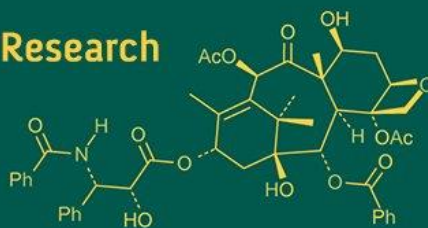
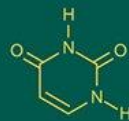
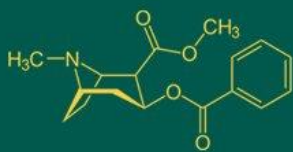


International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2026): 5.29
IJABR 2026; SP-10(6): 1343-1350
www.biochemjournal.com
Received: 29-04-2026
Accepted: 30-05-2026

Dev Nanda Aniljith
Department of Food Technology
and Quality Assurance, Indira
Gandhi College of Arts and Science,
Nellikuzhi, Kerala, India

Rahila MP
Assistant Professor, Department of
Dairy Chemistry, College of Dairy
Science and Technology, Kerala
Veterinary and Animal Sciences
University, Pookode, Kerala, India

Yancy Mary Issac
Assistant Professor, Department of
Dairy Husbandry, College of Dairy
Science and Technology, Kerala
Veterinary and Animal Sciences
University, Pookode, Kerala, India

Rachana CR
Assistant Professor, Department of
Dairy Chemistry, College of Dairy
Science and Technology, Kerala
Veterinary and Animal Sciences
University, Pookode, Kerala, India

Akhila V
Assistant Professor, Department of
Dairy Engineering, College of Dairy
Science and Technology, Kerala
Veterinary and Animal Sciences
University, Pookode, Kerala, India

Helna Pious
Assistant Professor, Department of
Dairy Chemistry, College of Dairy
Science and Technology, Kerala
Veterinary and Animal Sciences
University, Pookode, Kerala, India

Aarathy Bose
Assistant Professor, Department of
Dairy Chemistry, College of Dairy
Science and Technology, Kerala
Veterinary and Animal Sciences
University, Pookode, Kerala, India

Corresponding Author:
Rahila MP
Assistant Professor, Department of
Dairy Chemistry, College of Dairy
Science and Technology, Kerala
Veterinary and Animal Sciences
University, Pookode, Kerala, India

Development and evaluation of functional paneer spread incorporated with carrot paste

Dev Nanda Aniljith, Rahila MP, Yancy Mary Issac, Rachana CR, Akhila V, Helna Pious and Aarathy Bose

DOI: <https://www.doi.org/10.33545/26174693.2026.v10.i6Sp.8830>

Abstract

The present study was undertaken to develop a functional paneer spread supplemented with carrot paste and to evaluate its physicochemical, sensory, antioxidant, and microbiological properties. Paneer, a highly nutritious dairy product rich in protein and fat, lacks dietary fibre and certain bioactive compounds. To enhance its nutritional profile, carrot paste rich in β -carotene, dietary fibre, and antioxidants was incorporated into the formulation. The paneer spread was formulated by blending paneer with carrot paste, butter, salt, lecithin, ascorbic acid, and cardamom followed by pasteurization and refrigerated storage at 4°C. Response Surface Methodology (RSM) was employed to optimize the formulation by varying proportions of paneer, carrot paste, and water. The optimized formulation consisted of 60% paneer, 25% carrot paste, and 17.18% water with a desirability value of 0.786. The developed product exhibited improved spreadability (15 g·cm/s), higher sensory acceptability (score 8 on a 9-point hedonic scale), enhanced antioxidant activity, increased crude fibre (0.7%), and significantly higher vitamin A content compared to the control. The pH of the product was slightly lower than the control, indicating increased acidity due to carrot incorporation. Microbiological analysis confirmed that the product remained within acceptable safety limits. The study demonstrated that carrot paste incorporation significantly improved the nutritional, functional, and sensory qualities of paneer spread, making it a promising value-added dairy product.

Keywords: Paneer spread, carrot paste, functional dairy product, antioxidant activity, RSM, Vitamin A

Introduction

Paneer is a South Asian variety of soft cheese obtained by acid and heat coagulation of milk. It is a non-fermentative, non-renneted, non-melting and unripened type of cheese widely consumed throughout South Asia. Traditionally, paneer is prepared by coagulating heated milk using food-grade acids such as citric acid, lactic acid or sour whey, followed by whey drainage and pressing. Paneer occupies an important place in the Indian dairy industry due to its high nutritional value, versatility and widespread consumer acceptance. It is consumed both in raw form and as an ingredient in a wide variety of culinary dishes, snacks and desserts. Popular dishes such as *matar paneer*, *palak paneer*, *shahi paneer* and paneer-based snacks have significantly contributed to its increasing popularity. The production and consumption of paneer have now expanded beyond South Asia to many parts of the world owing to the growing demand for ethnic and functional dairy foods.

One of the most distinctive properties of paneer is its ability to retain shape and texture during cooking and deep frying. Unlike many other soft cheeses, paneer does not melt upon heating, making it highly suitable for preparation of fried products such as pakoras, paneer cubes and other ready-to-eat snacks. This characteristic has greatly enhanced its commercial importance and consumer acceptance. Paneer is considered an excellent source of high-quality animal protein available at a comparatively lower cost and serves as an important source of protein for vegetarians. The biological value of protein in paneer ranges from 80 to 86, indicating its high digestibility and nutritional quality [1]. In addition to protein, paneer is a rich source of milk fat, calcium, phosphorus and vitamins, thereby contributing significantly to human nutrition. Furthermore, paneer possesses a reasonably good shelf life under refrigerated storage conditions.

