

Analysis of sensory, textural and compositional attributes of protein-rich dairy spread using response surface methodology

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Abstract: A protein-rich dairy spread was formulated using white butter, WPC-80, and Greek yoghurt. Response surface methodology (RSM) was used to optimize the levels of white butter and WPC-80. The optimization considered sensory attributes like flavour, body and texture, colour and appearance, spreadability, and overall acceptability, as well as hardness, fat, and protein content. RSM suggested the optimal levels to be 38.10 per cent white butter and 18.10 per cent WPC-80. The experimental protein-rich dairy spread, prepared based on RSM suggestions, was compared to a control spread. The experimental spread showed statistical similarity to the control in terms of compositional parameters, except had a significantly higher protein content (14.85%) and lower carbohydrate content (5.54%) compared to the control spread. The acidity (% LA) and tyrosine value were also significantly higher in the protein-rich dairy spread. The experimental sample was also superior to the control sample in sensory attributes. Microbiologically, both the experimental and control samples were free from aerobic plate count, coliform count and yeast and mould count.

Key words: Protein-rich dairy spread, white butter, WPC-80, response surface methodology

Introduction

A dairy spread is a product consisting of an aqueous phase and a fat phase derived from milk fat, with additional ingredients that enhance its spreadability at refrigeration temperature. These

spreads can be categorized based on their type of fat into dairy spreads, such as butter spread, cheese spread, ghee spread, Channa spread, paneer spread etc. (Hirpara et al. 2016; Yadav et al. 2019); and plant-based spreads, such as nut or fruit spreads, chocolate spreads etc. (Kumari & Sharma, 2022). Margarine, a cost-effective alternative to butter, is primarily composed of vegetable fats, which results in a distinct lack of the characteristic flavor, body and texture of butter (Galindo-Cuspinera et al. 2017). Whereas butter has poor spreadability when refrigerated. Thus, new form of butter with improved spreadability emerged as spreads (Prajapati et al. 1991). Low-fat dairy spreads are spreadable products with less fat than butter or margarine, making them an alternative, particularly in regions where butter is expensive (Deshmukh et al. 2002).

These spreads not only enhance the flavor of food but also offer functional benefits due to the inclusion of proteins. Proteins in spreads contribute to the viscosity and water-holding capacity of the aqueous phase, thereby improving the stability of the emulsion during processing and storage (Mishra et al. 2019). Whey protein concentrate (WPC) is commonly utilized in such formulations due to its excellent functional properties, including solubility, emulsification, and water binding (Suthar et al. 2017). WPC also boasts a high biological value and a rich profile of essential amino acids, making it an ideal ingredient for enhancing the nutritional profile of low-fat dairy products (Smithers, 2008).

Greek yoghurt, also known as *labneh*, is a concentrated dairy product with higher protein and fat content compared to regular yoghurt. It is produced by allowing natural yoghurt to drain for a period, resulting in a thicker consistency (Kathiriya et al. 2018). This concentrated yoghurt enhances the texture and creaminess of dairy products, making it a valuable ingredient for improving the sensory and nutritional attributes of dairy spreads.

The current study focuses on optimizing the use of white butter and WPC-80 in the formulation of a protein-rich dairy spread using response surface methodology (RSM). The primary objective is to determine the optimal levels of white butter and WPC-80 to enhance sensory attributes while also improving the spreadability and nutritional content of the spread. This optimization aims to address the growing consumer demand for

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healthier, higher-protein options. By utilizing white butter, WPC-80 and Greek yoghurt, the study intends to produce a spread that excels in sensory and functional qualities and also meets the nutritional criteria for a high-protein product.

