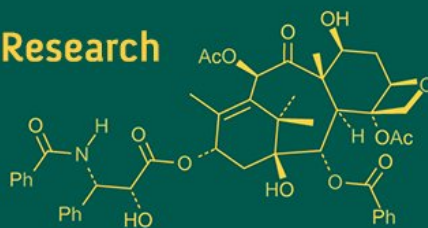


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Apeksha Aher
Department of Dairy
Technology, SMC College of
Dairy Science, Kamdhenu
University, Anand, Gujarat,
India

Komal Patel
Department of Dairy
Technology, SMC College of
Dairy Science, Kamdhenu
University, Anand, Gujarat,
India

SI Patel
Department of Dairy
Chemistry, SMC College of
Dairy Science, Kamdhenu
University, Anand, Gujarat,
India

RB Modi
Department of Food
Processing Technology, College
of Food Processing Technology
and Bio Energy, Anand
Agricultural University,
Anand, Gujarat, India

Corresponding Author:
Apeksha Aher
Department of Dairy
Technology, SMC College of
Dairy Science, Kamdhenu
University, Anand, Gujarat,
India

Technology for development of protein enriched probiotic frozen yoghurt using green gram

Apeksha Aher, Komal Patel, SI Patel and RB Modi

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Abstract

This study aimed to develop a functional frozen yoghurt by incorporating sprouted green gram powder in the range of 4-8%, coffee 0.5-0.8% and sugar 14-16%. A Central Composite Rotatable Design under response surface methodology was employed to optimize coffee powder, sprouted green gram powder and sugar levels based on sensory attributes (flavour, body & texture, melting quality, colour & appearance, total score). Developed quadratic models exhibited strong predictability ($R^2 = 0.85-0.95$, adequate precision = 8.85-19.07). The optimized formulation achieved high sensory scores, and appealing texture. On the basis of results, it was concluded that frozen yoghurt made with 6 % sprouted green gram powder with 0.8 % coffee powder and 15.04 % sugar was found to be highly acceptable among the other combinations after sensory evaluation. This frozen yoghurt represents a novel health-focused adaptation offering both functional benefits and consumer appeal.

Keywords: Frozen yoghurt, green gram, optimization, response surface methodology

Introduction

Fermented foods have been part of human life for thousands of years, and their beginnings are so ancient that they have been lost to history. (Prajapati and Nair, 2003) [6].

One of the most well-known fermented milk products in the world, yoghurt is now widely regarded as a nutritious diet (Mc Kinley, 2005).

A well-known category worldwide is frozen yoghurt, a tart blend of ice cream and probiotic yoghurt. The guilt-free, healthier dessert plank is making a name for itself in the conventional ice cream industry. The sensory and nutritional qualities of fermented milk products are combined with the physical attributes of ice cream to create frozen yoghurt, a complex fermented frozen dairy delicacy. The frozen yoghurt mix is made by combining all the ingredients with stabilisers and emulsifiers, sugar, and stirred yoghurt. The mixture of frozen yoghurt mix and stirred yoghurt is then frozen in a traditional ice cream freezer (Tamime and Robinson, 2007) [11].

Materials and Methodology

Standardized pasteurized milk (4.6 per cent fat, 8.5 per cent SNF) was used for the preparation of the yoghurt. Full cream milk (6 per cent fat, 9 per cent SNF) was used for the preparation of the premix. Pasteurized cream containing an average of 40.0 per cent milk fat was used for the preparation of the premix. Commercial skim milk powder (Sagar brand; Gujarat Co-operative Milk Marketing Federation, Anand) was purchased from the local market and used as a source of milk solids-not-fat (MSNF) in the frozen yoghurt mix. Sugar (M30 grade) of Madhur brand, manufactured by Shree Renuka Sugar Ltd., Mumbai, was procured from the local market of Anand and used as a sweetening agent. Commercial-grade instant coffee powder (Bru), manufactured by Hindustan Foods Ltd., was procured from the local market in Anand. Commercial-grade green gram (premium grade) was purchased from a local retail outlet. Commercial-grade cinnamon (premium grade) was purchased from a local retail outlet. Sodium alginate and soya lecithin (30%) were used as the stabilizer and emulsifier, respectively. These ingredients were manufactured by HiMedia Laboratories Pvt. Ltd., India. The yoghurt starter culture (Lyofast Y 350 B) was procured from Sacco System. The culture consisted of *Streptococcus salivarius* subsp. *thermophilus*, *Lactobacillus delbrueckii* subsp. *Bulgaricus* and *Lactobacillus helveticus*.