Good quality paneer is characterized by a marble white appearance, mildly acidic and sweetish taste, pleasant nutty flavour, spongy body and smooth, closely knit texture. According to the

Prevention of Food Adulteration ^[2] standards, paneer refers to the product obtained from cow milk, buffalo milk or a combination thereof by precipitation with sour milk, lactic acid or citric acid. The product should contain not more than 70% moisture and not less than 50% fat on dry matter basis. Milk solids may also be used in its preparation. The Bureau of Indian Standards ^[3] further specified a maximum moisture content of 60% and a minimum fat content of 50% on dry matter basis for paneer. Paneer is widely utilized as a base material for several culinary preparations and vegetable dishes and also as a major ingredient in various snacks and convenience foods.

Traditionally, paneer manufacture has been largely confined to the unorganized dairy sector where conventional methods of production are commonly employed. These traditional methods are often associated with poor standardization, low yield and inconsistent product quality. Significant pioneering work towards modernization and standardization of paneer manufacture was carried out by Bhattacharya *et al.* ^[4], which subsequently encouraged extensive research on the optimization of processing parameters for paneer production using different types of milk and varying technological conditions. Owing to the ever-increasing consumer demand, several attempts have been made to develop novel paneer-based products with enhanced nutritional, sensory and functional properties.

In recent years, changing lifestyle patterns, urbanization and increased consumer preference for convenience foods have accelerated the demand for ready-to-eat and ready-to-spread food products. Among these, spreads have gained immense popularity worldwide as sandwiches and bakery-based breakfast foods constitute a significant portion of the daily diet of millions of people. Presently, the market is dominated mainly by butter spread and cheese spread. Butter spread is often avoided by health-conscious consumers, obese individuals and people suffering from cardiovascular disorders due to its high fat content. Cheese spread, although highly nutritious and suitable for all age groups, is relatively expensive and less preferred by a section of the Indian population because of its characteristic flavour and the use of calf rennet in cheese manufacture, which is not acceptable to many vegetarians due to religious sentiments.

In this context, paneer spread offers considerable potential as a nutritious, economical and vegetarian-friendly alternative to cheese spread. Paneer spread combines the nutritional benefits of paneer with improved spreadability and convenience, making it suitable for consumption across all age groups. Furthermore, the incorporation of plant-based ingredients into paneer spread can improve its nutritional and functional properties while enhancing sensory quality and consumer appeal.

The development of functional dairy foods fortified with fruits and vegetables has gained increasing attention in recent years because of growing awareness regarding the health benefits of natural bioactive compounds. Among various vegetables, carrot (*Daucus carota* L.) is considered an excellent source of β -carotene, dietary fibre, vitamins, minerals and antioxidant compounds. β -carotene serves as a precursor of vitamin A and plays an important role in vision, immune function and protection against oxidative stress. Carrot also contains appreciable amounts of phenolic compounds and natural antioxidants that contribute to improved health benefits. Incorporation of carrot into dairy

products can therefore enhance nutritional quality, antioxidant activity and functional value.

Research on milk-based and vegetable-based spreads has been carried out to a reasonable extent; however, studies on carrot-based spreads are relatively limited. Incorporation of carrot paste into paneer spread may improve colour, flavour, spreadability, antioxidant properties and dietary fibre content while also enhancing consumer acceptability. Therefore, the present study was undertaken to develop and optimize a functional paneer spread incorporated with carrot paste and to evaluate its physicochemical, sensory, antioxidant and microbiological properties.

Materials and Methods

Raw Materials

Cow milk was obtained from the Instructional Livestock Farm, Kerala Veterinary and Animal Sciences University (KVASU), Pookode, Wayanad, Kerala, India, and used for the preparation of paneer. The milk contained 3.7% fat and 8.9% solids-not-fat (SNF). Fresh carrots, unsalted butter, citric acid, salt, cardamom powder, lecithin, and ascorbic acid were procured from the local market and utilized in the formulation of paneer spread. All chemicals and reagents used for analytical purposes were of analytical grade.

Preparation of Paneer

Paneer was prepared following the method described by Bhattacharya *et al.* (4). Milk was heated to 82°C and cooled to 70°C. A 2% citric acid solution preheated to 70°C was added for coagulation. The coagulum was collected in muslin cloth, pressed for 1 h, cooled in chilled water, and stored at 4°C.

Preparation of Carrot Paste

Fresh carrots were washed, peeled, cut into pieces, and boiled for 15 min. The softened carrot pieces were ground using a mixer grinder to obtain a smooth and uniform paste.

Preparation of Paneer Spread

Crumbled paneer was blended with carrot paste, unsalted butter, salt, cardamom powder, lecithin, ascorbic acid, and water. The mixture was pasteurized at 72°C for 15-20 s, packed in airtight containers, and stored at 4°C.

Optimization Using Response Surface Methodology

Response Surface Methodology (RSM) employing a Central Composite Design (CCD) was used to optimize the formulation of the paneer spread. The proportions of paneer, carrot paste, and water were selected as independent variables and varied systematically to evaluate their effects on spreadability, overall acceptability (using 9-point hedonic scale), and antioxidant activity. The levels of the remaining ingredients, namely butter (8 g), salt (0.1 g), cardamom powder (0.3 g), lecithin (0.15 g), and ascorbic acid (0.5 g), were kept constant throughout the study based on the results of preliminary sensory evaluation trials.

