds were drained, wrapped loosely in a damp muslin cloth to keep moisture, and incubated at 27±3°C for 48 hours to sprout. Once sprouted, the seeds were dried in a hot air oven at 65°C for 24 hours. The dried seeds were cooled and ground into fine flour using an electric grinder. The flour was stored in airtight bottles for future use.

Malted ragi flour added paneer spread preparation: The paneer was crumbled into small pieces. Crumbling the paneer is essential for evenly integrating it with the other ingredients and for ensuring a smooth texture in the final product. After crumbling, the paneer was blended with unsalted butter, water, malted ragi flour, salt (1%), rosemary extract (0.1%), and lecithin (0.3%) using a household mixer grinder. Once all the ingredients are thoroughly blended, the mixture is pasteurized at 72°C for 15-20 seconds. Following pasteurization, the paneer spread is cooled and packaged in airtight glass containers to prevent contamination and preserve its freshness. The containers are then stored at a controlled temperature of 4°C, which further inhibits the growth of microorganisms, ensuring the spread remains safe for consumption.

Optimization of ingredients using response surface methodology: Preliminary trials were conducted to determine the appropriate range for each major ingredient, namely paneer, malted ragi flour, unsalted butter, and water for preparing paneer spread. Based on the findings of these trials, the ingredient levels selected for optimization studies using Response Surface Methodology (RSM) with a Central Composite Rotatable Design (CCRD) are shown in Table 1. The other ingredients used were 1% edible salt, 0.1% rosemary extract, and 0.3% lecithin. The responses measured in each trial included viscosity, spreadability, and fiber content of the product.

Viscosity of paneer spread: The Brookfield viscometer was used to determine the viscosity of paneer spread by measuring the torque necessary to drive spindlerotation at a constant speed within the sample. The higher the torque, the greater the viscosity of the sample. The procedure involved filling the beaker with the sample homogeneously, ensuring no air bubbles were present. The spindle (no. L1) was inserted into the sample so that it was approximately 3 centimeters above the base of the beaker for accurate measurement. The viscometer was set to a rotation speed of 50 rpm, and the instrument recorded the resistance to spindle rotation. This resistance was then recorded as pascal-second (Pa.s).

Spreadability of paneer spread: Spreadability assessment relies on the force or work needed to separate two contacting surfaces that enclose the sample. A slightly modified parallel-plate approach, as described

Table 1. Experimental design matrix and values of viscosity, spreadability and crude fiber content of malted ragi flour incorporated paneer spread

Run	Factors/ ingredients (%)				Response variables		
	Paneer	Ragi	Water	Butter	Viscosity (Pa.s)	Spreadability (g.cm/s)	Fibre (%)
1	40	15.51	15	29.49	18.61	15.44	0.48
2	51.16	14.79	8.12	25.92	19.26	14.77	0.46
3	48.69	16.89	11.87	22.55	51.68	13.02	0.51
4	49.11	10	10.89	30	16.29	13.83	0.31
5	43.82	19.36	11.76	25.06	19.67	13.62	0.59
6	42	20	8	30	20.09	12.78	0.61
7	52	20	8	20	20.78	13.27	0.62
8	55.33	10	8	26.67	20.18	13.37	0.3
9	46.53	15.47	8	30	20.29	12.99	0.49
10	51.52	10	15	23.48	17.91	14.98	0.3
11	49.11	10	10.89	30	18.97	13.3	0.31
12	45	20	15	20	21.27	14.25	0.62
13	56.91	10	13.09	20	17.9	14.35	0.32
14	60	10	8.27	21.73	20.34	12.22	0.31
15	48.69	16.89	11.87	22.55	22.64	12.53	0.52
16	45.65	12.95	14.78	26.62	20.78	14.53	0.41
17	53.51	14.52	11.97	20	22.27	12.85	0.45
18	48.69	16.89	11.87	22.55	22.89	12.43	0.53
19	51.159	14.79	8.12	25.92	22.18	12.6	0.46
20	43.82	19.36	11.76	25.06	23.11	12.46	0.59