Preparation of dried sprouted green gram powder

Commercial-grade green gram procured from the local market of Anand was thoroughly cleaned and washed with potable water to remove any adhering impurities. The cleaned grains were soaked in water at 20°C for 16 h. During the soaking period, the grains were washed intermittently to minimize the development of undesirable odours and maintain hygienic conditions. After soaking, the water was drained, and the grains were transferred to a covered container for germination. Sprouting was carried out in an incubator maintained at 20°C for 72 h. The sprouted green gram was then dried in a vacuum tray dryer at 45 ± 5°C under a vacuum of 740-760 mm Hg until the desired level of drying was achieved. The dried sprouts were subsequently ground into a fine powder and stored in airtight containers until further use in the preparation of the frozen yoghurt premix.

Preparation of yoghurt

The milk was initially preheated to 35-40°C and filtered through a clean muslin cloth to remove any extraneous matter. It was then heated to 90°C for 15 min, followed by rapid cooling to 42 ± 2°C. The cooled milk was inoculated with a Direct Vat Set (DVS) starter culture at the rate of 0.03 g/L of milk. The starter culture (Lyofast Y 350 B) contained *Streptococcus salivarius subsp. thermophilus*, *Lactobacillus delbrueckii subsp. Bulgaricus* and *Lactobacillus helveticus*. After thorough mixing, the inoculated milk was transferred into a sanitized stainless-steel vessel, covered with a lid, and incubated at 42 ± 2°C until the acidity reached 0.60-0.70 per cent lactic acid. The freshly prepared yoghurt was immediately cooled to 4 ± 2°C and stored under refrigeration until its incorporation into the frozen yoghurt mix.

Preparation of premix base

The premix base was standardized in such way that final product should contain, milk fat as per fat requirement for medium fat ice cream, desired level of sugar, 0.4 per cent stabilizer, 0.4 per cent emulsifier, coffee powder, and 0.2 per cent cinnamon. In the experimental treatments, dried sprouted green gram powder was incorporated into the mix as a protein-enriching ingredient. The required quantities of all dry ingredients, namely sugar, stabilizer, emulsifier, dried sprouted green gram powder, coffee powder, and cinnamon powder, were accurately weighed according to the treatment plan. These ingredients were blended thoroughly to obtain a uniform dry mixture before incorporation into the dairy mix. The measured quantity of milk was transferred to a clean stainless-steel vessel and heated. Cream was added to the milk at approximately 60°C with continuous mixing. The temperature of the mix was then raised to 70°C, at which the blended dry ingredients were gradually incorporated with constant stirring to ensure uniform dispersion. The prepared mix was subjected to two-stage homogenization (pressures: 2000 psi and 500 psi). Following homogenization, the mix was heated to 80°C. During this stage, dried sprouted green gram powder was incorporated into the mix and the mix was held for 5 minutes at 80°C. The pasteurized mix was immediately cooled to 4°C and subsequently aged at the same temperature for approximately 12 h (overnight) before freezing.

Freezing of frozen yogurt

The aged premix and yoghurt were blended in the ratio of

60:40 and then subjected to freezing in batch type ice cream freezer. The frozen yoghurt then filled in PP cups and stored at -18°C for hardening.

Composition analysis

Frozen yoghurt was analyzed for proximate composition, physico-chemical properties, and microbial quality. Total solids, fat, protein, ash and total carbohydrates were determined using standard procedures as per FSSAI (2022), physico-chemical properties analyzed using reference method provided by different researchers and Microbiological quality was assessed by determining lactic acid bacteria count, coliform count and yeast and mold count (FSSAI, 2024).

Sensory evaluation

The sensory evaluation of frozen yoghurt was conducted by a panel of trained judges using a 100-point scale. (Salem *et al.*, 1994) [7] The panel included technical staff, and students of the institute. Samples were evaluated for flavour, body & texture, melting quality, colour & appearance, total score. Judges recorded their scores on a sensory evaluation score card. Saline water was provided to cleanse the palate before and after each tasting. Mean scores were calculated for each parameter to assess overall preference.

Statistical analysis

The levels of coffee powder, sprouted green gram powder and sugar were selected based on preliminary trials. A central composite rotatable design (CCRD) under response surface methodology (RSM) was used to optimize these three factors for the development of frozen yoghurt. The CCRD for three factors included a total of 20 experimental combinations covering the lower and upper limits, along with their corresponding responses for selected sensory attributes (shown in Table 1). The experimental data were analyzed using Design Expert® software (version 13.0.1.0, Stat-Ease, Inc., Minneapolis, USA). The adequacy of each model was assessed through the coefficient of determination (R^2) and analysis of variance (ANOVA) using the F-value to determine statistical significance. The influence of the independent variables on each response was interpreted at significance levels of $P < 0.01$ and $P < 0.05$. Additionally, a t-test assuming equal variance was performed using Microsoft Excel to compare predicted values with actual experimental results.