A total of twenty experimental runs were generated according to the CCD design matrix. The experimental data obtained for the selected response variables were fitted to a second-order polynomial model, and the adequacy of the model was assessed using analysis of variance (ANOVA). Numerical optimization was performed by setting spreadability within the desired range while maximizing overall acceptability and antioxidant activity.

Physicochemical Analysis

The developed paneer spread was analyzed for pH, moisture content, ash content, crude protein, crude fibre, and titratable acidity using the standard methods prescribed by the Association of Official Analytical Chemists [5]. Spreadability was determined according to the procedure described by Afsal *et al.* [6].

Estimation of Vitamin A content

The vitamin A content of the samples was estimated from the β -carotene concentration determined by a spectrophotometric method following the procedure described by Rodriguez-Amaya and Kimura [7] with slight modifications. Approximately 5 g of the sample was homogenized and extracted with 20 mL of acetone. The extract was transferred to a separating funnel and partitioned with petroleum ether. The petroleum ether layer containing the carotenoid pigments was collected, and the volume was made up to 20 mL with petroleum ether.

The absorbance of the petroleum ether extract was measured at 450 nm using a UV-Visible spectrophotometer against petroleum ether as the blank. The β -carotene concentration was calculated using the following equation:

$$\beta\text{-Carotene (mg/L)} = (A \times V \times 1000) / (2592 \times W)$$

where A is the absorbance of the extract at the respective wavelength, V is the final volume of the extract (mL), W is the weight of the sample (g), and 2592 is the specific absorption coefficient of β -carotene in petroleum ether.

The vitamin A activity was calculated from the β -carotene content and expressed as Retinol Activity Equivalents (RAE) using the conversion factor that 12 μ g of dietary β -carotene is equivalent to 1 μ g RAE.

Total Phenolic Content

Total phenolic content (TPC) was determined using the Folin-Ciocalteu colorimetric method described by Elfalleh *et al.* [8]. Phenolic compounds were extracted according to the method of Darwish *et al.* [9] with slight modifications. Briefly, 2 g of paneer spread was mixed with 30 mL of aqueous methanol (70:30, v/v) and stirred continuously for 24 h at room temperature under dark conditions to prevent photo-oxidative degradation of polyphenols. The mixture was centrifuged at $4000 \times g$ for 20 min, and the supernatant was collected. The residue was re-extracted with an additional 30 mL of the same solvent, and the supernatants were combined and used for analysis.

For TPC determination, 0.5 mL of the extract was mixed with 0.5 mL of Folin-Ciocalteu reagent, followed by the addition of 4.0 mL of 1 M sodium carbonate solution. The reaction mixture was incubated in a water bath at 45°C for 5 min and then rapidly cooled in a cold-water bath. Absorbance was measured at 765 nm using a UV-Visible spectrophotometer. The total phenolic content was calculated using a gallic acid standard curve and expressed as milligrams of gallic acid equivalents per gram of the sample (mM GAE/g).

DPPH Radical Scavenging Activity

The antioxidant activity of the paneer spread was evaluated by measuring its 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging activity according to the method described by Marinova *et al.* [10] with slight modifications.

Briefly, DPPH reagent was prepared by dissolving 0.0004 g of DPPH in 100 mL of methanol. An aliquot of the extract (250 μ L) was diluted with 2.25 mL of methanol. Subsequently, 1.0 mL of the diluted extract was mixed with 1.0 mL of freshly prepared DPPH reagent. The reaction mixture was vortexed thoroughly and incubated at room temperature in the dark for 30 min. The absorbance of the resulting solution was measured at 517 nm against a reagent blank using a UV-Visible spectrophotometer (Shimadzu UV-1600).

The DPPH radical scavenging activity was calculated using the following equation

$$\text{DPPH radical scavenging activity (\%)} = [(A_0 - A_s) / A_0] \times 100$$

where A_0 is the absorbance of the control and A_s is the absorbance of the sample.

Microbiological Analysis

Microbiological examination of the paneer spread was carried out under aseptic conditions. The Aerobic Plate Count (APC), coliform count and Yeast and Mould Count (YMC) were determined following the procedures outlined in the Food Safety and Standards Authority of India [11]. Microbial populations were enumerated and expressed as $\log_{10}$ colony-forming units per gram ($\log_{10}$ CFU/g) of sample.

Results and Discussion

Optimization of Paneer Spread Formulation Using Response Surface Methodology

The experimental design matrix generated using Response Surface Methodology (RSM) and the corresponding response values for spreadability, overall acceptability, and DPPH radical scavenging activity are presented in Table 1. The results demonstrated that the levels of paneer, carrot paste, and water significantly influenced the quality attributes of the developed paneer spread.

The adequacy of the developed models and the analysis of variance (ANOVA) for all responses are summarized in Table 2. For spreadability, the interaction between paneer and water content significantly influenced the response ($p < 0.05$), indicating that appropriate moisture adjustment was essential for achieving desirable spreading characteristics. The response surface plot (Figure 1A) illustrates that increasing water content improved spreadability, particularly at higher paneer levels. This may be attributed to the increased moisture retention and reduced firmness of the spread matrix. For overall acceptability, the quadratic effect of water content was found to be significant ($p < 0.05$) (Table 2). The response surface plot (Figure 1B) showed that moderate levels of water produced higher sensory scores, whereas excessive or insufficient water adversely affected consumer acceptance. Water content plays a crucial role in determining the texture, mouthfeel, and spreadability of dairy spreads, which ultimately influence overall acceptability.

