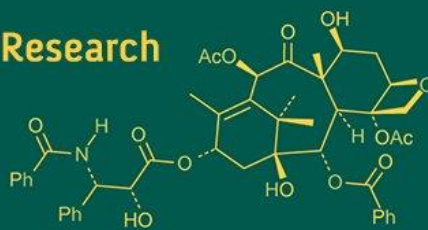


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## Development of Paneer based processed cheese

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DOI: <https://www.doi.org/10.33545/26174693.2026.v10.i8e.9571>**Abstract**

Paneer, a soft cheese, was prepared employing different levels of fat and was utilized to convert the same into processed cheese along with cheese flavour concentrate as flavoring at different rates and optimized product was selected using RSM software model. Optimization was carried out by selecting independent variables, level of milk fat in Paneer manufacture and rate of addition of cheese flavour concentrate; whereas sensory parameters such as flavour, colour and appearance, body and texture along with important compositional parameters such as % moisture and % FDM were taken as the response variables. The statistical analysis showed that both milk fat level and cheese flavour concentrate had a significant effect on all the responses under study. The RSM model suggested optimized solution, for milk fat level @3.50% and cheese flavour concentrate @ 3.22%, which produced processed cheese with highly desirable sensory quality attributes. The optimized formulation had a moisture content of 46.33%, fat (FDM) of 43.78%, protein content of 23.77%, ash content of 3.54%, titratable acidity of 1.05% (lactic acid), free fatty acid (FFA) content of 4.40 meq. of KOH/100g fat and water activity of 0.986.

**Keywords:** Paneer, Milk fat, Cheese flavour concentrate, Response surface methodology, Sensory

**Introduction**

Processed cheese is popular choice in Indian cheese market because of its extended shelf life, convenience and versatility in different food preparations. Processed cheese is manufactured by shredding, mincing or slicing natural cheeses at various stages of ripening and blending them with emulsifying salts under controlled heating conditions, either under partial vacuum or normal atmospheric pressure, until a smooth and uniform product is formed (Hladká *et al.*, 2014) [12]. The quality of processed cheese is primarily influenced by the selection of natural cheeses based on their composition, pH, flavour profile and level of ripening or proteolysis. A high-quality processed cheese should have a smooth texture, uniform colour and homogeneous body without any holes or defects caused by fermentation (Toro *et al.*, 2016) [17]. Different type of ingredient is used in processed cheese production including cheese, water, emulsifying salt, added protein, fat, stabilizer, gums, flavouring compound, humectants and minerals. Casein is the predominant protein in processed cheese and play important role in determining its textural properties (Abdeen *et al.*, 2018) [1].

Emulsifying Salts (ES) are important ingredients in the preparation of processed cheese and cheese spread. Primary functions of ES are to control the pH and interact with calcium present in cheese. By sodium chelating calcium, emulsifying salts help break down the calcium-linked protein network naturally present in cheese, which improves the emulsifying properties of casein proteins and contributes to a smooth and stable processed cheese product (Chen and Liu, 2012) [5].

Enzyme Modified Cheeses (EMC) is widely used in the food industry as a natural, economical and flexible alternative to enhance natural cheese flavouring in the product it contained. During EMC production, the breakdown of proteins into free amino acids and their further conversion into flavour compounds plays an important role in creating the characteristic cheese taste and aroma (Kendirici *et al.*, 2020) [13].

Paneer/chhana, a fresh unripened soft cheese that can be a suitable ingredient for use in processed cheese manufacture instead of traditionally used ripened cheeses. Its use thus can help in production of processed cheese in a more economical and less time-consuming way. Since only limited research work has been reported on Paneer-based processed cheese, this

study was carried out to explore its potential in processed cheese manufacture. Cheese flavour concentrate helped in improving the overall cheese flavour and umami taste, which increased consumers' acceptability.

### Materials and methods

The paneer milk was formulated as per experimental design using raw chilled milk (4.5% fat and 8.7% SNF) and skim milk (0.05% fat and 8.5% SNF) obtained from the Department of Dairy Processing and Operation, SMC College of Dairy Science, Anand and subsequently converted into paneer. Cheese flavour concentrate of cheddar cheese was obtained from Adare Food Ingredients Pvt. Ltd., Vitthal Udyog Nagar, Anand and used in the formulation of processed cheese.

### Preparation method

Milk was standardized as per experimental design (Table-1) and subjected to heat treatment at 90°C for 15 min, followed by cooling to 70°C prior to coagulation with 1% (w/v) citric acid solution. The coagulum was drained through muslin

cloth and pressed to obtain paneer. The obtained paneer ground into a smooth paste. Emulsifying salts and common salt were then added in predetermined proportions during grinding and blending to ensure uniform mixing, proper emulsification and improved homogeneity and resulting into pre cheese blend.

### Manufacture of Processed Cheese

Pre cheese blend was then heated to 80-85°C for 10-15 minutes with continuous stirring and frequent scraping of the surface using a stainless-steel. At the last stage of heating cheese flavour concentrate was added. The processed cheese was subsequently transferred into mould and allowed to cool at room temperature for 2-3 hours. Thereafter, the moulded product was kept under refrigeration overnight to facilitate proper setting and texture development. The processed cheese was cut into uniform portions, wrapped in aluminum foil (11 µ) as primary packaging material and placed in polyethylene pouches (75 µ) and vacuum packed.