Result and Discussion

The optimization of frozen yoghurt was carried out based on its sensory qualities, specifically flavour, body & texture, melting quality, colour & appearance, total score. The study utilized a central composite rotatable design (CCRD) of the response surface methodology (RSM) to optimize the levels of coffee powder, sprouted green gram powder and sugar. Successive regression analysis of the data produced quadratic models for each response. The coefficient of determination (R^2) values for the fitted models ranged from 85.80 % to 95.70 %, indicating that a high proportion of variability was explained by the models (Table 2). The model F-values were found to be significant for all responses, confirming the adequacy of the models. Non-significant lack of fit demonstrated that the models were suitable for prediction within the experimental range. The adequacy of the models was further supported by the adequate precision values (APV), which ranged from 8.85 to 19.07, well above the minimum requirement of 4, signifying

an adequate signal-to-noise ratio. These results clearly indicate that the developed quadratic models were robust and can be effectively used to predict and optimize the

quality attributes of frozen yoghurt formulated with varying levels of coffee powder, sprouted green gram powder and sugar.

Table 1: Experimental design matrix, attributes of frozen yoghurt

Run no.	Coffee (%)	Sprouted green gram powder (%)	Sugar (%)	Flavour	Body& Texture	Melting Quality	Colour& Appearance	Total score
1	0.65	6.00	15.00	38.80	28.20	4.26	8.00	89.26
2	0.50	4.00	16.00	38.00	25.20	3.66	8.66	85.52
3	0.65	6.00	15.00	37.90	27.80	4.33	8.00	88.03
4	0.65	6.00	16.00	37.73	27.66	4.64	7.97	88.00
5	0.50	8.00	16.00	40.69	25.60	4.00	8.83	89.12
6	0.65	6.00	15.00	38.70	28.50	4.15	8.19	89.54
7	0.80	6.00	15.00	41.00	27.00	3.58	8.00	89.58
8	0.65	6.00	15.00	39.17	28.50	4.24	8.24	90.15
9	0.80	8.00	16.00	39.42	26.20	3.89	7.66	87.17
10	0.65	6.00	14.00	36.00	27.42	5.00	8.04	86.46
11	0.65	8.00	15.00	40.15	27.50	3.81	8.21	89.67
12	0.65	6.00	15.00	39.14	28.00	4.40	8.14	89.68
13	0.80	4.00	14.00	40.00	24.50	4.66	9.16	88.32
14	0.65	4.00	15.00	40.54	24.40	4.00	8.46	87.4
15	0.65	6.00	15.00	38.85	27.86	4.20	7.87	88.78
16	0.50	4.00	14.00	37.47	24.60	4.66	8.66	85.39
17	0.50	8.00	14.00	41.48	26.67	4.21	8.00	90.36
18	0.50	6.00	15.00	40.00	27.60	3.50	8.50	89.60
19	0.80	4.00	16.00	39.55	25.70	4.12	7.87	87.24
20	0.80	8.00	14.00	39.00	27.60	3.87	7.75	88.22

Effect of variables on flavour

Flavour of any product decides its acceptability. Moreover, higher flavours scores also lead to overall acceptability of the product. The flavour score of frozen yoghurt ranged from 36 to 41.48 (out of 45) on 100- point score.

The experimental frozen yoghurt prepared in run17 was rated best for the flavour as it had highest percent of sprouted green gram powder (8%), lowest percent of coffee (0.5%) and sugar (14%) which helped make mild, well-balanced flavour. Run 10 was least for flavour score which had 0.65 per cent coffee, 6 per cent sprouted green gram powder and 14 per cent sugar as it had slightly higher amount of coffee which was attributing bitterness to the flavour. The coefficient of determination (R^2) of 0.858 indicates a strong fit of the model to the data, suggesting a good explanation of the variability. Additionally, the adequate precision value of 8.879, well above the minimum desirable value of 4.00, supports the model's high prediction ability. Statistical analysis confirmed the model's good fit to the data with a model F value of 6.72. It can be seen in Table 2 that the coffee (A) had a non-significant positive effect on the flavour score. The sprouted green gram powder (B) had a significant ($p < 0.05$) positive effect on flavour score at linear term. The sugar (C) had a non-significant positive impact on flavour score at linear term.