The DPPH radical scavenging activity was significantly affected by the interaction between paneer and carrot paste levels and by the quadratic effect of paneer content (Table 2). The response surface plot (Figure 1C) demonstrated that antioxidant activity increased with carrot paste incorporation. The improvement in antioxidant activity can be attributed to the presence of carotenoids and phenolic compounds

naturally present in carrots, which possess free radical scavenging properties.

Numerical optimization was performed to obtain the most desirable combination of ingredients. The optimized formulation consisted of 60.0% paneer, 25.0% carrot paste, and 17.18% water, with predicted values of 17.79 g·cm⁻¹ spreadability, 7.34 overall acceptability score, and 34.34% DPPH radical scavenging activity (Table 3). The desirability value of 0.786 indicated that the optimized formulation successfully balanced sensory, functional, and technological properties.

Physicochemical, Functional, and Microbiological Characteristics of Optimized Paneer Spread

The physicochemical, nutritional, antioxidant, and microbiological characteristics of the optimized paneer spread and control sample are presented in Table 4. The optimized paneer spread exhibited higher moisture content (58.30%) than the control (52.33%), which may be attributed to the high moisture content of carrot paste. Increased moisture contributed to improved spreadability and a softer texture, thereby enhancing consumer acceptability. Similar observations have been reported for vegetable-fortified dairy spreads, where moisture retention positively influenced texture and spreadability.

The pH of the optimized product (5.51) was slightly lower than that of the control (5.73), while titratable acidity increased from 0.05% to 0.06%. The decrease in pH may be due to the presence of naturally occurring organic acids in carrot paste. A lower pH can contribute to improved microbial stability and enhanced flavour development.

The ash content significantly increased from 1.13% in the control to 1.31% in the optimized paneer spread, indicating improved mineral content following carrot incorporation. Similarly, the crude protein content increased from 12.13% to 15.40%, suggesting that the optimized formulation retained its dairy nutritional value while providing additional functional benefits. In contrast, crude fat content decreased significantly from 27.40% to 26.30%, indicating partial replacement of fat-rich dairy solids with carrot constituents. A notable increase in crude fibre content was observed in the optimized paneer spread (0.70%) compared with the control. This increase can be attributed to the dietary fibre naturally present in carrots and represents an important nutritional advantage of the developed product. Dietary fibre contributes to digestive health and enhances the functional value of food products.

Vitamin A content was substantially higher in the optimized paneer spread (750 µg/100 g) than in the control (110 µg/100 g). This approximately seven-fold increase is primarily due to the high β-carotene content of carrot paste, which serves as a precursor of vitamin A. The enrichment of paneer spread with carrot paste therefore significantly improved its nutritional quality and potential health benefits related to vision, immunity, and antioxidant protection.

The total phenolic content of the optimized paneer spread was higher than that of the control (Table 4). The increase in phenolic compounds may be attributed to the natural phenolics present in carrot tissues. Phenolic compounds are recognized for their antioxidant properties and play an important role in reducing oxidative stress. The enhanced phenolic content indicates the successful development of a functional dairy product with improved bioactive potential.

The DPPH radical scavenging activity of the optimized paneer spread (25.33%) was higher than that of the control sample (23.01%), confirming the contribution of carrot-derived antioxidants. Carotenoids and phenolic compounds present in carrot paste likely acted synergistically to improve the antioxidant capacity of the product. The increase in antioxidant activity supports the functional food potential of the developed paneer spread.

The microbiological quality of the optimized paneer spread was satisfactory, as indicated by the low Aerobic Plate Count (APC), Yeast and Mould Count (YMC), and Coliform Count values presented in Table 4. The APC of the optimized product (1.2×10^3 CFU/g) was slightly lower than that of the control (1.3×10^3 CFU/g), suggesting good hygienic practices during processing. Yeast and mould counts as well as coliform counts were not detected in either the control or treatment samples. These results indicate that the incorporation of carrot paste did not adversely affect the microbiological quality of the paneer spread and that the product complied with acceptable microbiological standards. Overall, the optimized paneer spread incorporated with carrot paste demonstrated improved nutritional composition, enhanced antioxidant activity, increased vitamin A and phenolic contents, and satisfactory microbiological quality. The product therefore possesses considerable potential as a functional dairy spread with enhanced health-promoting attributes.

Discussion

The physicochemical, nutritional, antioxidant, and microbiological characteristics of the optimized paneer spread and control sample are presented in Table 4. The incorporation of carrot paste significantly improved several quality attributes of the product while maintaining acceptable microbiological quality.

The optimized paneer spread exhibited higher moisture content than the control sample. The increase in moisture may be attributed to the high water content and water-binding capacity of carrot tissues. Similar observations were reported by Mohamed *et al.* [12], who found that incorporation of carrot paste into spreadable cheese increased moisture content and improved product consistency. Furthermore, vegetable incorporation has been shown to enhance water retention and modify the rheological properties of processed cheese products, resulting in improved spreadability and consumer acceptability.

The pH of the optimized product was slightly lower, while titratable acidity was marginally higher than the control. This may be attributed to naturally occurring organic acids present in carrots. A similar trend has been reported in vegetable-fortified cheese products where incorporation of plant materials contributed to slight acidification of the final product, which may positively influence flavour and storage stability.