Materials and Methods

The protein-rich dairy spread was formulated using white butter (82% fat) from Vidya Dairy, Anand, WPC-80 from a local dealer, and skim milk (0.5% fat, 8.7% SNF) for Greek yoghurt from Vidya Dairy. Skim milk powder for the control spread was also obtained from Vidya Dairy. Non-dairy ingredients included a starter culture (*Streptococcus thermophilus* and *Lactobacillus delbrueckii* spp. *bulgaricus*) from DSM Food Specialties, Netherland; stabilizer Carboxy methyl cellulose (CMC) from Molychem, Mumbai; emulsifier Lecithin soya (30%) from HiMedia laboratories Pvt. Ltd., Mumbai and emulsifying salt Disodium hydrogen orthophosphate (Na_2HPO_4) from Central Drug House Pvt. Ltd., New Delhi. Common salt was purchased from Tata Chemicals, Mumbai. Annatto butter colour formulated within department. The spread was packaged in polypropylene cups (125 mL) with thickness of 0.52 mm purchased from an authorized dealer.

Preparation of Greek yoghurt: For the preparation of Greek yoghurt, skim milk was heated to 90°C for 15 minutes. Milk was cooled to $42 \pm 2^\circ\text{C}$ followed by inoculation with Direct-to-Vat Starter (DVS) culture (*Streptococcus thermophilus* and *Lactobacillus delbrueckii* spp. *bulgaricus*) and incubation at that temperature for 3-4 h (or until acidity of 0.6% lactic acid was obtained). Thereafter, the curd was hung in a cloth bag (at refrigeration temperature) and allowed to drain the whey until it reached the desired Greek yoghurt consistency.

Preparation of protein-rich dairy spread: Potable water was initially heated to 60°C. Dry ingredients, including lecithin (0.5%), CMC (0.25%) and common salt (0.5%), were then added to the water, which was subsequently heated to 90°C (without a holding period). Following this, disodium hydrogen orthophosphate (0.5%) and Greek yoghurt (10%) were incorporated into the mixture. WPC-80 was then added and blended until a smooth texture was achieved. Then white butter tempered overnight at 20°C was added. Once the butter had fully dissolved, 0.2 per cent annatto colour was incorporated. The product was then heated to 70°C without a holding period and hot filled into polypropylene cups at 50°C. The filled cups were stored at $7 \pm 2^\circ\text{C}$.

Analysis of protein-rich dairy spread: Greek yoghurt was analyzed for total solids, fat, protein, ash, lactose and titratable acidity. Titratable acidity and total solids were determined by method FSSAI (2022). Fat content was analyzed using IS: 2785-1979 (1992). Protein was determined by the Block Digestion/Steam Distillation method (ISO 8968-2:2001). Ash content was analyzed using AOAC, (1981) method. Lactose was calculated by difference. Butter was analyzed for fat, moisture, and curd content using the method given in FSSAI

(2022). In spread moisture was determined as per the method for butter. Fat, Protein and ash were analyzed using the method for Greek yogurt. Total carbohydrates were calculated by difference. Hardness was measured by the cone penetrometer method (Verma, 1996). Titratable acidity was determined following the FSSAI (2022), free fatty acids (FFA) using the procedure by Thomas et al. (1954), and peroxide value by the AOAC (1981) method. Protein breakdown, assessed by measuring tyrosine content, followed Hull (1947) procedure, while water activity was measured with a water activity meter. Aerobic plate count, coliform count, and yeast and mould count were determined using FSSAI (2023), IS:5401 Part I (2002), and IS:5403 (1999) methods respectively.

Sensory evaluation of protein-rich dairy spread: The sensory evaluation of protein rich dairy spread was done by panel of 7 judges using a 9-point hedonic scale. The panellist included scientists, technical officers/assistants and students of the institute. Each panellist was asked to taste the samples and evaluate the sensory parameters on a 9-point hedonic scale. They were asked a series of questions pertaining to flavour, body and texture, colour and appearance, spreadability and overall acceptability of each sample. Panellists were requested to give the scores and comments on a sensory evaluation score card. Saline water was provided to rinse the palate before and after tasting the sample. Sensory responses were evaluated based on a 9-point hedonic scale (Meilgaard et al. 1999). Mean score was calculated from the responses of panellists for each set of samples.