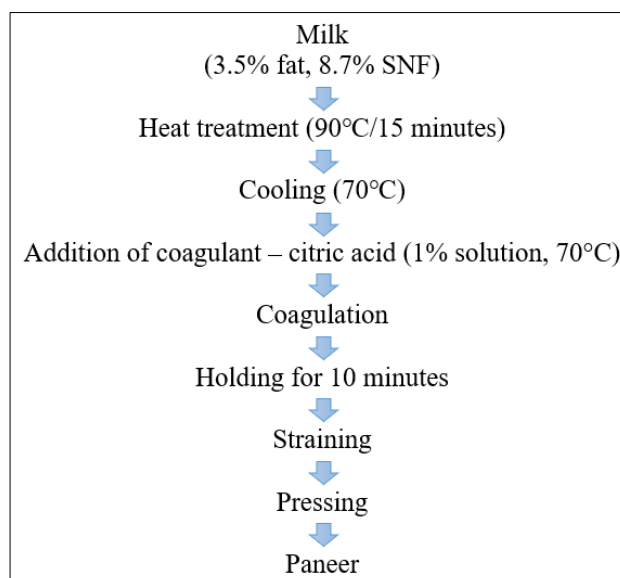


Fig 1: Flow diagram for paneer

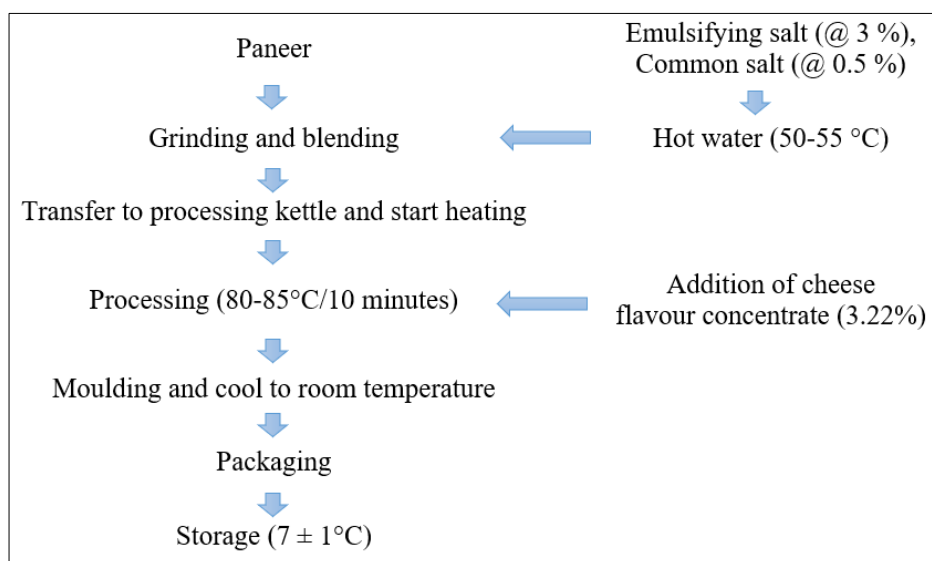


Fig 2: Flow diagram for processed cheese

**Composition Analysis:** Processed cheese was analyzed for proximate composition, physico-chemical properties and microbial quality. Moisture, fat, protein and total ash were determined using standard procedures as per FSSAI (2022) [6]. Microbiological quality was assessed by determining aerobic plate count, coliform count and yeast and mold count (FSSAI, 2024) [7].

### Sensory evaluation

Sensory evaluation was performed by a panel of 7 trained judges, using a 100-point score card (BIS 10:281, 1982) [3]. The samples were evaluated for colour and appearance, flavour, body and texture and overall acceptability.

**Texture profile analysis:** Texture analysis of the processed cheese was carried out using a Lloyd Texture Analyzer (Model 01/2962, Hampshire, UK) equipped with a 5kN load cell. Before analysis, the samples were allowed to equilibrate at  $23\pm1^{\circ}\text{C}$  for 1 h. The measurements were performed under controlled laboratory conditions maintained at  $23\pm1^{\circ}\text{C}$  and  $55\pm1\%$  relative humidity. Processed cheese cubes measuring  $20 \times 20 \times 20$  mm were placed on the compression platform and compressed to 70% of their original height at a test speed of 20.0 mm/min. Four samples from each treatment were analyzed and the average value was used for further statistical analysis.

### Statistical analysis

Two factors face centered Response Surface Methodology (RSM) and Completely Randomized Design (CRD) were used to analyze the data generated during the study. Initially, the levels of milk fat and cheese flavour concentrate were optimized using design experts' software version 13.0.1.0. Based on preliminary trials, suitable ranges of the variables were selected and 13 experimental runs were generated by the software. The optimum formulation suggested by the software was validated by preparing the product in seven replications.

$Y = a_0 + a_1x_1 + a_2x_2 + a_{11}x_1^2 + a_{22}x_2^2 + a_{12}x_1x_2 + \text{Error term}$   
In the model, Y represents the predicted response, while  $a_0$  is the intercept. The coefficients  $a_1$  and  $a_2$  describe the linear effects of milk fat ( $x_1$ ) and cheese flavour concentrate ( $x_2$ ), respectively. The quadratic effects are represented by  $a_{11}$  and  $a_{22}$ , whereas  $a_{12}$  indicates the interaction between the two independent variables. The adequacy of the fitted model was evaluated using the coefficient of determination ( $R^2$ ) and analysis of variance (ANOVA). The significance of the model and its individual terms was determined by the F-test and the effects of the independent variables were considered significant at  $P < 0.05$  and  $P < 0.01$ .

### Results and discussion

The optimization of processed cheese was carried out based on its sensory qualities, specifically colour & appearance, flavour, body & texture and overall acceptability, as well as its moisture percentage and fat on dry matter basis (%FDM) as governed by legal standards. The level of milk fat and cheese flavour concentrate was optimized using two factors FCRD Response Surface Methodology (RSM). Based on preliminary trials, level of milk fat content used for paneer preparation was selected ranging from 2.0 to 6.0% while the cheese flavour concentrate level varied from 1.0 to 4.0% (w/w). The concentration of emulsifying salt (3.0%) and

common salt (0.5%) was kept constant in all experiments.