The response surface plot showed that the interactions among coffee, sprouts, and sugar significantly influenced the flavour score of the formulation. Coffee-sprouts interaction exhibited a quadratic response, with lower flavour scores at intermediate levels and higher scores at the extreme concentrations. Both coffee-sugar and sprouts-sugar interactions displayed saddle-shaped response surfaces, indicating that higher coffee or sprouts levels combined with lower sugar concentrations produced the highest flavour scores. Overall, the contour patterns confirmed significant interactive effects, highlighting the need to optimize these ingredients simultaneously for improved sensory acceptance Pardhi *et al.* (2013) [5], prepared lassi incorporated with millets that demonstrated increasing flavour scores with the increasing finger millet flour, but after a certain limit flavour score decreased subsequently. Hence combining either legumes or millets with fermented dairy products gives almost same results for sensory evaluation of the product in terms of flavours. In the current study with incorporation of sprouted green gram powder flavour score has been increased this is might because of nutty taste of sprouted green gram powder in Protein Enriched Probiotic Frozen Yoghurt.

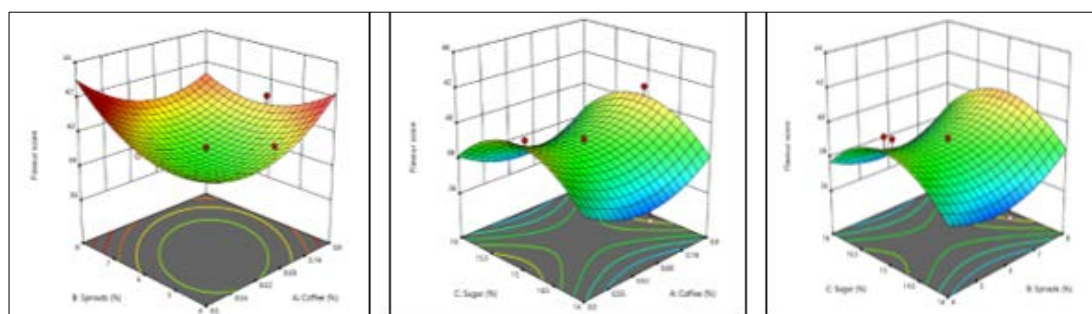


Fig 1: Response surface plot of flavour score

Table 2: P values and partial coefficients of the regression equation for the suggested models related to the sensory qualities of frozen yoghurt

Terms		Sensory scores (100-point score)				
		Flavour	Body and texture	Melting quality	Colour and appearance	Total score
Intercept		38.867	27.960	4.2058	8.0907	89.125
Linear level	A	0.133	0.133	0.009	-0.221*	0.054
	B	0.518*	0.917*	-0.132*	-0.236*	1.067*
	C	0.144	-0.043	-0.209*	-0.062	-0.17
Interactive Effect	AB	-0.979*	0.141	-0.114*	-0.141*	-1.093*
	AC	0.029	0.034	0.086	-0.276*	-0.128
	BC	-0.056	-0.534*	0.169*	0.254*	-0.168
Quadratic Level	A ²	1.471*	-0.387	-0.580*	0.133	0.638
	B ²	1.316*	-1.737*	-0.215*	0.218*	-0.417
	C ²	-2.164*	-0.147	0.700*	-0.112	-1.722*
R ²		0.858	0.921	0.957	0.945	0.865
Model F-value		6.72	13.01	25	19.21	7.11
APV		8.879	9.926	19.078	16.202	8.85
Suggested Model		Quadratic	Quadratic	Quadratic	Quadratic	Quadratic

A: Coffee, B: Sprouted green gram powder, C: Sugar

*: $p < 0.05$; R²=Coefficient of determination, APV= Adequate Precision Value**Effect on body & texture score**

The body and texture score of frozen yoghurt depicted in Table 1 indicated variation from 24.4 to 28.5 (out of 30) and frozen yoghurt prepared by using 0.65 per cent coffee, 6 per cent sprouted green gram powder and 15 per cent sugar was rated highest for body and texture score and that prepared using 0.65 per cent coffee, 4 per cent sprouted green gram powder and 15 per cent sugar was rated lowest for body and texture score by the panelists.

From this it is concluded that least score was observed when sprouted green gram powder was used at lowest rate which decreased the total solids and made the product much lighter, in contrary highest score was observed when sprouted green gram powder was used in higher concentration which increased the total solids content and it ultimately helped in dense, nutty product.

