Indian J Dairy Sci 78(5): 430-438
https://doi.org/10.33785/IJDS.2025.v78i05.005

RESEARCH ARTICLE

Formulation and optimization of a high protein bar using Response Surface Methodology

Manvi Rajoria[1](✉), Rekha Chawla[1], Sunil Kumar Khatkar[1] and Gopika Talwar[2]

Received: 22 August 2025 / Accepted: 10 October 2025 / Published online: 23 October 2025

Abstract: With the rise in health awareness among consumers, particularly school-age children, athletes, and fitness enthusiasts, the demand for protein-rich, nutrient-dense, and convenient snack options has increased. Developing such products, however, poses challenges in achieving the right balance between nutritional quality, sensory appeal, and consumer acceptance. In the present study, a protein-enriched bar was formulated using a blend of nuts, nutrient-rich seeds, and the legume moong bean, complemented by whey protein concentrate (WPC), defatted soy granules (DFGs), and dates as a natural sweetener. Optimization was carried out using Response Surface Methodology (RSM), with sensory attributes considered as response variables. Regression analysis indicated that color and sweetness were significantly affected by the quadratic effects of soy and moong. The optimized formulation, comprising approximately 11%, 19%, and 5.5% of the selected independent variables, produced predicted sensory scores closely matching the experimental values, with no significant differences ($p < 0.05$), confirming the model's validity. The optimized bar exhibited high overall acceptability, achieving a desirability index of 0.859. These results demonstrate that integrating plant-based and dairy protein sources with statistical optimization techniques can yield a nutritionally enhanced and sensorially well-accepted protein bar. The findings offer a scientific basis for developing functional snack products suited to the needs of health-conscious and younger consumer groups.

[1] Department of Dairy Technology, [2] Department of Dairy Engineering, Guru Angad Dev Veterinary & Animal Sciences University, Ludhiana, Punjab
(✉)**Email:** 11mannu.4444@gmail.com

Keywords: Natural ingredients, Optimization, Protein-rich bar, Sensory evaluation, Surface response methodology

Introduction

The contemporary consumer has new perspective of nutrition, consisting of not only a balanced diet, but the healthy snacks too. Despite growing awareness for nutrition and health, many commercially available food products are loaded with sugars, unhealthy fats, and synthetic additives, which are associated with various health risks such as obesity, diabetes, and cardiovascular diseases (Monteiro et al. 2019). Although the selection criteria of food products for every consumer is entirely different, yet the increasing craving for snacks and other processed foods, has led to a rise in consumer demand for wholesome snacks as well. Adults who have a sweet tooth and often jump for chocolates and bars, have prompted the food scientists to create something vital and nutrient dense along with being convenient. Further, a balance of important nutrients like fats, proteins, and carbohydrates is a prudent choice for modern consumers. Along with this, there has been seen a growing dietary need for good quantity and quality protein which is often ignored and results in malnutrition, especially in developing country like India. Therefore, sensing the urgency of the deprivation, and convenience in hands, high protein bars are embraced by educated community.

In the market loaded with wide array of choices, a product to be the preferred choice of consumers, must meet the consumer expectations for sensory acceptability. Sensory evaluation provides a scientific approach to assessing the product's characteristics through the human senses taste, smell, sight, touch, and sound (Stone et al. 2004). It also plays an important role in the food business, especially in new product development, quality assurance, and customer research (Lawless and Heymann, 2010). According to Muñoz (2002), sensory qualities such as appearance, aroma, flavor, texture, and aftertaste have a substantial impact on consumer preferences and product acceptability. It has been advocated that if a food product has high nutritional value, even though sometimes it may not succeed in the market unless it has appealing sensory features (Deliza et al. 2003). During product development, sensory evaluation aids formulation optimization by determining how constituent or process modifications affect organoleptic qualities (Stone et al. 2004). It has also been seen that fortification or enrichment processes (proteins, fibers, or phytochemicals) may affect taste or mouthfeel, necessitating sensory alterations to keep the product appealing. Herein, consumer testing approaches like hedonic scaling and preference mapping are crucial tools for anticipating market performance and steering innovation (Lawless and Heymann, 2010). However, to eradicate any chances of human error, some mathematical models could be of help wherein response surface methodology (RSM) occupies a pivotal importance. It has been scientifically validated as an effective technique for optimizing a process where the independent factors, such as protein sources, are assumed to have a sovereign or cumulative effect on the intended responses. According to Baþ and Boyacý (2007), response surface methodology (RSM) is a widely used multivariate statistic technique for optimizing food operations. The approach is beneficial for optimizing, creating, developing, and enhancing processes where a response or reactions are influenced by multiple variables (Yolmeh and Jafari, 2017). Many studies have undertaken involving RSM as an adequate approach for product optimization like soy dessert (Chattopadhyay et al. 2013); vegan probiotic ice-cream (Devalekar and Udachan, 2025); Sweet and Sour Chicken Meat Spread (Arya et al. 2017) etc.