The experimental design matrix, sensory, moisture (%) and fat (%FDM) attributes of processed cheese are presented in Table 1.

The  $R^2$  values of the fitted models ranged from 85.51% to 94.99%, showing that the models accounted for most of the variation in the experimental data (Table 2). The ANOVA results showed that the model F-values were significant for all the responses, confirming that the developed models provided a good fit to the data. Model adequacy was further supported by the Adequate Precision Values (APV), which ranged from 8.50 to 14.36. As all the APV values were higher than the recommended value of 4, the models had an adequate signal-to-noise ratio and were considered reliable for prediction. Therefore, the developed quadratic models were suitable for predicting the quality characteristics of processed cheese and for optimizing the levels of milk fat and cheese flavour concentrate.

The P values and partial coefficients of the regression equation for the suggested models related to the sensory qualities of processed cheese are presented in Table 2.

### Effect of variables on colour and appearance score

Color and appearance are primary attributes that influenced the visual appeal and initial acceptability of product. Sensory evaluation scores for this parameter ranged from 11 to 14 (Table 1). The colour and appearance scores obtained during the study were fitted to a quadratic model with an  $R^2$  value of 0.8642, indicating that 86.42 per cent of the variation in colour and appearance scores was explained by the model. The Adequate Precision value of 8.7194, which exceeded the desirable value of 4.0, confirmed the adequacy of the model for optimization purposes.

Milk fat led to development of a desirable creamy colour and enhanced glossiness at higher levels. Milk fat level (A) exerted a significant positive effect on colour and appearance score ( $+0.850$ ,  $p < 0.05$ ), indicating that increasing milk fat content improved the visual quality of processed cheese. Cheese flavour concentrates level (B) exhibited a non-significant negative effect ( $-0.0833$ ,  $p > 0.05$ ) on colour and appearance score. Likewise, the interaction effect between milk fat and cheese flavour concentrate (AB) was found to be non-significantly negative ( $-0.1750$ ,  $p > 0.05$ ).

The colour and appearance scores increased with increasing milk fat levels (Figure 3) and reached maximum values at intermediate concentrations. Further increases in milk fat resulted in a decline in the response due to the significant negative quadratic effect.

Similar findings were reported by Hamdy *et al.* (2026) [10], who observed that balanced moisture and fat/DM basis improved the appearance of processed cheese by producing a smooth, glossy surface and a homogeneous matrix. Likewise, Wadhwani and McMahon (2012) [19] reported that full-fat cheese exhibited greater opacity and a more desirable appearance than low-fat cheese due to improved light scattering.

The increase in milk fat improved the colour and appearance scores of processed cheeses by producing a smoother, glossier and more homogeneous surface. Milk fat globules scattered incident light within the cheese matrix, resulting in greater opacity and a creamy yellow appearance that is preferred by consumers.

### Effect of variables on body & texture score

Body and texture are important quality attribute that influence the sensory acceptance of any food products including processed cheese. These features cover firmness, smoothness, cohesiveness and overall mouthfeel of the product. Sensory evaluation scores for this parameter ranged from 24.48 to 28.08 (Table 1) indicating a favorable texture. The body and texture scores obtained during the study were fitted to a quadratic model with an  $R^2$  value of 0.8781, indicating that 87.81 per cent of the variation in body and texture scores was explained by the model. The Adequate Precision value of 8.5013, which exceeded the desirable value of 4.0, confirmed the adequacy of the model for optimization purposes.

Milk fat (A) had positive effect (Figure 4) on body and texture (+1.450 coefficient,  $p < 0.05$ ), indicating that increasing milk fat content improved the body and texture of processed cheese. Cheese flavour concentrates level (B) exhibited a non-significant negative effect (-0.0616,  $p > 0.05$ ) on body and texture score. Similarly, the interaction effect between milk fat and cheese flavour concentrate (AB) was found to be non-significantly positive (+0.4075,  $p > 0.05$ ).

The quadratic effect of milk fat ( $A^2$ ) was significant and negative (-1.6482,  $p < 0.05$ ), indicating that body and texture scores increased up to an optimum level and

declined thereafter (Figure 4). This suggests that excessive incorporation of milk fat may adversely affect the structural integrity and consistency of processed cheese. The quadratic effect of cheese flavour concentrate ( $B^2$ ) was non-significant ( $p > 0.05$ ).

Similar findings have been reported by several researchers. Hirpara *et al.* (2016) [11] reported that milk fat significantly influenced the body and texture of processed cheese spread. Spread with lower fat content had a hard body and poor spreadability, whereas increasing the fat level resulted in a softer, smoother body and improved spreadability. Hamdy *et al.* (2026) [10] also reported that higher fat levels and adequate protein, promoted the formation of a cohesive cheese matrix with a lubricating cream phase and fine fat dispersion, resulting in superior body and texture. Similarly, Cai *et al.* (2024) [4] founded that higher fat content produced a softer and more cohesive cheese structure during mastication, improving smoothness, creaminess and overall mouthfeel. Singh *et al.* (2023) [16] further explained that reducing fat levels increases protein-protein interactions leading to a denser protein matrix and consequently a firmer, tougher and less creamy cheese. In addition, Guinee and O'Callaghan (2013) [9] found that reducing fat while increasing protein at constant moisture and emulsifying salt levels significantly increased the firmness of processed cheese, indicating that milk fat acts as a softening and lubricating component within the cheese matrix.