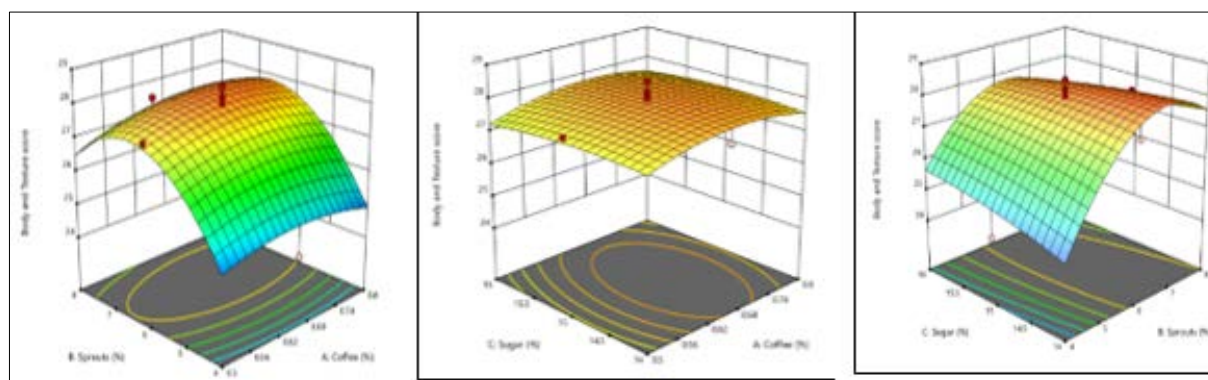
The coefficient of determination (R²) for body and texture scores, was 0.921 indicates the proportion of variability in the data that is explained by the model. A high R² value suggests a strong fit of the model to the data, meaning that the model accounts for a large portion of the variation in body and texture scores.

Furthermore, the Adequate Precision Value was 9.926 which was significantly higher than the minimum desirable value, supporting the model's high prediction ability and its usefulness in navigating the design, as it indicates a strong signal-to-noise ratio.

Statistical analysis, as indicated by the model F-value of 13.01, further confirms the model's good fit to the data. This suggests that the model is well-suited for predicting body and texture scores based on the formulation variables.

The response surface plots suggest that the highest body and texture scores are achieved at balanced, moderate levels of coffee, sprouts, and sugar rather than at their extreme concentrations

Forbes *et al.* (1996) [3]. found that the body and texture score of high protein frozen yoghurt samples were higher on 10-point scale, whereas commercial sample of frozen yoghurt received lower score. Also, this study showed similar trend that adding moderate amount of sprouted green gram powder for the purpose of protein enrichment resulted in increase in body and texture score which could be because of hydration of starch along with the protein at the time of aging of the mix which resulted in denser product.

**Fig 2:** Response surface plot of body & texture score**Effect on melting quality Score**

The melting quality scores of frozen yoghurts depicted in table 1 indicated variation from (out of 5) and the frozen yoghurt prepared by using 0.65 per cent coffee, 6 per cent sprouted green gram powder, 14 percent sugar was rated highest for melting quality score (Table 1) because it had an

optimum balance of ingredients, resulting in a smooth texture and controlled melting. While the frozen yoghurt prepared by using 0.5 per cent coffee, 6 per cent sprouted green gram powder, 15 percent sugar was rated lowest for melting quality score as the higher sugar level may have

lowered the freezing point, leading to faster melting and a softer consistency that was least acceptable by the panellists. The coefficient of determination (R^2) represents the proportion of variation in the observed data that is explained by the model. The obtained R^2 value of 0.957 indicates a satisfactory fit of the model to the experimental data, as presented in Table 2. Furthermore, the adequate precision value of 19.078 suggests that the model has an adequate signal-to-noise ratio and can be effectively used to navigate the design space. The response surface plots depict the interactive effects of three independent variables Coffee (%), Sprouts (%), and Sugar (%) on the sensory Melting quality score of the product. The interaction between Coffee and Sprouts forms a clear parabolic dome, indicating that a

moderate, balanced concentration of both yields the highest melting quality score near 4.5. Conversely, the plots illustrating Sugar interacting with Coffee and Sprouts display complex, saddle-shaped surfaces; this demonstrates a strong synergistic impact where higher sugar levels combined with specific proportions of coffee or sprouts significantly alter the melting characteristics, allowing optimization across different formulation ranges. The results of the present experiment also coincided with the trials of Shingala (2025) [9], for manufacturing a protein rich, sugar free, medium fat ice cream using milk protein concentrate as a source of protein and found that the highest melting quality scores (around 4.10) are observed when MPC-80 levels are moderate.