Other ingredients: 1.0% edible salt, 0.1% rosemary extract and 0.3% lecithin

by Bakhrushina et al. (2022), is employed to determine the paneer spread's spreadability. In the procedure, 2 g of the sample is placed between two glass plates each measuring 20 x 20 cm. A weight of 500 g is then placed on top of the plates for 2 minutes to facilitate the spreading of the sample between the plates. Subsequently, the diameter of the spread sample between the plates is measured. Spreadability was calculated by applying the formula below.

$$S = \frac{W X I}{t}$$

Where,
S: Spreadability in g.cm/s
W: weight used (in g)
I: Distance travelled by the spread from the centre in centimetre
t: time (in second)

Sensory analysis of paneer spread: A panel of 15 semi-trained analysts was selected. Paneer spread at room temperature, along with bread, was served, and each panellist evaluated the sample for selected attributes such as colour, texture, flavour, and overall acceptability. They marked their responses on a 9-point hedonic scale for each attribute.

Chemical and shelf-life study of paneer spread: The optimized paneer spread was stored under refrigerated conditions (4±1°C) in sterile glass containers, which provided an airtight and moisture-proof barrier, for a period of 12 days. The storage study was designed to monitor product stability at four-day intervals, during which key quality attributes including chemical, microbiological, and sensory properties were systematically evaluated.

The chemical composition of the developed paneer spread was analysed using standard methods. The moisture content was assessed using the gravimetric technique as described by Food Safety and Standards Authority of India [FSSAI] (2015), and the fat content was analyzed following the Gerber method outlined by Bureau of Indian Standards [BIS] (1977). Protein levels were assessed via the Kjeldahl method (Association of Official Analytical Chemists [AOAC], 2003). The ash content was estimated following the procedure outlined by Bureau of Indian Standards [BIS] (1981), and crude fiber content was determined according to AOAC (2003). Additionally, acidity was measured using the method described by Bureau of Indian Standards [BIS] (1983).The samples for microbiological analyses were prepared under aseptic conditions. Aerobic plate count (APC), yeast and mold count (YMC), and coliform count of paneer were determined according to Food Safety and Standards Authority of India [FSSAI] (2024).

RESULTS

Optimization of paneer spread incorporating malted ragi flour: The RSM results revealed how formulation variables influenced the viscosity, spreadability, and crude fiber content of the final spread. Significant interactions were observed, which guided the optimization of the product. The optimized conditions derived from the 20 trials, as shown in Table 1, were applied, and the final product was evaluated to confirm the predicted results.

A higher viscosity indicates a thicker spread that requires more pressure to spread, while a lower viscosity indicates a thinner spread that flows more easily. Ingredient composition can influence a spread's viscosity. The viscosity of malted ragi flour supplemented paneer spread ranged from 16.29 to 51.68 Pa.s., depending on the variations in ingredient levels. A linear model was proposed to describe this relationship; however, it was not statistically significant (p=0.6053), and the low adjusted and predicted R^2 values suggest a poor fit (Fig. 1a). Despite this, the non-significant lack of fit (p=0.2674) indicates that the model adequately fits the data.

Spreadability is the most important physico-functional characteristic of dairy spreads. A notable feature of the spread is its ability to be spread even at low temperatures. The spreadability scores for the malted ragi flour-supplemented paneer spread ranged from 12.22 to 15.44 g.cm/s. The linear model for spreadability was statistically significant (p=0.0356) and showed no significant lack of fit (p=0.5784), indicating that the model provides a good fit to the data (Fig. 1b). However, the moderate R^2 values suggest that the model has limited predictive strength.