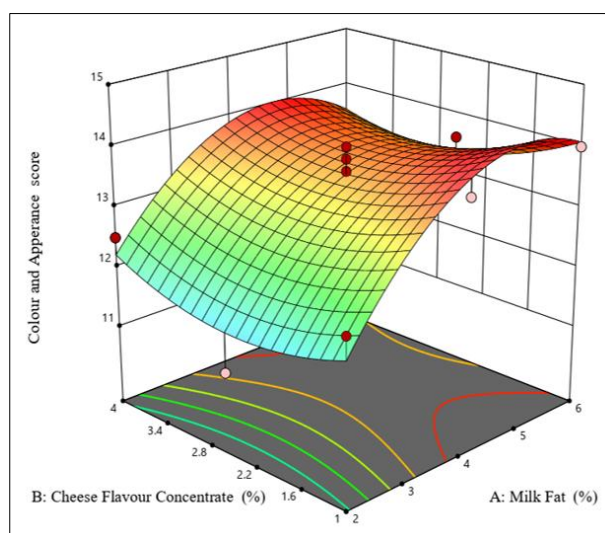


Fig 3: Colour and Appearance score as affected by level of milk fat and cheese flavour concentrate

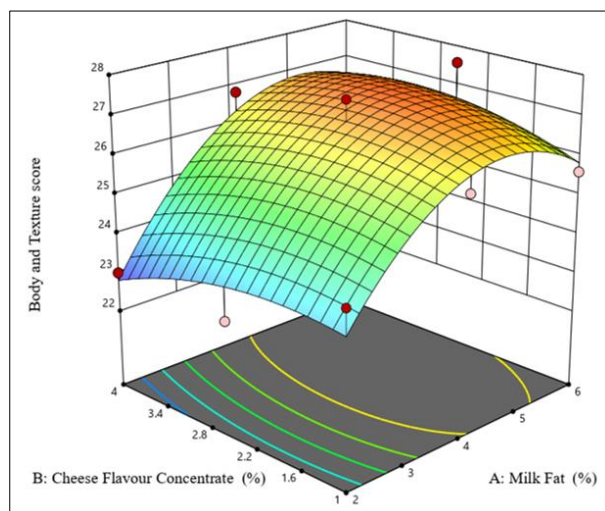


Fig 4: Body and texture score as affected by level of milk fat and cheese flavour concentrate

### Effect of variables on flavour score

Flavour is the overall sensory experience of a food, mainly influenced by its taste, smell and mouthfeel. It is one of the most important factors in judging the quality of a product. Sensory evaluations yielded flavour scores ranging from 38.4 to 44.14 (Table 1). The flavour scores obtained during the study were fitted to a quadratic model with an  $R^2$  value of 0.8711, indicating that 87.11 per cent of the variation in flavour scores was explained by the model. The Adequate Precision value of 9.5355, which was greater than the desirable value of 4.0, confirmed the adequacy of the model for navigating the design space.

Milk fat had a strong positive linear effect (+ 1.806 coefficient,  $p < 0.05$ ), confirming its role in enhancing flavour. Cheese flavour concentrates level (B) showed a positive but non-significant linear effect (+0.170,  $p > 0.05$ ) on flavour score. The interaction effect between milk fat and cheese flavour concentrate (AB) was non-significant ( $-0.500$ ,  $p > 0.05$ ). The quadratic effect of cheese flavour concentrate ( $B^2$ ) was significant and negative ( $-1.522$ ,  $p < 0.05$ ), indicating that flavour scores increased up to an optimum concentration of cheese flavour concentrate and declined thereafter at higher levels. The quadratic effect of milk fat ( $A^2$ ) was found to be non-significant ( $p > 0.05$ ).

The present findings are in agreement with those of several researchers who have highlighted the importance of milk fat and flavour concentrate in the flavour development of processed cheese. Tran *et al.* (2026) [18] found that milk fat enhances oral lubrication and regulates the release of aroma compounds during consumption, thereby improving creaminess, smoothness, mouth-coating, flavour persistence and overall sensory perception. Yoo and Lee (2024) [20] also demonstrated that milk fat play's significant role in flavour development, as lipolysis during ripening releases free fatty acids that directly contribute to cheese flavour and act as precursors for several volatile aroma compounds. Similarly, Hirpara *et al.* (2016) [11] observed that increasing the fat content of cheese milk from 2 to 4-6% significantly enhanced the cheesy flavour of processed cheese, indicating that an adequate level of milk fat is essential for desirable flavour characteristics

Flavour scores increased (Figure 5) with increasing milk fat levels, whereas cheese flavour concentrate showed an optimum effect, beyond which flavour acceptability declined. Thus, the study demonstrated that milk fat was the

major factor influencing flavour perception, while cheese flavour concentrate contributed significantly only at its quadratic level.

### Effect on overall acceptability score

Overall acceptability represents the combine sensory perception of a product and it considered one of the most important indicators for product success. Scores for this critical parameter ranged from 78.2 to 90.31 (Table 1).

The overall acceptability scores obtained during the study were fitted to a quadratic model with an  $R^2$  value of 0.8995, indicating that 89.95 per cent of the variation in overall acceptability scores was explained by the model. The adequate precision value of 8.8668, which exceeded the desirable value of 4.0, confirmed the adequacy of the model for optimization purposes.

Milk fat level (A) had a significant positive effect on overall acceptability score (+4.1066,  $p < 0.05$ ), indicating that increasing milk fat content improved the overall sensory quality of processed cheese. Cheese flavour concentrates level (B) exhibited a non-significant positive effect (+0.0250,  $p > 0.05$ ) on overall acceptability (Figure 6). Similarly, the interaction effect between milk fat and cheese flavour concentrate (AB) was found to be negative and non-significant ( $-0.2675$ ,  $p > 0.05$ ).