Statistical analysis: Design Expert software is to be used for all statistical work including the selection of the number of trials, range of parameters to be studied, number of replications and final analysis of the data generated. An advanced statistical software programmed named RSM Design Expert 13.0.1.0 was employed in the study. The experiment was conducted using various combination of treatment with some range of the parameters under study for manufacture of an acceptable quality of protein-rich dairy spread. RSM design expert 13.0.1.0 was used to optimize two selected variables namely white butter and WPC-80 in the study. On the basis of preliminary trials, the range of variables was obtained. RSM with faced centered rotatable design (FCRD) for two variables at five levels and six replicates at central point was adopted to optimize the quality of protein-rich dairy spread with respect to selected sensory responses. The result of the 13 trials (Table 1) formed the base for an optimized level of white butter and WPC-80 which were suggested by software. The optimized level of ingredients was then replicated seven times and actual values of sensory analysis was compared with predicated value.

Results and Discussion

The optimization of white butter and WPC-80 was conducted based on sensory properties such as flavour, body and texture, colour and appearance, spreadability and overall acceptability, as well as other

attributes like hardness, fat, and protein. Successive regression analysis produced quadratic models for each response, with the coefficient of determination (R^2) ranging from 0.76 to 0.97 (Table 2). The model F-value for all responses was significant, indicating a strong fit. The adequacy of the models in predicting response variables for any combination of variables within the range was confirmed by a non-significant lack of fit. These indicate that the obtained quadratic model fitted the data strongly. Adequate precision value (APV), a measure of signal-to-noise ratio, exceeded the threshold of 4, with APVs ranging from 7.12 to 19.64. These results suggest that the developed model is reliable for optimizing the formulation of the protein-rich dairy spread.

Effect on flavour scores: Flavour is a critical parameter in food quality assessment, primarily determined by taste and smell, and greatly affects consumer acceptability. In protein-rich dairy spread samples, the flavour score ranged from 7.86 to 8.43 on a 9-point hedonic scale (Table 1). The spread with 40.00 per cent white butter and 17.50 per cent WPC-80 was rated best, while that with 35.00 per cent white butter and 20.00 per cent WPC-80 scored the lowest. The R^2 value of 0.88 indicates a good model fit (Table 2), with an APV of 10.54 suggesting reliability. White butter had a significant positive linear effect on flavour ($p < 0.05$), while WPC-80 had a non-significant negative effect. Interactive effects showed non-significant results, but quadratic effects of white butter were significantly positive ($p < 0.05$) and WPC-80 significantly negative. Kumar (2014) found that in the chocolate spread with added butter fat, olive oil, and WPC, WPC did not significantly affect the flavour score of the chocolate spread ($P > 0.05$). Popalia (2018) found that in the development of a value-added milk-cereal-based product with added MPC-85 and white butter, butter had a significant positive effect on the flavour score of the milk-cereal product ($P > 0.05$), while interaction had non-significant effect ($P > 0.05$). Hamid (2023) investigated the effect of total fat, omega fat, and diacetyl on the flavour of omega fatty acids enriched fat spread. The study found that total fat had a significant positive effect on flavour ($P > 0.1$).

Effect on body and texture scores: Body and texture reflect the physical feel and structure of a food product, including attributes like firmness, smoothness, and consistency, which impact the sensory experience and mouthfeel. The body and texture score for protein-rich dairy spread samples ranged from 7.29 to 8.39 on a 9-point hedonic scale (Table 1). The spread with 37.50 per cent white butter and 17.50 per cent WPC-80 received the highest rating, while that with 35.00 per cent white butter and 20.00 per cent WPC-80 scored the lowest. The R^2 value of 0.90 (Table 2) and an APV of 12.47 indicate a good model fit and reliability. White butter had a significant positive linear effect on body and texture ($p < 0.05$), whereas WPC-80 had a non-significant negative effect. Interactive effects showed a significant positive impact, while quadratic effects of white butter were non-significant and WPC-80 had a significant negative effect ($p < 0.05$). Kumar (2014) found that in the chocolate spread with added butter fat, olive

oil, and WPC, WPC did not significantly affect the body and texture score of the chocolate spread ($P > 0.05$). Chaudhari et al. (2023) demonstrated that the body and texture of low-fat paneer were significantly influenced by the rate of WPC addition. Hamid (2023) examined the influence of total fat, omega fat, and diacetyl on the body and texture of omega fatty acids enriched fat spread. The results showed that total fat had a significant negative effect on body and texture ($P > 0.05$).