The ash content of the optimized paneer spread was significantly higher than that of the control, which may be attributed to the mineral contribution of the incorporated carrot paste. Carrots contain appreciable amounts of minerals such as potassium, calcium, phosphorus, magnesium, iron, and manganese, which contribute to their nutritional value [13, 14]. Therefore, the higher ash content observed in the present study suggests an increase in the mineral constituents of the product following carrot incorporation.

The crude fibre content of the control paneer spread was negligible, whereas a significant increase was observed in the optimized paneer spread following the incorporation of carrot paste. Since milk and traditional paneer do not contain dietary fibre, the fibre detected in the optimized product can be attributed entirely to the incorporated carrot paste. Carrots are recognized as important sources of dietary fibre and are widely utilized in the development of functional foods to enhance nutritional quality [15]. The increase in crude fibre content observed in the present study therefore reflects the contribution of carrot-derived fibre and adds functional value to the paneer spread.

The fat content of the optimized paneer spread was slightly lower than that of the control. This reduction may be attributed to the partial replacement of the dairy matrix by carrot paste, which contains negligible fat compared with milk solids. Consequently, incorporation of carrot paste diluted the fat fraction of the product, resulting in a lower overall fat content. Similar reductions in fat content have been reported in processed cheese products supplemented with carrot-derived ingredients, where replacement of a portion of the cheese base with carrot pomace paste led to a decrease in fat content compared with the control product [16]. The most notable nutritional enhancement was the substantial increase in vitamin A content. Carrot is widely recognized as one of the richest natural sources of β -carotene, the principal precursor of vitamin A. The increase observed in the present study confirms the effectiveness of carrot fortification in improving the nutritional quality of dairy products. Nicolle *et al.* [17] reported considerable concentrations of carotenoids in carrot cultivars, while Rodriguez-Amaya and Kimura [7] highlighted the importance of β -carotene-rich foods as dietary sources of vitamin A. The significantly higher vitamin A content of the optimized paneer spread therefore represents an important nutritional advantage.

The total phenolic content of the optimized paneer spread was higher than that of the control, indicating successful enrichment with bioactive compounds. Carrots contain

several phenolic constituents, including chlorogenic acid and caffeic acid derivatives, which contribute to their antioxidant properties. Similar increases in phenolic content have been reported in dairy products fortified with carrot concentrate and other plant-derived ingredients rich in polyphenols. Pandey *et al.* [18] reported enhanced polyphenol levels in dairy products supplemented with black carrot concentrate, while Kandyliari *et al.* [19] demonstrated that plant-based fortification significantly increased phenolic content and antioxidant capacity of dairy foods.

The DPPH radical scavenging activity of the optimized paneer spread was higher than that of the control, indicating improved antioxidant potential. The increase in antioxidant activity can be attributed to the combined effects of carotenoids and phenolic compounds present in carrot paste. Similar improvements in antioxidant activity have been reported in spreadable processed cheese fortified with date seed powder, grape skin powder, and vegetable ingredients rich in phenolic compounds. Darwish *et al.* [9] observed a significant increase in antioxidant activity following fortification of processed cheese spread with date seed powder, while vegetable-enriched processed cheese formulations also demonstrated enhanced antioxidant capacity due to their elevated phenolic content.

The microbiological analysis indicated satisfactory quality of both the control and optimized paneer spread. The APC, yeast and mould count, and coliform count remained within acceptable limits, suggesting good hygienic practices during manufacture and handling. The slightly lower APC observed in the optimized product may be associated with its lower pH and the presence of carrot-derived bioactive compounds. Plant phenolics have been reported to exhibit antimicrobial activity through multiple mechanisms, including disruption of microbial cell membranes and inhibition of microbial growth, thereby contributing to improved microbial stability in food products [20, 21]. The optimized formulation therefore represents a promising functional dairy product with improved health-promoting attributes and consumer appeal.

Table 1: Experimental design matrix and observed responses for optimization of paneer spread incorporated with carrot paste

Run	Paneer (%)	Carrot paste (%)	Water (%)	Overall acceptability	Spreadability (g·cm/s)	DPPH RSA (%)
1	45.00	35.00	20.00	6	23.33	32.43
2	60.00	35.00	10.00	7	24.17	28.43
3	45.00	25.00	10.00	6	18.33	30.63
4	60.00	35.00	20.00	7	18.33	30.63
5	52.50	30.00	15.00	8	20.00	23.40
6	52.50	30.00	15.00	8	20.00	22.50
7	52.50	30.00	15.00	8	20.83	23.40
8	52.50	30.00	23.41	6	19.17	19.82
9	60.00	25.00	20.00	7	18.33	34.23
10	60.00	25.00	10.00	6	17.50	39.64
11	45.00	35.00	10.00	7	17.50	19.82
12	52.50	30.00	15.00	7	18.33	39.64
13	52.50	21.59	15.00	7	19.17	28.83
14	52.50	30.00	15.00	7	18.33	25.23
15	45.00	25.00	20.00	8	19.17	23.42
16	52.50	38.41	15.00	6	17.50	20.70
17	52.50	30.00	15.00	8	18.33	38.73
18	52.50	30.00	6.59	6	17.50	23.42
19	39.89	30.00	15.00	6	17.50	36.94
20	65.11	30.00	15.00	7	18.33	36.04

Table 2: Analysis of variance (ANOVA) summary and model statistics for response surface models

Parameter	Spreadability	Overall Acceptability	DPPH Activity
Selected model	2FI	Quadratic	Quadratic
Model F-value	1.34	2.60	3.55
Model p-value	0.3092	0.0766	0.0306
Significant terms	AC	C ²	AB, A ²
Lack-of-fit p-value	0.0931	0.1047	0.3257
Adjusted R ²	0.0962	0.4307	0.5469
Predicted R ²	-2.2013	-0.8636	-0.1950

A = Paneer; B = Carrot paste; C = Water.