The quadratic effect of milk fat ( $A^2$ ) was significant and negative ( $-3.9434$ ,  $p < 0.05$ ), indicating that overall acceptability increased up to an optimum level of milk fat and declined thereafter. This suggests that excessive incorporation of milk fat may adversely affect the overall sensory balance of processed cheese. The quadratic effect of cheese flavour concentrate ( $B^2$ ) was non-significant ( $p > 0.05$ ), indicating that its effect on overall acceptability remained relatively constant within the experimental range studied.

Similar findings have been reported by Noronha *et al.* (2008) [14] that enzyme-modified cheese improved the cheesy flavour of imitation cheese; however, excessive levels of cheese flavour concentrate produced off-flavours and reduced sensory acceptability. Likewise, Hirpara *et al.* (2016) [11] reported that increasing milk fat improved the flavour, body and texture, spreadability and overall sensory quality of processed cheese up to an optimum level, whereas further increases in fat adversely affected these sensory attributes.

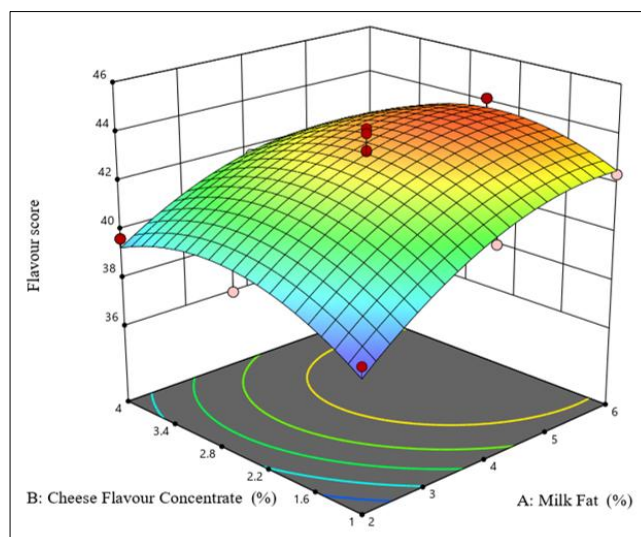


**Fig 5:** Flavour score as affected by level of milk fat and cheese flavour concentrate

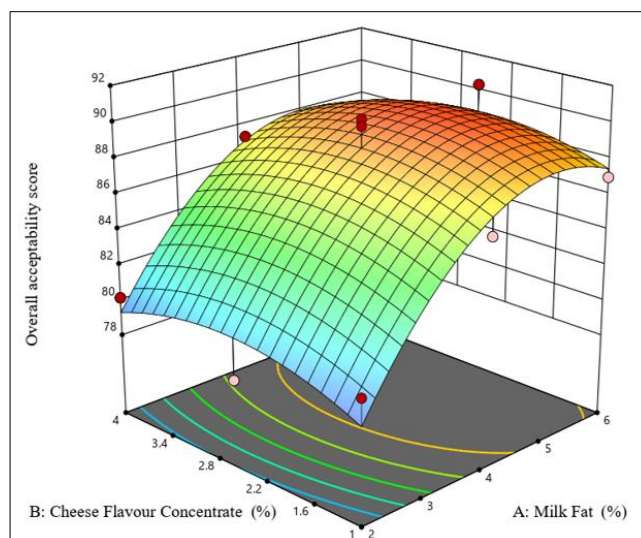


**Fig 6:** Overall acceptability score as affected by level of milk fat and cheese flavour concentrate

### Effect of variables on moisture content

Moisture content is an important composition attribute influencing the texture and shelf life of product. The moisture content of the sample was adequately described by a quadratic model with an  $R^2$  value of 0.8551, indicating 85.51 percent of the variation in moisture content was explained by the model. The adequate precision value of 10.3019 confirmed the adequacy of the model.

Milk fat level (A) had a significant negative effect on moisture content ( $-1.8583$ ,  $p < 0.05$ ), indicating that moisture content decreased with increasing milk fat. The interaction effect (AB) was significant and positive ( $+2.555$ ,  $P < 0.05$ ), suggesting that the combined effect of milk fat and cheese flavour concentrate influenced moisture retention (Figure 7). The effect of cheese flavour concentrate (B), quadratic effect of milk fat ( $A^2$ ) and quadratic effect of cheese flavour concentrate ( $B^2$ ) were non-significant on moisture content of processed cheese.

The present findings are in agreement with those reported by Rudan *et al.* (1999) [15] observed that reducing the fat content of cheese significantly increased the moisture, protein and calcium contents; however, the reduction in fat was not fully compensated by an increase in moisture, resulting in lower moisture in the non-fat substance (MNFS) and a reduced moisture-to-protein ratio. Similarly, Guinee *et*

*al.* (2000) [8] reported that increasing the fat level decreased the moisture, protein and ash contents while increasing fat in dry matter (FDM), demonstrating the inverse relationship between fat and moisture. Amelia *et al.* (2013) [2] also observed that full-fat cheddar cheese contained lower moisture and protein than reduced-fat cheese, further supporting this relationship.

### Effect of variables on fat (% FDM)

Milk fat content is an important compositional parameter that contribute to the nutritional value and sensory quality of processed cheese. Milk fat content of the sample was adequately described by a quadratic model with an  $R^2$  value of 0.9499, indicating 94.99 percent of the variation in milk fat was explained by the model. The Adequate Precision value of 14.3637 confirmed the adequacy of the model.