Effect on colour and appearance scores: Colour and appearance refer to the visual attributes of a food product, including hue, brightness, and uniformity, which influence consumer perception and initial acceptability. The colour and appearance score of protein-rich dairy spread ranged from 7.80 to 8.43 on a 9-point hedonic scale (Table 1). The spread with 35.00 per cent white butter and 20.00 per cent WPC-80 was rated highest, while that with 35.00 per cent white butter and 15.00 per cent WPC-80 scored the lowest. The R^2 value of 0.82 (Table 2) and an APV of 9.68 indicate a good model fit. WPC-80 had a significant positive effect ($p < 0.05$) on colour and appearance, while white butter's effect was non-significant. The interaction effect of white butter and WPC-80 was significantly negative ($p < 0.05$), while quadratic effects were non-significant for both variables ($p < 0.05$). Kumar (2014) found that in the chocolate spread with added butter fat, olive oil, and WPC, WPC did not significantly affect the color and appearance score of the chocolate spread ($P > 0.05$). Popalia (2018) noted that in the development of a value-added milk-cereal-based product with added MPC-85 and white butter, butter had a significant positive effect on the colour and appearance score ($P > 0.05$). Hamid (2023) analyzed the effect of total fat, omega fat, and diacetyl on the color and appearance of omega fatty acids enriched fat spread. The study revealed that none of the variables total fat, omega fat, or diacetyl had a significant effect on color and appearance ($P > 0.05$).

Effect on spreadability scores: Spreadability measures the ease with which a product can be spread, assessing its smoothness and consistency. The spreadability scores for protein-rich dairy spread ranged from 7.88 to 8.44 on a 9-point hedonic scale (Table 1). The spread with 37.50 per cent white butter and 17.50 per cent WPC-80 was rated highest, while the spread with 37.50 per cent white butter and 15.00 per cent WPC-80 scored the lowest. The coefficient of determination (R^2) was 0.81 (Table 2), with an APV of 7.54, indicating a good fit of the model. White butter had a significant positive effect on spreadability at the linear level ($p < 0.05$), whereas WPC-80 had a non-significant positive effect. The interactive effect of white butter and WPC-80 on spreadability was non-significant, while a significant negative effect of WPC-80 at quadratic terms was observed ($p < 0.05$). Kumar (2014) found that in the chocolate spread with added butter fat, olive oil, and WPC, WPC did not significantly affect the spreadability score of the chocolate spread ($P > 0.05$). In contrast, Hamid (2023) found total fat had significant negative effect on spreadability ($P > 0.05$) in omega fatty acids enriched fat spread.

Effect on overall acceptability scores: Overall acceptability is a crucial sensory attribute that reflects the consumer's overall judgment of the product, integrating aspects such as flavour, body and texture, colour and appearance and spreadability. The scores for overall acceptability of the protein-rich dairy spread ranged from 7.68 to 8.42 on a 9-point hedonic scale (Table 1). The spread with 40.00 per cent white butter and 17.50 per cent WPC-80 was rated highest, while the spread with 35.00 per cent white butter and 20.00 per cent WPC-80 scored the lowest. The coefficient of determination (R^2) was 0.91 (Table 2), with an APV of 12.38, indicating a good fit of the model. White butter had a significant positive effect on overall acceptability at the linear level ($p < 0.05$), whereas WPC-80 had a non-significant negative effect. The interactive effect of white butter and WPC-80 was non-significant, while a significant negative effect of WPC-80 at quadratic terms was observed ($p < 0.05$). The impact of different variables on overall acceptability is shown in Figure 1. In contrast Chaudhari et al. (2023) illustrated that the overall acceptability of low-fat paneer was significantly affected by the rate of WPC addition. Hamid (2023) explored the effect of total fat, omega fat, and diacetyl on the overall acceptability of omega fatty acids-enriched fat spread. Diacetyl had a significant positive effect on overall acceptability ($P < 0.1$), whereas total fat and omega fat did not significantly affect overall acceptability ($P > 0.05$).