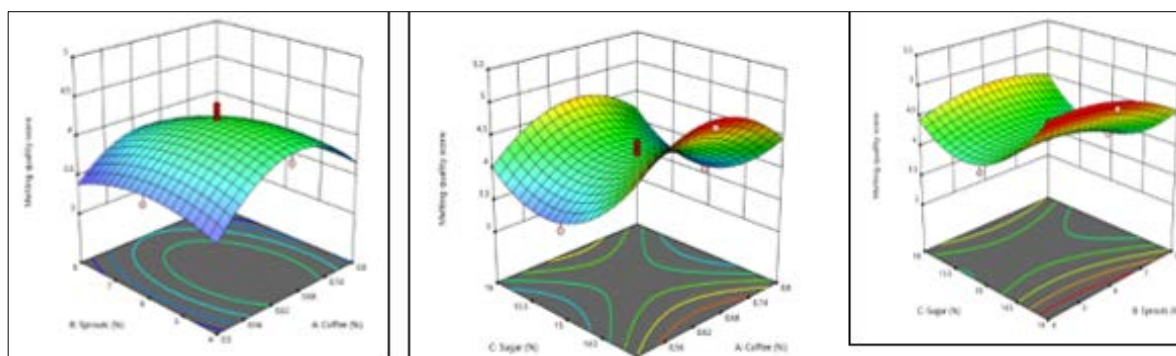


Fig 3: Response surface plot of melting quality score

Effect on colour and appearance Score

The colour and appearance scores of frozen yoghurt incorporated with coffee, sprouted green gram powder, sugar as shown in Table 1, indicated variation from 7.66 to 9.16 (out of 10). Frozen yoghurt prepared by using 0.8 per cent coffee, 4 per cent sprouted green gram powder, 14 percent sugar was rated highest for colour and appearance score due to its appealing coffee colour, uniform appearance, and smooth texture, while frozen yoghurt prepared by using 0.8 per cent coffee, 8 per cent sprouted green gram powder, 16 percent sugar was rated lowest colour and appearance score possibly because the higher sprouts content imparted darkness to the products visual appeal, resulting in lower colour and appearance. The coefficient of determination (R^2) is the degree of variability in the data explained or accounted for the model and a 0.945 value of R^2 indicates a better fit of the model to the data. Additionally, the adequate precision value of 16.202 i.e., greater than 4 is desirable and recommends the use of this response to navigate the design. Additionally, the statistical analysis showed that the model (model F-value: 19.21) adequately fit the data. It can be seen in Table 2 that the

coffee (A) had a significant negative effect on the colour and appearance score. The sprouted green gram powder (B) had a significant negative effect on colour and appearance score at linear terms. The sugar (C) had a non-significant negative impact on colour and appearance score at linear term. The three-dimensional response surfaces exhibited characteristic quadratic and saddle-shaped curvatures, confirming the presence of significant interaction effects among the formulation variables. Overall, the findings suggest that optimizing coffee concentration while controlling sprout and sugar levels is essential for enhancing the colour and appearance of the developed product. Shaikh *et al.* (2017) [8] incorporated finger millet flour for manufacture of a fermented milk product. The Colour and appearance scores increased by 15 per cent and then decrease by 20 per cent as level of addition of finger millet flour increased. Incorporation of millets and pulses shows similar colour and appearance pattern due to added powder or chunks into the fermented milks. Similar observations have been recorded in this study, wherein increase in the concentration of sprouted green gram powder led to decrease in the colour and appearance score.