Milk fat level (A) had a significant positive effect on fat (%FDM) content ( $+11.3933$ ,  $p < 0.05$ ), indicating that increasing milk fat levels resulted in a corresponding increase in the final fat (%FDM) content of processed cheese (Figure 8). This may be greater incorporation of fat into cheese matrix with increasing fat (%FDM) levels. The effect of cheese flavour concentrate (B), quadratic effect of milk fat ( $A^2$ ) and quadratic effect of cheese flavour concentrate ( $B^2$ ) were non-significant.

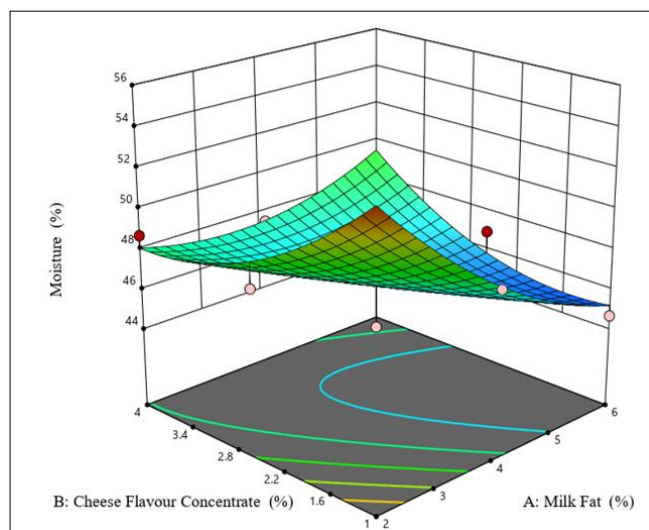


**Fig 7:** Moisture as affected by level of milk fat and cheese flavour concentrate

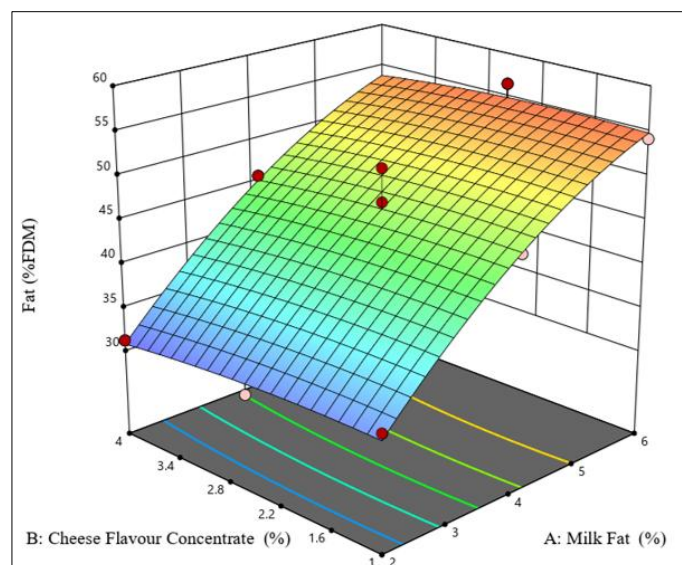


**Fig 8:** Fat content (%FDM) as affected by level of milk fat and cheese flavour concentrate

The optimized formulation as suggested by design expert software, was prepared and evaluated to verify the adequacy of the developed model. The product was manufactured using the optimum levels of milk fat and cheese flavour concentrate and the selected response were analyzed in seven replications ( $n=7$ ). Statistical validation was performed using a t-test and calculated t values for all response are presented in Table 3.

The comparison of predicted v/s actual values of responses used for optimization of processed cheese are presented in Table 3.

#### Optimization of product formulation for processed cheese

Optimization of processed cheese formulation was carried out using Design Expert Software to determine the optimum levels of milk fat and cheese flavour concentrate for obtaining the most acceptable product. The selected sensory and compositional response, along with their minimum and maximum value, were used for numerical optimization. The goal and constraint are applied during optimization are presented in Table 4.

The criteria/responses chosen for optimization of processed cheese are presented in Table 4.

#### Analysis of processed cheese

The optimized processed cheese was analyzed for its proximate composition, physicochemical properties, acidity, water activity and FFA (Table 5). The moisture content of the processed cheese was  $46.33 \pm 0.75\%$ , which was well within the legal limit prescribed by FSSAI. The moisture level contributed to a smooth body and desirable texture of the product. The fat content and FDM content was  $23.50 \pm 0.58\%$  and  $43.78 \pm 1.08\%$ , respectively which, contributing to the characteristic richness, smooth texture and energy value of the processed cheese. The protein content was  $23.77 \pm 0.64\%$ . The ash content was  $3.54 \pm 0.20\%$  and the total carbohydrate content was  $3.34 \pm 0.38\%$ , which was also well within the legal standard's limit.

The physicochemical properties of the optimized processed cheese are presented in Table 5. The product had a titratable acidity of  $1.05 \pm 0.05\%$  lactic acid and the free fatty acid (FFA) content was  $4.40 \pm 0.13$  meq. KOH/100g fat, indicating good fat quality with little hydrolytic deterioration. The water activity was  $0.986 \pm 0.07$ , which was within the normal range for processed cheese.

The analysis of optimized processed cheese is presented in Table 5.