Milk is a concentrated source of life-sustaining nutrients with high digestibility and is purely devoid of fiber. These fibers can be added to dairy products for health benefits, technological advantages, or sensory reasons. Supplementing the spread with malted ragi flour resulted in higher fiber content. From the optimization trials, it is evident that as the content of ragi flour in the formulation increases, the fiber content of the finished product also increases. It varies from 0.3% to 0.62% depending on the different formulations. RSM identified the quadratic model (Fig. 1c) as optimal for fiber content, with high adjusted (0.9645) and predicted (0.8663) R^2 values. The model was

statistically significant (p=0.0001), and the lack of fit was not significant (p=0.1790), indicating a strong and reliable fit.

The response values were entered into the software to determine the best ingredient combination that maximized fiber content while keeping the rheological parameters-viscosity and spreadability within the acceptable limits. Using the 'Analysis' command in Design Expert, two suggested solutions with the highest 'desirability' were generated. Among the tested formulations, the blend containing 49.17% paneer, 17.33% malted ragi flour, 20% butter, and 13.5% water showed the highest desirability (0.66). It was selected as the optimal combination for preparing the malted ragi flour–based paneer spread, with predicted viscosity, spreadability, and crude fiber values of 21.86 Pa·s, 13.58 g·cm/s, and 0.54%, respectively.

The malted ragi flour-supplemented paneer spread was prepared using optimized levels of ingredients and analyzed for actual values of viscosity, spreadability, and crude fiber content. The results indicated that the optimal paneer spread exhibited a viscosity of 21.87 Pa.s, a spreadability of 13.53 g.cm/s, and a crude fiber content of 0.53% (Table 2). There was no significant difference between the predicted and actual values of these parameters.

Sensory scores of paneer spread: The results of the sensory analysis are displayed in the Table 3. The malted ragi flour-supplemented paneer spread showed acceptable scores for body and texture, colour and appearance, and flavour. There was no significant difference in these sensory scores compared to the control paneer spread. In the developed spread, body and texture received the highest ratings (8.0), while colour and appearance, and flavour also received strong, acceptable scores, reflecting excellent overall acceptance and consumer appeal.

Effect of storage on the chemical and microbiological stability of paneer spread: Using the optimized formulation, a malted ragi flour–enriched paneer spread was prepared, and its shelf-life was examined under refrigeration to monitor the maintenance of its chemical and microbiological properties.

Different chemical properties such as moisture, ash, protein, crude fibre, titratable acidity, and fat content of developed paneer spread samples were measured and compared with paneer spread without

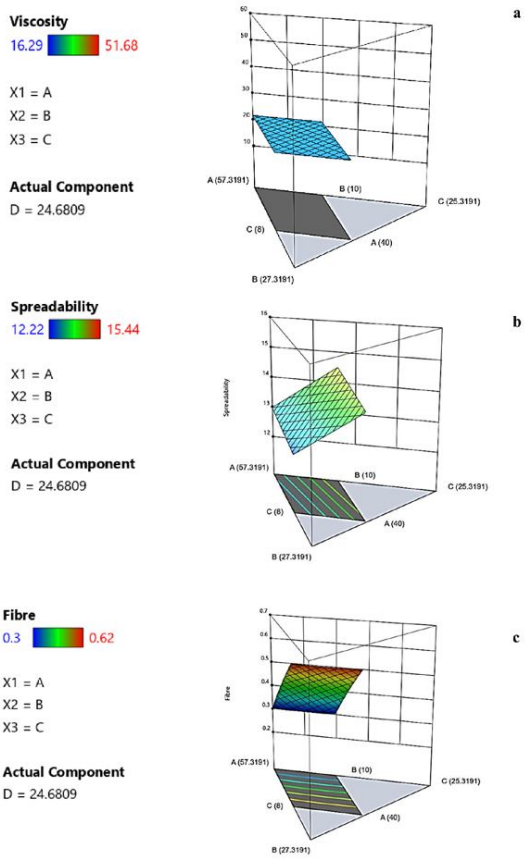

Fig. 1. Response surface plots of viscosity (a), spreadability (b) and crude fibre content (c) as influenced by levels of the ingredients