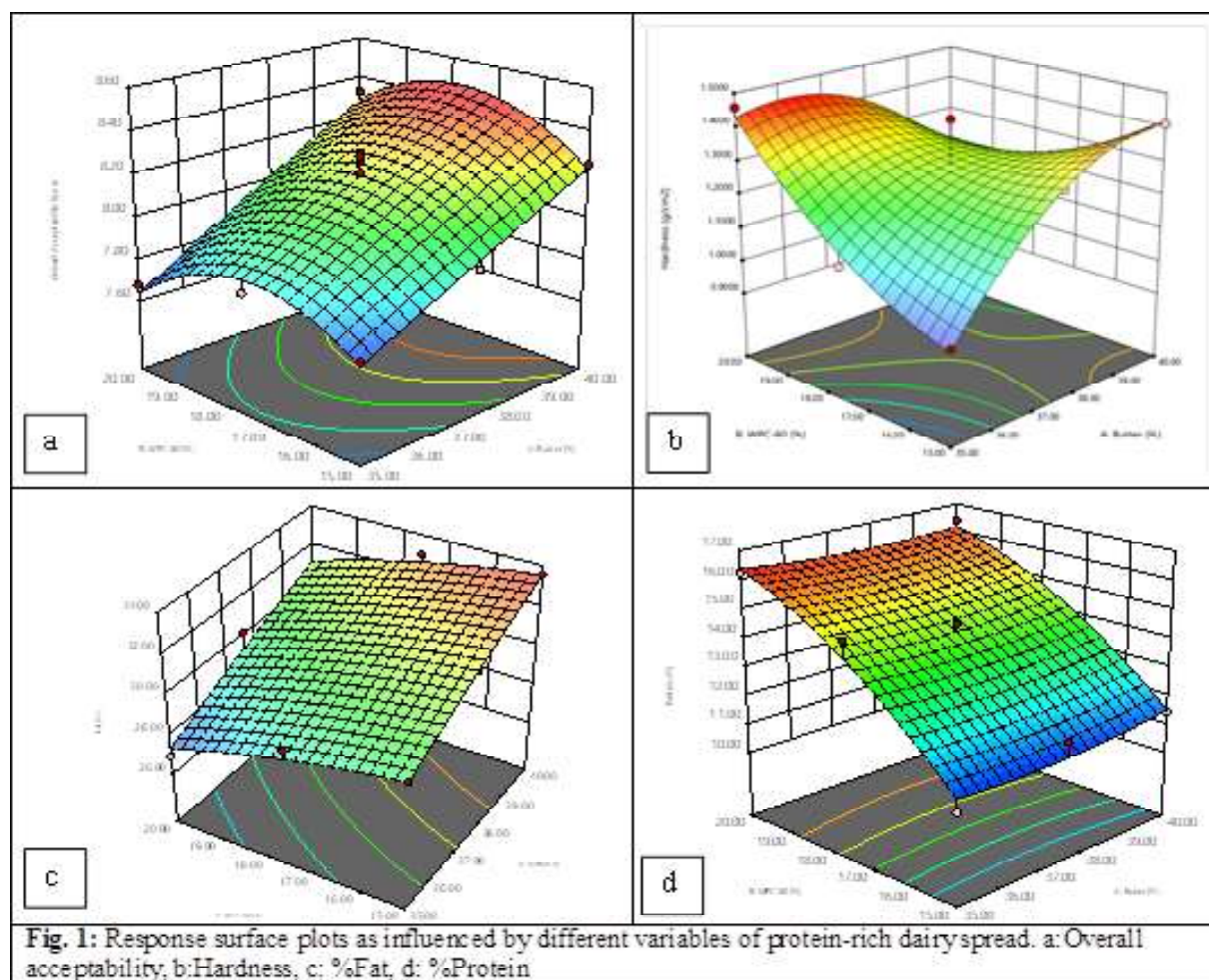
Effect on hardness: Hardness describes the resistance to deformation in food products, influencing the firmness and overall texture experienced during consumption. The hardness of protein-rich dairy spread samples ranged from 0.98 g/cm² to 1.46 g/cm² (Table 1). The spread with 35.00 per cent white butter and 20.00 per cent WPC-80 exhibited the highest hardness, while the one with 35.00 per cent white butter and 15.00 per cent WPC-80 had the lowest. The