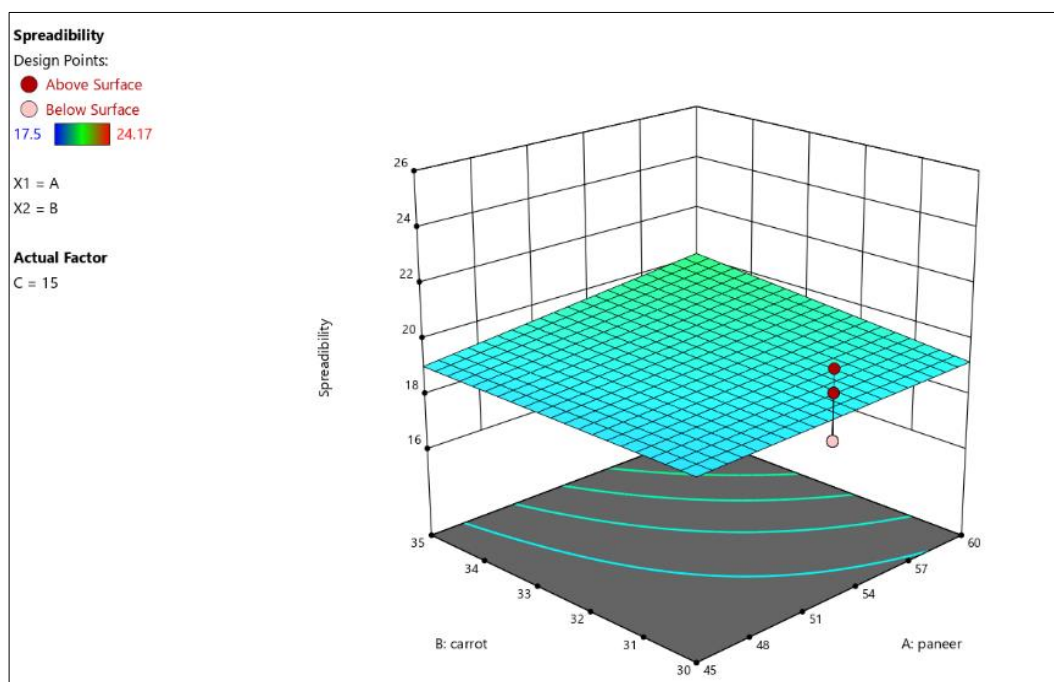
Table 3: Optimized formulation and predicted responses of paneer spread incorporated with carrot paste

Parameter	Value
Paneer (%)	60.00
Carrot paste (%)	25.00
Water (%)	17.18
Spreadability (g·cm/s)	17.79
Overall acceptability	7.34
DPPH radical scavenging activity (%)	34.34
Desirability	0.786

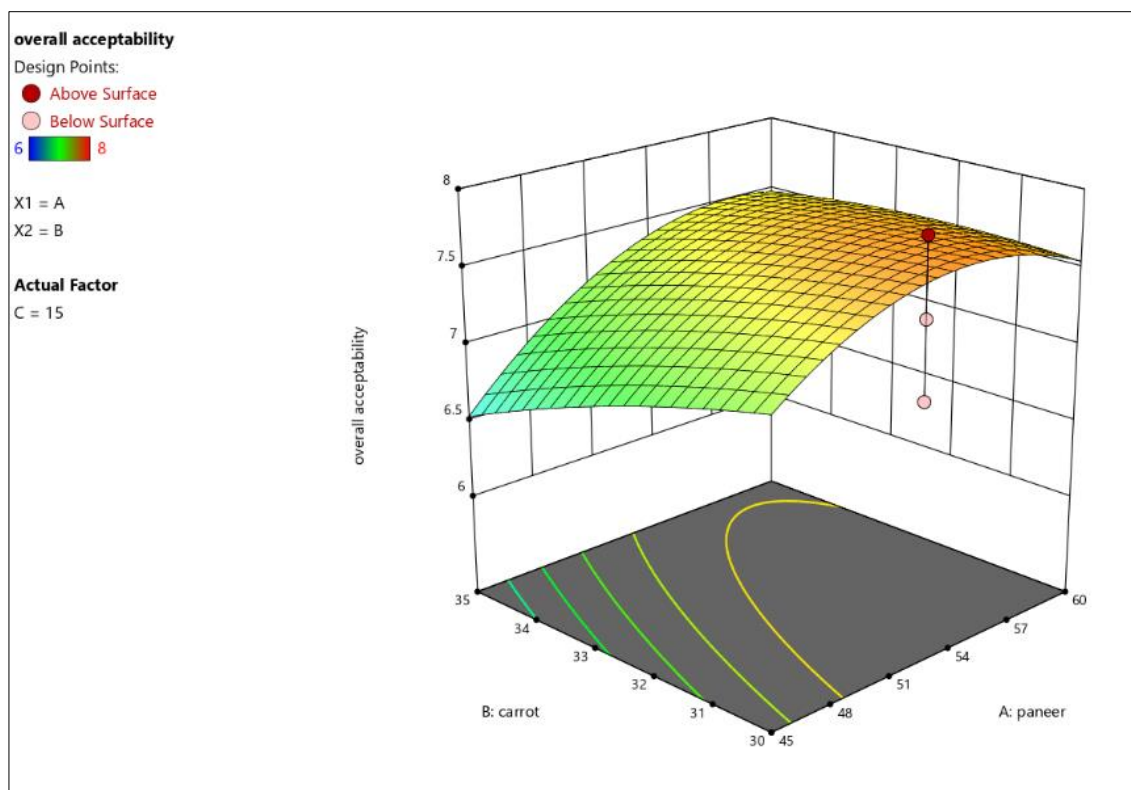
Table 4: Physicochemical, nutritional, antioxidant and microbiological characteristics of control and optimized paneer spread