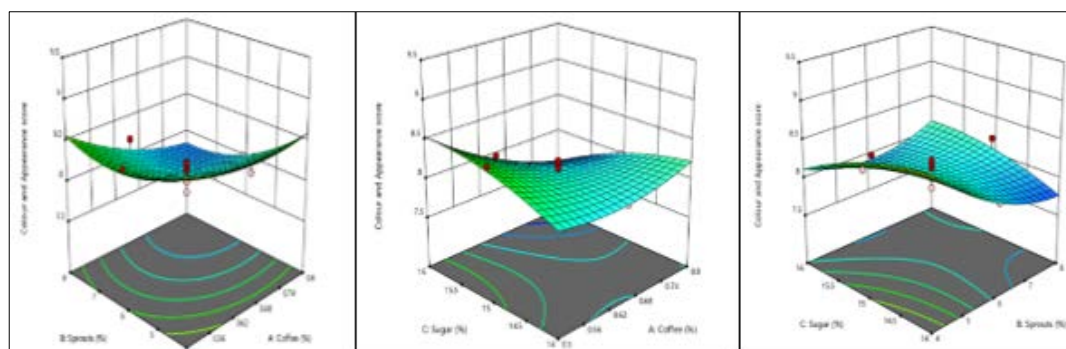


Fig 4: Response surface plot of colour & appearance score

Table 3: Regression equation for predicting sensory score of frozen yoghurt

Property	Equation
Colour & appearance	$8.09 - 0.2210 A - 0.2360 B - 0.0620 C - 0.1413 AB - 0.2763 AC + 0.2537 BC + 0.1332 A^2 + 0.2182 B^2 - 0.1118 C^2$
Flavour	$38.87 + 0.1330A + 0.5180B + 0.1440C - 0.9787AB + 0.0288AC - 0.0562BC + 1.47A^2 + 1.32B^2 - 2.16C^2$
Body & texture	$+27.96 + 0.133A + 0.917B - 0.043C + 0.141AB + 0.033AC - 0.533BC - 0.386A^2 - 1.74B^2 - 0.146C^2$
Melting quality	$+4.21 + 0.009A - 0.132B - 0.209C - 0.113AB + 0.0862AC + 0.168BC - 0.579A^2 - 0.214B^2 + 0.700C^2$
Total score	$89.12 + 0.0540 A + 1.07 B - 0.1700 C - 1.09 AB - 0.1275 AC - 0.1675 BC + 0.6382 A^2 - 0.4168 B^2 - 1.72 C^2$

Effect of different variables on total score

The total score of frozen yoghurt was measured in a 100-point scale. The total score of frozen yoghurt ranged from 85.52 to 90.36 (out of 100) as shown in Table 1. The lowest scores was obtained for experimental run 16, which was made-up of 0.5 per cent coffee, 4 per cent sprouted green gram powder and 14 per cent sugar likely due to the lowest sprout level, which may have caused lack of nutty flavour and reduced overall acceptability. The highest score was obtained for experimental run 17 containing 0.5 per cent coffee, 8 per cent sprouted green gram powder and 14 per cent sugar suggesting that the lowest coffee and sugar levels, combined with a highest sprout content, produced a

more balanced flavour greater overall consumer acceptance.

The coefficient of determination (R^2) is the proportion of variability in the data explained or accounted for the model and a 0.865 value of R^2 indicates a better fit for the model. Also, the adequate precision value of 8.85 i.e., greater than 4 is desirable, and recommends the use of this response to navigate the design. The Model F-value of 7.11 implies the model is significant.

The response surface plot indicated that optimizing coffee concentration while maintaining controlled levels of sprouted green gram powder and sugar is essential for achieving maximum overall acceptability of the developed product.

Table 4: Comparison of predicted v/s actual values of responses used for optimization of frozen yoghurt

Response	P Value	Predicted Value *	Actual Value @	Cal. t Value#	Level of Significance
Sensory Attributes (100-point hedonic scale)					
Flavour	0.1	40.47	41.355	1.737	NS
Body & Texture	0.06	27.7	26.85	2.235	NS
Melting quality	0.42	3.63	3.785	0.846	NS
Colour & appearance	0.17	7.98	8.261	1.519	NS
Total score**	0.2	89.80	89.331	1.38	NS

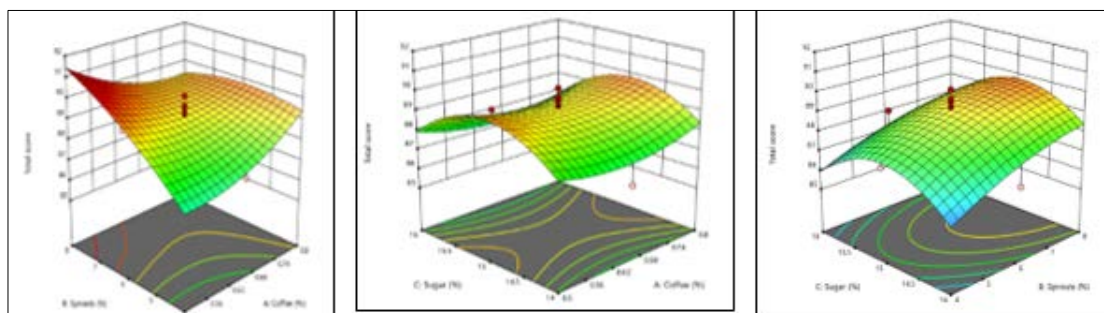
* Predicted values of Design Expert 13.0.1.0 package