coefficient of determination (R^2) was 0.76 (Table 2), with an APV of 7.12, suggesting a good model fit. White butter and WPC-80 had non-significant positive effects on hardness at the linear level. The interactive effect of white butter and WPC-80 was significantly negative, while non-significant effects were noted for quadratic terms of white butter and WPC-80 ($p < 0.05$). The impact of different variables on hardness is shown in Figure 1. Radoëaj et al. (2011) found that the stabilizer and hemp oil had significant positive effect on the hardness of the spread ($P < 0.01$). The quadratic effect of hemp oil was also significant positive ($P < 0.05$), while the interaction between the stabilizer and hemp oil did not significantly affect hardness ($P > 0.05$). Patel et al. (2016) observed that increasing *fada* (germinated and dried wheat semolina) significantly increased hardness ($P < 0.01$) in Halvasan, while increasing gluten significantly decreased hardness ($P < 0.05$).

Effect on fat: Fat content is crucial for determining the nutritional profile and sensory characteristics such as flavour, mouthfeel and spreadability. The fat content of protein-rich dairy spread samples ranged from 26.92 per cent to 33.60 per cent (Table 1). The spread with 35.00 per cent white butter and 20.00 per cent WPC-80 had the lowest fat content, while the one with 40.00 per cent white butter and 15.00 per cent WPC-80 had the highest. The coefficient of determination (R^2) was 0.95 (Table 2), indicating an excellent model fit. The APV of 19.64, well above the minimum desirable APV (4.00), supports the use of this response for design. Statistical analysis showed a significant positive effect of white butter and a significant negative effect of WPC-80 on fat content at the linear level ($p < 0.05$). The interactive effect had a non-significant positive effect, while quadratic terms for white butter and WPC-80 had non-significant

Table 1 Experimental design matrix, sensory, hardness and compositional attributes of protein-rich dairy spread

Run No.	White butter (%)	WPC-80 (%)	Flavour	Body & texture	Sensory scores Colour & appearance	Spreadability	Overall acceptability	Hardness (g/cm ²)	Fat (%)	Protein (%)
1	35.00	17.50	8.08	7.78	8.03	7.89	7.83	1.09	29.30	15.01
2	35.00	15.00	7.92	7.67	7.80	7.92	7.73	0.98	29.88	10.80
3	37.50	17.50	8.17	8.39	8.22	8.44	8.31	1.27	30.83	14.24
4	37.50	15.00	8.00	7.81	8.00	7.88	7.94	1.31	31.81	11.70
5	40.00	17.50	8.43	8.31	8.13	8.43	8.42	1.22	33.00	14.35
6	37.50	20.00	7.89	7.60	8.35	8.09	7.90	1.38	30.19	16.01
7	40.00	15.00	8.43	7.86	8.36	8.07	8.25	1.41	33.60	11.45
8	37.50	17.50	8.19	8.06	8.38	8.34	8.29	1.14	30.83	14.15
9	40.00	20.00	8.29	8.21	8.29	8.37	8.33	1.17	30.77	16.40
10	35.00	20.00	7.86	7.29	8.43	8.00	7.68	1.46	26.92	16.25
11	37.50	17.50	8.14	8.29	8.21	8.29	8.21	1.43	30.42	14.50
12	37.50	17.50	7.93	8.04	8.24	8.29	8.04	1.43	30.83	13.80
13	37.50	17.50	8.16	8.23	8.34	8.37	8.26	1.27	30.83	14.15



negative effects. The impact of different variables on fat is shown in Figure 1.

Effect on protein: Protein content is crucial for determining the nutritional profile and functionality of the spread, impacting body and texture, and overall nutritional value. The protein content of protein-rich dairy spread samples ranged from 10.80 per cent to 16.40 per cent (Table 1). The spread with 35.00 per cent white butter and 15.00 per cent WPC-80 had the lowest protein content, while the one with 40.00 per cent white butter and 20.00 per cent WPC-80 had the highest. The coefficient of determination (R^2) was 0.97 (Table 2), indicating an excellent model fit. The APV of 18.73, well above the minimum desirable APV (4.00), supports using this response for design. Statistical analysis showed a significant positive effect of WPC-80 and a non-significant positive effect of white butter on protein content at the linear level ($p < 0.05$). The interactive effect had a non-significant negative effect, while white butter had a non-significant positive effect and WPC-80 had a significant negative

effect at the quadratic level ($p < 0.05$). The impact of different variables on protein is shown in Figure 1.