Parameter	Control	Optimized paneer spread
Spreadability (g·cm/s)	14.17±0.09 ^b	15.07±0.12 ^a
Overall acceptability	7.23±0.15 ^b	8.13±0.19 ^a
DPPH radical scavenging activity (%)	23.01±0.22 ^b	25.33±0.05 ^a
pH	5.74±0.03 ^a	5.51±0.02 ^b
Ash (%)	1.13±0.02 ^b	1.31±0.02 ^a
Moisture (%)	52.33±0.20 ^b	58.30±0.21 ^a
Titrate acidity (% lactic acid)	0.046±0.002 ^b	0.061±0.002 ^a
Crude fat (%)	27.40±0.21 ^a	26.30±0.21 ^b
Crude fibre (%)	0.00±0.00 ^b	0.73±0.02 ^a
Crude protein (%)	12.13±0.15 ^b	15.40±0.25 ^a
Vitamin A (µg RAE/100 g)	110.00±0.13 ^b	750.00±0.37 ^a
Total phenolic content (mM GAE)	1.12±0.07 ^b	52.85±0.21 ^a
Aerobic plate count (CFU/g)	1.3 × 10 ³	1.2 × 10 ³
Yeast and mould count (CFU/g)	0.00	0.00
Coliform count (CFU/g)	0.00	0.00

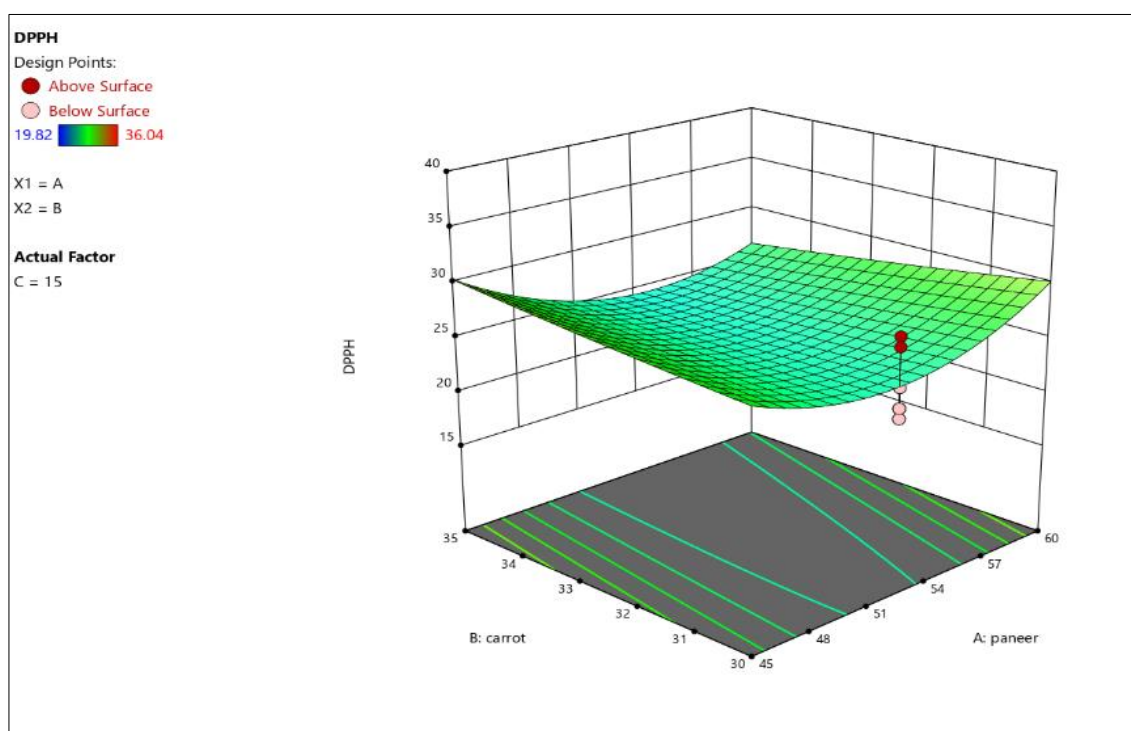
Values are expressed as mean ± standard error (SE) of triplicate determinations (n = 3). Means within a row bearing different superscripts (a, b) differ significantly ($P < 0.05$).



a)



b)



c)

Fig 1: Response surface plots showing the effects of paneer, carrot paste, and water levels on (A) spreadability, (B) overall acceptability, and (C) DPPH radical scavenging activity of paneer spread.

Conclusion

The present study successfully developed a functional paneer spread fortified with carrot paste. Incorporation of carrot paste significantly improved the nutritional composition, antioxidant activity, sensory acceptability, and functional properties of paneer spread. The optimized formulation containing 60% paneer, 25% carrot paste, and 17.18% water exhibited desirable spreadability, enhanced fibre and vitamin A content, and good microbial safety. The product

demonstrated potential as a value-added functional dairy food suitable for health-conscious consumers. The study highlights the possibility of utilizing vegetable fortification to enhance the nutritional and functional quality of traditional dairy products.