@ Actual values are average of seven trials for optimized product

t-values found non-significant at 5 per cent level of significance

NS = Non-Significant

** 10 marks of packaging was considered in the total score.

**Fig 5:** Response surface plot of total score**Optimization of product formulation for frozen yoghurt using green gram**

The optimization of frozen yoghurt using green gram formulation was carried out using numerical optimization techniques. The primary aim was to determine the most suitable levels of coffee powder, sprouted green gram powder and sugar to achieve high sensory scores. During

this process, coffee powder, sprouted green gram powder and sugar were maintained within the ranges of 0.5-0.8% and 4.00-8.00% per cent and 14-16%, respectively. Sensory parameters such as, flavour, body & texture, melting quality colour & appearance and total score, were all kept within targeted limits to ensure a well-balanced product.

Table 5: Criteria/responses chosen for optimization of frozen yoghurt using green gram

Name	Goal	Lower Limit	Upper Limit	Importance
A: Coffee	in range	0.5	0.8	3
B: Sprouted green gram powder	Maximize	4	8	5
C: Sugar	in range	14	16	3
Sensory Attributes (100-point hedonic scale)				
Flavour	Maximize	36	41.48	5
Body & texture	in range	24.4	28.5	3
Melting quality	in range	3.5	5	3
Colour & appearance	in range	7.66	9.16	3
Total score	in range	85.39	90.36	3

Suggested Solution from RSM analysis for frozen yoghurt.

The optimized formulation of 0.8 % coffee, 6 % sprouted green gram powder, and 15.04 % sugar, with a desirability value of 0.90, was therefore selected for subsequent validation and further compositional, physicochemical, microbiological studies.

Analysis of frozen yoghurt using green gram.

The product exhibited a total solids (TS) content of 41.02 ± 0.23 , indicating a relatively high solids content, which contributes to improved body, texture, and melting resistance. The fat content was 8.61 ± 0.03 , providing desirable richness and creaminess to the product. The ash

content (1.10 ± 0.10) reflects the mineral composition of the frozen yoghurt, whereas the total carbohydrate content was 26.30 ± 0.34 , mainly contributed by lactose, added sugar, and carbohydrates from green gram. Overall, the proximate composition confirms that the incorporation of green gram successfully enhanced the nutritional quality of the probiotic frozen yoghurt, particularly by significantly increasing its protein content without adversely affecting the overall composition.

Among the physico-chemical properties of Frozen yoghurt had included 0.40 ± 0.01 percent acidity (% lactic acid), 4.70 ± 0.05 pH, 52.10 ± 0.78 melting resistance, 38.13 ± 0.32 per cent overrun, 7.43 ± 0.11 mm hardness and 5701.33 ± 242.12 cP viscosity respectively.

Table 6: Analysis of optimized product

Parameter	Frozen yoghurt
Proximate composition (%)	
Total solids	41.02 ± 0.23
Protein	4.73 ± 0.21
Fat	8.61 ± 0.03
Ash	1.10 ± 0.1
Total carbohydrates	26.30 ± 0.34
Physico-chemical properties	
Acidity (% LA)	0.40 ± 0.01
pH	4.70 ± 0.05
Melting resistance (%)	52.10 ± 0.78
Overrun (%)	38.13 ± 0.32
Hardness (mm)	7.43 ± 0.11
Viscosity (cP)	5701.33 ± 242.12
Microbial quality	
Lactic count ($\log_{10}$ cfu/g)	8.44 ± 0.31
Probiotic count ($\log_{10}$ cfu/g)	8.16 ± 0.25
Yeast and mold count	Absent
Coliform count	Absent

Conclusion

The suggested optimized solution specified by RSM analysis was coffee 0.8 per cent, sprouted green gram powder was 6 per cent and sugar 15.04 per cent, in the preparation of frozen yoghurt. The average fat, protein, ash, total carbohydrates and total solids of the optimized frozen yoghurt samples were 8.61 per cent, 4.73 per cent, 1.10 per cent, 26.30 per cent and 41.02 respectively. In terms of physico-chemical characteristics, the optimized Frozen yoghurt had 0.40% acidity (% lactic acid), 4.7. pH, 52.10 % melting resistance, 38.13 % overrun, 5701.33 cP viscosity, and 7. 43mm hardness. The microbiological quality of Frozen yoghurt had LAB count ($\log_{10}$ cfu/g) 8.44 and probiotic count ($\log_{10}$ cfu/g) 8.16. The coliform as well as yeast and mold count were absent/g in the same sample.

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