**Table 1:** Experimental design matrix, sensory, moisture (%) and fat (%FDM) attributes of processed cheese

| Run | A: Milk fat (%) | B: Cheese flavour concentrate (%) | Flavour score | B & T score | C & A score | Overall acceptability | Moisture (%) | Fat (%FDM) |
|-----|-----------------|-----------------------------------|---------------|-------------|-------------|-----------------------|--------------|------------|
| 1   | 4.00            | 4.00                              | 41.70         | 26.80       | 13.80       | 87.30                 | 47.30        | 45.69      |
| 2   | 4.00            | 2.50                              | 41.60         | 26.80       | 13.80       | 87.20                 | 44.08        | 42.91      |
| 3   | 4.00            | 2.50                              | 43.28         | 26.71       | 13.30       | 88.29                 | 47.00        | 47.16      |
| 4   | 4.00            | 2.50                              | 44.00         | 26.80       | 14.00       | 89.80                 | 46.90        | 45.19      |
| 5   | 6.00            | 2.50                              | 44.14         | 27.57       | 13.60       | 90.31                 | 46.92        | 56.51      |
| 6   | 4.00            | 2.50                              | 43.33         | 26.50       | 13.50       | 88.33                 | 47.03        | 50.97      |
| 7   | 4.00            | 1.00                              | 41.20         | 26.00       | 13.80       | 86.00                 | 48.20        | 46.33      |
| 8   | 2.00            | 4.00                              | 39.66         | 23.00       | 12.50       | 80.16                 | 48.71        | 31.19      |
| 9   | 6.00            | 4.00                              | 41.66         | 25.83       | 13.40       | 85.89                 | 48.90        | 52.83      |
| 10  | 6.00            | 1.00                              | 42.40         | 25.60       | 14.00       | 87.00                 | 44.65        | 54.20      |
| 11  | 4.00            | 2.50                              | 44.20         | 27.40       | 13.60       | 90.20                 | 47.00        | 45.28      |
| 12  | 2.00            | 1.00                              | 38.40         | 24.40       | 12.40       | 80.20                 | 54.68        | 33.09      |
| 13  | 2.00            | 2.50                              | 39.30         | 22.90       | 11.00       | 78.20                 | 48.23        | 30.90      |

**Table 2:** P values and partial coefficients of the regression equation for the suggested models related to the sensory qualities of processed cheese

| Terms                         | Flavour score | Body & Texture score | Colour & Appearance score | Overall score | Moisture (%) | Fat (%FDM) |
|-------------------------------|---------------|----------------------|---------------------------|---------------|--------------|------------|
| Intercept                     | 43.193        | 26.853               | 13.555                    | 88.602        | 46.371       | 46.382     |
| A: Milk fat                   | 1.806*        | 1.45*                | 0.85*                     | 4.1066*       | -1.8583*     | 11.3933*   |
| B: Cheese flavour concentrate | 0.17          | -0.0616              | -0.0833                   | 0.025         | -0.4066      | -0.6516    |
| AB                            | -0.5          | 0.4075               | -0.175                    | -0.2675       | 2.555*       | 0.1325     |
| A <sup>2</sup>                | -1.252        | -1.6482*             | -1.0431*                  | -3.9434*      | 1.2801       | -2.8796    |
| B <sup>2</sup>                | -1.522*       | -0.4832              | 0.4568                    | -1.5484       | 1.5451       | -0.5746    |
| R <sup>2</sup>                | 0.8711        | 0.8781               | 0.8642                    | 0.8995        | 0.8551       | 0.9499     |
| F-value                       | 9.46          | 24.57                | 8.91                      | 12.53         | 8.26         | 26.57      |
| Adeq. Precision               | 9.5355        | 8.5013               | 8.7194                    | 8.8668        | 10.3019      | 14.3637    |
| Suggested Model               | Quadratic     | Quadratic            | Quadratic                 | Quadratic     | Quadratic    | Quadratic  |

\*:  $p < 0.05$ ; APV = Adequate Precision Value, R<sup>2</sup> = Coefficient of determination**Table 3:** Comparison of predicted v/s actual values of responses used for optimization of processed cheese

| Response              | P Value | Predicted Value * | Actual Value @ | Cal. t-Value <sup>#</sup> | Level of Significance |
|-----------------------|---------|-------------------|----------------|---------------------------|-----------------------|
| Flavour               | 0.2847  | 42.50             | 42.70          | 1.174                     | NS                    |
| Body & Texture        | 0.0631  | 26.13             | 26.58          | 2.276                     | NS                    |
| Colour & Appearance   | 0.8578  | 13.33             | 13.30          | 0.1871                    | NS                    |
| Overall Acceptability | 0.3348  | 86.87             | 87.14          | 1.048                     | NS                    |
| Moisture (%)          | 0.3124  | 46.80             | 46.28          | 1.1                       | NS                    |
| Milk fat (% FDM)      | 0.1589  | 42.59             | 40.99          | 1.608                     | NS                    |

\* Predicted values of Design Expert 13.0.1.0 package  
 @ Actual values are average of seven trials for optimized product  
 # t-values at 5% level of significance  
 NS = non-significant  
 Tabulated t-value = 2.447 (cal. t-value less than tabulated value)

**Table 4:** Criteria/responses chosen for optimization of processed cheese

| Sr No. | Parameter                         | Units      | Goal        | Lower Limit | Upper Limit | Level of Importance |
|--------|-----------------------------------|------------|-------------|-------------|-------------|---------------------|
| 1.     | A: Milk fat (%)                   | %          | is in range | 2.00        | 6.00        | 3                   |
| 2.     | B: Cheese flavour concentrate (%) | %          | is in range | 1.00        | 4.00        | 3                   |
| 3.     | Colour & Appearance Score         | Out of 15  | is in range | 11.00       | 14.00       | 3                   |
| 4.     | Flavour Score                     | Out of 50  | is in range | 40.00       | 44.20       | 5                   |
| 5.     | Body & Texture Score              | Out of 30  | is in range | 25.00       | 27.57       | 4                   |
| 6.     | Overall Acceptability Score       | Out of 100 | is in range | 78.20       | 90.31       | 3                   |
| 7.     | Moisture (%)                      | %          | is in range | 45.00       | 46.90       | 3                   |
| 8.     | Fat (% FDM)                       | % FDM      | is in range | 40.00       | 56.51       | 3                   |