Table 3. Sensory Scores paneer spread

Sensory properties	Malted ragi flour incorporated paneer spread	Control paneer spared
Colour and appearance	7.933±0.16	8.033±0.19
Flavour	8.067±0.17	8.1±0.16
Body and texture	8.276±0.11	7.943±0.16
Overall acceptability	8.167±0.17	7.861±0.18

Mean±Standard error of 15 scores
Values in a row are not significantly different from each other ($p \geq 0.05$)

Table 2. Comparison of predicted and actual values of responses to validate the optimised composition

Response	Predicted value	Actual value	t-value
Viscosity (Pa.s)	21.86	21.87±0.09	0.021^{ns}
Spreadability (g.cm/s)	13.58	13.53±0.07	0.30^{ns}
Crude fiber (%)	0.54	0.53±0.003	0.002^{ns}

Mean±Standard error of 3 replicates
^{ns}- not significant ($p \leq 0.05$), t: Student's t-test for difference of means.

added malted ragi flour (MRF) (Table 4). The paneer spread with added MRF was found to have significantly lower moisture content throughout the storage period compared to the control paneer spread. The product recorded significantly higher ash content (1.43%) than the control (1.13%), due to the mineral-rich malted ragi flour. The product also had significantly lower crude fat and total protein contents (23.18% and 10.57%, respectively) compared to the control paneer spread (26.24% and 10.97%, respectively). The crude fibre content of the product was 0.53%, attributed to the inclusion of malted ragi flour, whereas the control had none. Regarding titratable acidity values, no statistically significant differences were observed between the control and malted ragi flour-incorporated paneer spread throughout the storage period.

Table 4. Chemical composition of malted ragi flour incorporated paneer spread

Parameter	Malted ragi flour incorporated paneer spread	Control paneer spread
Moisture (%)	44.60±0.12[a]	50.55±0.23[b]
Crude protein (%)	10.57±0.01[a]	10.97±0.02[b]
Crude fibre (%)	0.53±0.002[a]	Absent[b]
Crude fat (%)	23.18±0.11[a]	26.24±1.20[b]
Ash (%)	1.43±0.01[a]	1.13±0.01[b]
Viscosity (Pa.s)	22.10±0.03[a]	21.75±0.02[b]
Spreadability (g.cm/s)	13.70±0.01[a]	13.81±0.01[a]

Mean±Standard error of 3 replicates

Means that don't share same alphabet (a,b) in the row are significantly different from each other ($p \leq 0.05$).

The microbiological attributes of the developed paneer spread were assessed through aerobic plate count (APC), yeast and mold count (YMC), and coliform count. In our study, the APC for malted ragi flour incorporated and control paneer spreads increased from 1.2 to 22.6 cfu/g and 1.5 to 47.8 cfu/g, respectively, from the 1st to the 12th day of storage under refrigeration temperature. No coliforms or yeast and molds were detected in any samples tested during the 12-day storage period (Table 5).

Table 5. Effect of storage on the chemical and microbiological stability of malted ragi flour incorporated paneer spread at refrigeration conditions

Parameter	Samples	Storage period (Day)			
		Day 1	**Day 4**	**Day 8**	**Day 12**
Moisture (%)	Malted ragi flour incorporated paneer spread	44.6	44.3	44.0	43.5
	Control	50.5	50.2	49.7	49.4
Titratable acidity (% lactic acid)	Malted ragi flour incorporated paneer spread	0.08	0.08	0.09	0.09
	Control	0.07	0.07	0.07	0.08
Viscosity (Pa.s)	Malted ragi flour incorporated paneer spread	22.10	21.70	21.80	21.45
	Control	21.75	21.48	21.69	21.69
Spreadability (g.cm/s)	Malted ragi flour incorporated paneer spread	13.70	13.40	13.50	13.60
	Control	13.80	13.60	13.50	13.70
Aerobicplate count (cfu/g)	Malted ragi flour incorporated paneer spread	1.2	3.6	7.9	22.6
	Control	1.5	5.1	18.4	47.8
Coliform count (cfu/g)	Malted ragi flour incorporated paneer spread	Absent	Absent	Absent	Absent
	Control	Absent	Absent	Absent	Absent
Yeast and mold count (cfu/g)	Malted ragi flour incorporated paneer spread	Absent	Absent	Absent	Absent
	Control	Absent	Absent	Absent	Absent