Acknowledgments

The authors express their sincere gratitude to the Director of Academics and Research, Kerala Veterinary and Animal

Sciences University, and the Special Officer, College of Dairy Science and Technology, Pookode, for providing the necessary facilities and institutional support to carry out this research.

Conflict of Interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

References

1. Srivastava S, Goyal GK. Preparation, properties and application of paneer: a review. *Indian J Dairy Sci.* 2007;60(6):405-415.
2. Government of India. Prevention of Food Adulteration Rules, 1955 (as amended up to 2010). New Delhi: Ministry of Health and Family Welfare; 2010.
3. Bureau of Indian Standards. IS 10484:1983. Specification for Paneer. New Delhi: Bureau of Indian Standards; 1983.
4. Bhattacharya DC, Mathur ON, Srinivasan MR, Samlik O. Studies on the method of production and shelf life of paneer (cooking type of acid coagulated cottage cheese). *J Food Sci Technol.* 1971;8(5):117-120.
5. Association of Official Analytical Chemists. Official Methods of Analysis. 18th ed. Gaithersburg (MD): AOAC International; 2003.
6. Hafsal TM, Rahila MP, Simha HVV, Rachana CR, Krishna G, Akhila V. Formulation of paneer spread incorporated with malted ragi (*Eleusine coracana*) flour. *Indian J Anim Health.* 2025;64(2 Suppl):409-417. DOI:10.36062/ijah.2025.spl.04125.
7. Rodriguez-Amaya DB, Kimura M. HarvestPlus Handbook for Carotenoid Analysis. HarvestPlus Technical Monograph No. 2. Washington (DC): International Food Policy Research Institute and International Center for Tropical Agriculture; 2004.
8. Elfalleh W, Hannachi H, Tlili N, Yahia Y, Nasri N, Ferchichi A. Total phenolic contents and antioxidant activities of pomegranate peel, seed, leaf and flower. *J Med Plants Res.* 2009;3(11):991-996.
9. Darwish AA, Tawfek MA, Baker EA. Texture, sensory attributes and antioxidant activity of spreadable processed cheese with adding date seed powder. *J Food Dairy Sci.* 2020;11(12):377-383. DOI:10.21608/jfds.2020.160404.
10. Marinova G, Batchvarov V, Aleksiev K. Evaluation of the methods for determination of the free radical scavenging activity by DPPH. *Bulg J Agric Sci.* 2011;17(1):11-24.
11. Food Safety and Standards Authority of India. Manual of Methods of Analysis of Foods: Microbiological Testing. New Delhi: Ministry of Health and Family Welfare, Government of India; 2024.
12. Mohamed AG, Shalaby SM, Gafour WA. Quality characteristics and acceptability of an analogue processed spreadable cheese made with carrot paste (*Daucus carota* L.). *Int J Dairy Sci.* 2016;11(3):91-99. DOI:10.3923/ijds.2016.91.99.
13. Sharma KD, Karki S, Thakur NS, Attri S. Chemical composition, functional properties and processing of carrot: a review. *J Food Sci Technol.* 2012;49(1):22-32.
14. Durazzo A, Lucarini M, Souto EB, Cicala C, Caiazzo E, Izzo AA, *et al.* Chemical composition, functional and anticancer properties of carrot. *Molecules.* 2023;28(20):7161. DOI:10.3390/molecules28207161.
15. Ikram A, Rasheed A, Khan AA, Khan R, Ahmad M, Bashir R, *et al.* Exploring the health benefits and utility of carrots and carrot pomace: a systematic review. *Int J Food Prop.* 2024;27(1):180-193. DOI:10.1080/10942912.2023.2301569.
16. El-Shibiny S, Mehanna NS, El-Sayed EM, *et al.* Impact of carrot pomace paste (*Daucus carota* L.) addition on some properties of processed cheese. *Egypt J Agric Sci.* 2021. DOI:10.21608/EJAS.2021.195258.
17. Nicolle C, Simon G, Rock E, Amouroux P, Rémésy C. Genetic variability influences carotenoid, vitamin, phenolic, and mineral content in white, yellow, purple, orange, and dark-orange carrot cultivars. *J Am Soc Hortic Sci.* 2004;129(4):523-529. DOI:10.21273/JASHS.129.4.0523.
18. Pandey P, Grover K, Dhillon TS, Kaur A, Javed M. Evaluation of polyphenols enriched dairy products developed by incorporating black carrot (*Daucus carota* L.) concentrate. *Heliyon.* 2021;7(5):e06880. DOI:10.1016/j.heliyon.2021.e06880.
19. Kandyliari A, Mallouchos A, Papandroulakis N, Kapsokefalou M. Development of dairy products fortified with plant extracts: antioxidant and phenolic content characterization. *Antioxidants (Basel).* 2023;12(2):500. DOI:10.3390/antiox12020500.
20. Mandal MK, Domb AJ. Antimicrobial activities of natural bioactive polyphenols. *Pharmaceutics.* 2024;16(6):718. DOI:10.3390/pharmaceutics16060718.
21. Sun S, Liu Z, Lin M, Gao N, Wang X. Polyphenols in health and food processing: antibacterial, anti-inflammatory, and antioxidant insights. *Front Nutr.* 2024;11:1456730. DOI:10.3389/fnut.2024.1456730.