Optimization of product formulation for protein-rich dairy spread

The optimization of protein-rich dairy spread was performed using numerical optimization techniques, as summarized in Table 3. The goal was to optimize various parameters including white butter and WPC-80 percentages while maximizing sensory attributes. In the optimization process, white butter and WPC-80 were maintained within their specified ranges (35-40% and 15-20% respectively). The sensory attributes, hardness, fat and protein were also kept in range. The RSM suggested optimal levels of 38.10 per cent white butter and 18.10 per cent WPC-80, achieving a desirability of 1.00. Protein-rich dairy spread was prepared by adding white butter and WPC-80 as suggested by RSM. The predicted values for flavour, body and texture, colour and appearance, spreadability, overall acceptability, hardness,

fat, and protein were 8.15, 8.21, 8.29, 8.36, 8.25, 1.31 g/cm², 31.03 per cent and 14.82 per cent respectively. The observed values for these parameters were not significantly different from the predicted values (Table 4), confirming that the selected levels of white butter and WPC-80 are optimal for achieving desirable sensory, hardness, fat and protein in the protein-rich dairy spread.

Analysis of protein-rich dairy spread

The protein-rich dairy spread (T₂) was analysed and compared with the control spread (T₁) for its proximate composition, sensory attributes, and hardness, with results statistically analysed using a t-test as shown in Table 5. The moisture content of T₂ was significantly (P<0.05) lower than T₁, while its protein content was significantly (P<0.05) higher, being twice that of T₁. This increase in protein is due to the inclusion of WPC-80 in T₂.

Table 2: Partial coefficients of regression equations of suggested models for sensory, hardness and compositional attributes of protein-rich dairy spread

Terms	Sensory scores (9-point hedonics scale)					Hardness (g/cm ²)	Fat (%)	Protein (%)
	Flavour score	Body & texture score	Colour & appearance score	Spreadability score	Overall acceptability score			
Intercept	8.11	8.17	8.24	8.31	8.20	1.30	30.90	14.26
A: White Butter	0.215*	0.275*	0.085	0.178*	0.294*	0.045	1.878*	0.023
B: WPC-80	-0.051	-0.039	0.151*	0.099	-0.001	0.051	-1.234*	2.452*
AB	-0.020	0.183*	-0.175*	0.054	0.033	-0.179*	0.032	-0.125
A ²	0.158*	-0.056	-0.083	-0.045	-0.012	-0.119	-0.133	0.202
B ²	-0.153*	-0.394*	0.014	-0.222*	-0.218*	0.067	-0.283	-
R ²	0.88	0.90	0.82	0.81	0.91	0.76	0.95	0.97
Model F-Value	10.63	12.28	6.57	6.10	13.69	4.35	28.22	44.43
APV	10.54	12.47	9.68	7.54	12.38	7.12	19.64	18.73
Suggested Model	Quadratic	Quadratic	Quadratic	Quadratic	Quadratic	Quadratic	Quadratic	Quadratic

*: p < 0.05; APV= Adequate Precision Value, R² = Coefficient of determination

Table 3: Criteria/responses chosen for optimization of protein-rich dairy spread

Sr No.	Parameter	Units	Goal	Lower Limit	Upper Limit
1.	A: Whit butter	%	In range	35	40
2.	B: WPC-80	%	In range	15	20
3.	Flavour	Out of 9	In range	7.85	8.43
4.	Body & texture	Out of 9	In range	7.29	8.39
5.	Colour & appearance	Out of 9	In range	7.80	8.43
6.	Spreadability	Out of 9	In range	7.87	8.44
7.	Overall acceptability	Out of 9	In range	7.67	8.42
8.	Hardness	g/cm ²	In range	0.98	1.46
9.	Fat	%	In range	26.92	33.60
10.	Protein	%	In range	10.80	16.40

which has a higher protein content (~78%) compared to SMP used in T₁ (~35%). The total solids content of T₂ was significantly higher due to the incorporation of Greek yogurt. Carbohydrate content in T₂ was significantly (P<0.05) lower, attributed to the lower lactose content of WPC-80 (10.8%) compared to the higher lactose content of SMP (52%) in T₁. Sensory evaluation showed T₂ had significantly (P<0.05) better scores for flavour, body and texture, spreadability and overall acceptability. Hardness was slightly higher in T₂ but not significantly (P>0.05) different from