DISCUSSION

This study aimed to develop and optimize a malted ragi flour-supplemented paneer spread. Paneer is a traditional Indian product rich in milk proteins. Ragi flour is a valuable source of essential nutrients, and its incorporation into spreads offers several benefits over conventional spreads, which are often high in fat and sugar. The high fiber and mineral content in the ragi-based spread make it an ideal choice for improving bone health and preventing cardiovascular diseases. The amounts of paneer, ragi flour, butter, and water were optimized through RSM, using viscosity, spreadability, and fiber content as response variables. The optimized formulation suggests the following ingredient levels on a weight/weight basis: 49.17% paneer, 17.33% malted ragi flour, 13.50% water, and 20% butter, with a desirability of 0.658. Additionally, the formulation includes 1.0% edible salt, 0.3% lecithin, and 0.1% rosemary extract. The viscosity, spreadability, and crude fiber content of the optimized spread were estimated and the observed values closely agreed with the predicted values, thereby validating the optimized levels of ingredients obtained through the statistical design.

Our findings are in agreement with Amitraj et al. (2016), who reported an optimized solution with a maximum desirability of 0.889 for the preparation of low-fat, Chhana-based dairy spread using response surface methodology, considering sensorial and textural attributes as responses. The optimized Chhana spread, containing 55.6% Chhana, 6.2% skimmed milk powder (SMP), 4% maltodextrin, and 2% whey powder, demonstrated good acceptance. Mahrooghi et al. (2017) investigated the influence of three key variables namely konjac glucomannan gum, xanthan gum, and butter on the firmness, flavour, spreadability, colour, overall acceptability, and pH of spreadable processed cheese using RSM. Their findings revealed that variations in hydrocolloid and butter levels had a significant impact on both the sensory and physicochemical properties of the optimized cheese spread.

In a related study, Pavithra et al. (2024) analyzed the rheological behavior of a functional dairy spread and reported a viscosity value of 123 cP for the developed product, compared to 117 cP for the control. The control sample exhibited higher spreadability (1.9 cm/h) than the functional version (1.6 cm/h), which was attributed to an increased total solids content resulting from spice incorporation, consequently reducing the moisture level. Likewise, Gulzar et al. (2015) formulated a fruit-enriched cream cheese spread containing 10% apple puree and 2% hydrocolloids. Their results showed that the viscosity of the control spread (without hydrocolloids) was 120.61 cP, while the inclusion of gelatin and carrageenan elevated the viscosity to 189.33 cP.

Sensory quality of paneer spread: The sensory characteristics of a food product are of immense importance for market acceptance and industrial processing. The colour of the paneer spread is particularly significant, as it influences consumer acceptance. In general, the colour of malted ragi flour-incorporated paneer spread tends to shift towards a brown hue compared to the control; however, it still received excellent sensory scores. Similarly, the addition of MRF does not affect other sensory parameters, including body and texture, flavour, and appearance scores. The results indicate that differences in colour and appearance did not adversely affect the overall acceptability of the developed paneer spread. It received high scores on the 9-point hedonic scale, surpassing a score of 7, which reflects a strong consumer preference for the paneer-ragi-based spread. Chauhan and Gupta (2025) formulated spreads enriched with sprouted pearl and finger millet and observed that incorporating up to 10% sprouted millet flour did not produce any significant changes in the sensory characteristics of the product. In another study, Kumari et al. (2021) prepared a paneer spread using cow milk with the addition of ginger and garlic. Their findings indicated that varying spice concentrations had a notable effect on the sensory properties of the spreads. Among the tested variations, the garlic-fortified paneer spread achieved the highest overall acceptability score of 7.47. The observed differences in sensory evaluation among the spice-enriched paneer spreads were primarily attributed to variations in consumer perception of flavour, colour and appearance, body and texture, and overall appeal.