**Table 5:** Analysis of optimized processed cheese

| Parameter                          | Processed cheese |
|------------------------------------|------------------|
| <b>Proximate composition (%)</b>   |                  |
| Moisture                           | 46.33±0.75       |
| Fat                                | 23.50±0.58       |
| Protein                            | 23.77±0.64       |
| Ash                                | 3.54±0.20        |
| Total carbohydrates                | 3.34±0.38        |
| Salt                               | 0.70±0.03        |
| <b>Physico-chemical properties</b> |                  |
| Acidity (% LA)                     | 1.05±0.05        |
| FFA (meq. KOH/100g fat)            | 4.40±0.13        |
| Water activity (aw)                | 0.986±0.07       |

## Conclusion

Paneer can be successfully utilized in manufacture of processed cheese which can lead to significant reduction in ripening cost of traditional natural cheese. The final optimized formulation contained 3.50% fat milk used for paneer making and cheese flavour concentrate @ 3.22% to convert paneer into processed cheese. The optimized processed cheese exhibited desirable compositional characteristics with reference to moisture content and fat on

a dry matter basis (FDM) and achieving an appropriate balance between flavour, body and texture, colour and appearance resulting in highly acceptable sensory quality. The validation study further confirmed the reliability of the optimized formulation, demonstrating its potential for the production of high-quality paneer-based processed cheese.

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## References

1. Abdeen ES, El-Shafei SM, Khalifa SA. Manufacture of processed cheese spread from camel cheese based: evaluation of cheese characteristics. *Am J Food Sci Nutr Res*. 2018;5(4):76-86.
2. Amelia I, Drake M, Nelson B, Barbano DM. A new method for the production of low-fat Cheddar cheese. *J Dairy Sci*. 2013;96(8):4870-4884.
3. Indian Standards Institution. IS 10281:1982. Method for sensory evaluation of processed cheese. New Delhi: Indian Standards Institution; 1982.
4. Cai H, Bijl E, Sala G, Scholten E. Relationship between the perception of complex textural attributes and the bolus properties of cheese. *Food Hydrocoll*. 2024;150:109713.
5. Chen L, Liu H. Effect of emulsifying salts on the physicochemical properties of processed cheese made from Mozzarella. *J Dairy Sci*. 2012;95(9):4823-4830.
6. Food Safety and Standards Authority of India. Manual of methods of analysis of foods: Dairy and dairy products. New Delhi: Food Safety and Standards Authority of India; 2022.
7. Food Safety and Standards Authority of India. Manual of methods of analysis: Microbiological examination of food and water. New Delhi: Food Safety and Standards Authority of India; 2024.
8. Guinee TP, Auty MA, Fenelon MA. The effect of fat content on the rheology, microstructure and heat-induced functional characteristics of Cheddar cheese. *Int Dairy J*. 2000;10(4):277-288.
9. Guinee TP, O'Callaghan DJ. Effect of increasing the protein-to-fat ratio and reducing fat content on the chemical and physical properties of processed cheese product. *J Dairy Sci*. 2013;96(11):6830-6839.
10. Hamdy SM, Metwally AA, Deghedie MA, Abdelmontaleb HS. Characterization of fatty acid profiles and nutritional quality indices in commercial spreadable processed cheeses: comparative analysis and health implications. *Food Saf Health*. 2026.
11. Hirpara K, Patel HG, Gokhale AJ, Patel AM. Effect of level of fat on compositional, physico-chemical, rheological and sensory attributes of processed cream cheese based (PCCB) spread. *Indian J Dairy Sci*. 2016;69(1):1-7.
12. Hladká K, Randulová Z, Tremlová B, Ponížil P, Mančík P, Černíková M, *et al*. The effect of cheese maturity on selected properties of processed cheese without traditional emulsifying agents. *LWT - Food Sci Technol*. 2014;55(2):650-656.
13. Kendirci P, Salum P, Bas D, Erbay Z. Production of enzyme-modified cheese (EMC) with ripened white cheese flavour: II-effects of lipases. *Food Bioprocess Process*. 2020;122:230-244.
14. Noronha N, Cronin D, O'Riordan D, O'Sullivan M. Flavouring reduced fat high fibre cheese products with enzyme modified cheeses (EMCs). *Food Chem*. 2008;110(4):973-978.
15. Rudan MA, Barbano DM, Yun JJ, Kindstedt PS. Effect of fat reduction on chemical composition, proteolysis, functionality, and yield of Mozzarella cheese. *J Dairy Sci*. 1999;82(4):661-672.
16. Singh S, Chauhan AK, VP A, Prakash R, Maiti P, Ranjan R, *et al*. Quarg cheese: the impact of fat content change on its microstructure, characterization, rheology, and textural properties. *Curr Res Nutr Food Sci*. 2023;11(3):1061.
17. Toro EE, Valencia JU, Molina DA. Characterization of a processed cheese spread produced from fresh cheese (quesito antioqueño). *Rev Fac Nac Agron Medellín*. 2016;69(2):8015-8022.
18. Tran KM, Hoang OT, Nguyen LT. Integrated insights into structural and flavor functions of milk fat in cheese systems: implications for fat reduction and replacement strategies. *Dairy*. 2026;7(3):41.
19. Wadhvani RD, McMahon DJ. Color of low-fat cheese influences flavor perception and consumer liking. *J Dairy Sci*. 2012;95(5):2336-2346.
20. Yoo J, Lee WJ. Impact of milk fat on cheese flavor and novel technologies for its enhancement. *J Dairy Sci Biotechnol*. 2024;42(1):113-120.