T₁. Protein-rich dairy spread showed significantly higher acidity, FFA and tyrosine values than the control spread, primarily due to the addition of Greek yogurt. While peroxide value and water activity remained similar between the two spreads. Microbiologically, both the experimental and control samples were free from aerobic plate count, coliform count and yeast and mould count.

Conclusion

Table 4: Comparison of predicted v/s actual values of responses used for optimization of protein-rich dairy spread

Response	P Value	Predicted Value *	Actual Value @	Cal. t-Value #	Level of Significance
Flavour	0.30	8.15	8.18	1.12	NS
Body & Texture	0.08	8.21	8.28	2.10	NS
Colour & Appearance	0.25	8.29	8.24	1.27	NS
Spreadability	0.73	8.36	8.35	0.35	NS
Overall Acceptability	0.83	8.25	8.26	0.22	NS
Hardness	0.08	1.31	1.24	2.05	NS
Fat	0.41	31.03	31.00	0.87	NS
Protein	0.48	14.82	14.84	0.75	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 per cent level of significance

NS = non-significant

Tabulated t-value = 2.447 (cal. t-value less than tabulated value)

Table 5 : Comparison of protein-rich dairy spread with control spread (n=3)

Parameter	Control spread	Protein-rich dairy spread	CD (0.05)
Chemical composition			
Moisture, %	47.97±0.11	46.89±0.14	0.19
Fat, %	31.08±0.04	31.05±0.03	NS
Protein, %	7.81±0.13	14.85±0.11	0.17
Ash, %	1.65±0.01	1.67±0.01	0.01
Carbohydrates, %	11.49±0.10	5.54±0.17	0.2
Rheological attribute			
Hardness (g/cm ²)	1.19±0.01	1.22±0.09	NS
Physico-chemical properties			
Acidity (% LA)	0.320±0.01	0.536±0.01	0.015
FFA (% oleic acid)	0.251±0.01	0.338±0.01	0.008
Peroxide value (meq/kg fat)	0.077±0.01	0.078±0.01	NS
Tyrosine value (µg tyrosine/ 5 ml filtrate)	11.96±0.18	20.68±0.18	0.26
Water activity	0.925±0.01	0.919±0.01	NS
Sensory attributes			
Flavour	8.06±0.07	8.19±0.08	0.11
Body & texture	8.10±0.08	8.28±0.10	0.13
Colour & appearance	8.40±0.09	8.25±0.12	NS
Spreadability	8.26±0.10	8.38±0.06	0.12
Overall acceptability	8.09±0.05	8.28±0.11	0.12
Microbial analysis			
APC (cfu/g)	Absent/g		
Coliform	Absent/g		
Y&M	Absent/g		

A protein-rich dairy spread was developed using response surface methodology (RSM), optimizing the proportions of white butter and WPC-80 to achieve a sensorially acceptable product. At the linear level, the addition of WPC-80 significantly improved the protein content due to its high protein concentration while white butter also contributed to the desired fat content. At the quadratic level, white butter and WPC-80 showed non-significant effects on sensory attributes. Additionally, the hardness of the spread was not significantly impacted by the quadratic levels of these ingredients. Based on these outcomes, RSM suggested preparing the protein-rich dairy spread using 38.10 per cent white butter and 18.10 per cent WPC-80. The predicted values for sensory attributes, hardness, fat and protein content were closely aligned with actual values, confirming the reliability of the optimization. In conclusion, a protein-rich dairy spread with superior sensory attributes and enhanced nutritional value can be successfully developed through the optimization process using RSM.

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