Chemical and microbial parameters of paneer spread during storage: The study evaluating the shelf-life stability of malted ragi flour-supplemented paneer spread provides valuable insights into its chemical and microbiological qualities during refrigerated storage. The incorporation of malted ragi flour notably influenced several chemical properties of the product. Specifically, the spread with added malted ragi flour exhibited consistently lower moisture content compared to the control, which is advantageous for shelf-life extension by reducing water activity that can promote microbial growth. The

increased ash content reflects mineral enrichment from the ragi flour, potentially enhancing the nutritional profile of the spread. Furthermore, the observed reductions in crude fat and crude protein contents in the malted ragi flour-incorporated product suggest a dilution effect due to the added ragi flour. The presence of crude fiber, absent in the control, remained stable throughout storage, indicating the fiber's contribution to the product's functional properties. These findings align with the study by Pavithra et al. (2024), who formulated a functional dairy spread using vegetable oils as the fat component. They reported that the experimental spreads exhibited lower moisture and fat contents and higher ash levels compared to the control samples. Similarly, Giri et al. (2018) observed that a probiotic soy cheese spread contained reduced fat and sugar levels and increased protein content relative to commercially available dairy cream cheese spreads, with these nutritional characteristics remaining stable for up to two weeks of storage.

From the microbiological perspective, malted ragi flour-supplemented paneer spread demonstrated acceptable safety profiles over the 12-day refrigerated period, with no detection of coliforms, yeast and molds. The aerobic plate count increased modestly in control and developed samples but remained within safe limits. The malted ragi flour product showed a lower initial and final count, suggesting a potential preservative or inhibitory effect of the added flour. These findings fall significantly short of the criteria set by the Food Safety and Standards Authority of India for spreads, thereby confirming the sufficiency of the proposed process in terms of food safety. A similar result was reported by Amitraj et al. (2016) in the case of chhana-based dairy spread. The average APC of the freshly prepared spread samples was found to be 56 cfu/g, and yeast, mold, and coliform counts were absent in 1 g of the samples.

Overall, the findings suggest that incorporating malted ragi flour into paneer spread can enhance certain nutritional attributes and may contribute to improved shelf-life stability by lowering moisture content and microbial proliferation. These results support the potential of malted ragi flour as a functional ingredient in dairy-based spreads, although further studies could explore longer storage durations and sensory attributes to comprehensively assess product quality.

The study on developing a functional paneer spread enriched with malted ragi flour highlighted considerable improvements in both nutritional quality and product characteristics. Utilizing RSM enabled the optimization of the formulation, producing a spread with improved viscosity and spreadability, increased fiber and mineral content, and reduced fat levels. The product demonstrated good shelf stability, maintaining its quality for up to 12 days under refrigerated conditions, and achieved high scores in sensory evaluations, reflecting strong consumer acceptance. Incorporating ragi provides additional benefits, including higher dietary fiber, essential minerals, and potential health-promoting effects, positioning it as a more nutritious alternative to conventional dairy spreads, which typically have higher fat content and fewer functional nutrients. Overall, the optimized paneer spread represents a health-focused option with improved functional and sensory attributes.

Conflict of interest: There are no conflicts of interest associated with this publication.

Author's contribution: TMH, MPR: Carried out the research concept and implementation; HVVS, VA: Analyse the research findings; CRR: Critically reviewed the draft manuscript; GK: Interpreted the data and corrections to the manuscript.

Data availability statement: The datasets generated and analyzed during this study are available from the corresponding author upon reasonable request.

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