Moving on same trend, understanding the dietary needs along with an enhanced acceptability, the research formulation of protein bars was sought, targeting to combat protein malnutrition, involving a wide array of protein rich ingredients like Whey protein powder, nuts and seeds, such as crisp walnuts, cashews, pistachios, and almonds. These were supplemented with a variety of seeds including watermelon, muskmelon, pumpkin, sunflower, and cucumber, each adding unique textures, enhanced flavours, and a wealth of nutritional value to the mixture. To eradicate the harmful effect of sugar, dates were preferred having an advantage over other sweet confections since they include not only natural sugars, sucrose, and fructose, but also a high level of nutritional fiber, particularly when combined with cereals and legumes (Al-Farsi and Lee, 2011). The high moisture content of fresh dates can be absorbed by cereal and legume flours, creating a suitable matrix for date bars and increasing their storability. Furthermore, the nutritious qualities of WPC, dates, nuts, grains, and legumes complement one another. Therefore, the developed product must be sensorily acceptable by the consumer along with bridging gaps of nutrition and wholesomeness.

Therefore, the present study aimed to develop a protein-enriched bar using selected ingredients and to optimize its formulation using Response Surface Methodology (RSM). The objective was to achieve a balance between nutritional enhancement and sensory acceptability through statistically guided formulation design.

Materials and Methods

Procurement of raw materials

A variety of ingredients were sourced from local market to develop the composite protein bar, rich in culinary seeds such as watermelon, muskmelon, pumpkin, sunflower, and cucumber seeds, along with omega-rich seeds including sesame, flaxseeds, and chia seeds. All the raw materials were procured from the local market of Ludhiana, Punjab, India keeping the high quality in mind. Nuts including almonds, cashew nuts, walnuts, and pistachios were also locally sourced, carrying high quality. To enhance the flavor and palatability of the product, natural taste enhancers such as sugar, honey, dates (Kimia variety), and grated coconut (coconut powder) were incorporated. Protein-rich plant sources like defatted soy flakes and mung beans were included to boost the nutritional profile, both of which were also procured locally. Additionally, milk-derived ingredients such as Whey Protein Concentrate (WPC-70) was kind consented by Model Dairy Plant, Karnal, Haryana, while pure ghee was sourced from the Experimental Dairy Plant of the College of Dairy and Food Science and Technology, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana.

Pre-treatments

Prior to formulation, selected ingredients underwent specific pre-treatment steps to enhance their functionality and suitability for bar preparation. Defatted soy flakes (ranging from 10-15 percent) were soaked in warm water (50-55 °C) for few minutes (7-10 min), followed by draining. Moong bean (ranging from 4-6 percent) was germinated, followed by roasting pre-heated pan at medium flame (approx. 140–160 °C) until a nutty aroma developed and a light brown color was achieved (Adsule et al. 1986) and dates (Kimia Iranian variety) were treated with hot water (75-80 °C) for a short span of time to facilitate kernel and peel removal (18-20 percent) (Li et al. 2023). After de-seeding, to eliminate excess surface moisture, hot air treatment employing laboratory scale oven was opted. Seeds and nuts were subjected to roasting in ghee to enhance their flavour, aroma, and shelf-stability, while also improving their texture (Kahyaoglu and Kaya, 2006). Post-roasting, the nuts were chopped into smaller, uniform pieces to ensure better distribution within the composite bar and to contribute to a desirable mouthfeel. WPC was used in the range of 16-20 percent.

Preparation of protein bar

Protein bar was made employing protein rich quality sources, carrying a good amount of protein content with additional additives for its better acceptability. Different preliminary trials were taken (kindly refer to the supplementary material), and broad levels of ingredients was determined. With 3 independent variables, the minimum and maximum limit of these variables was selected and can be seen in (Table 1). The process of protein bar

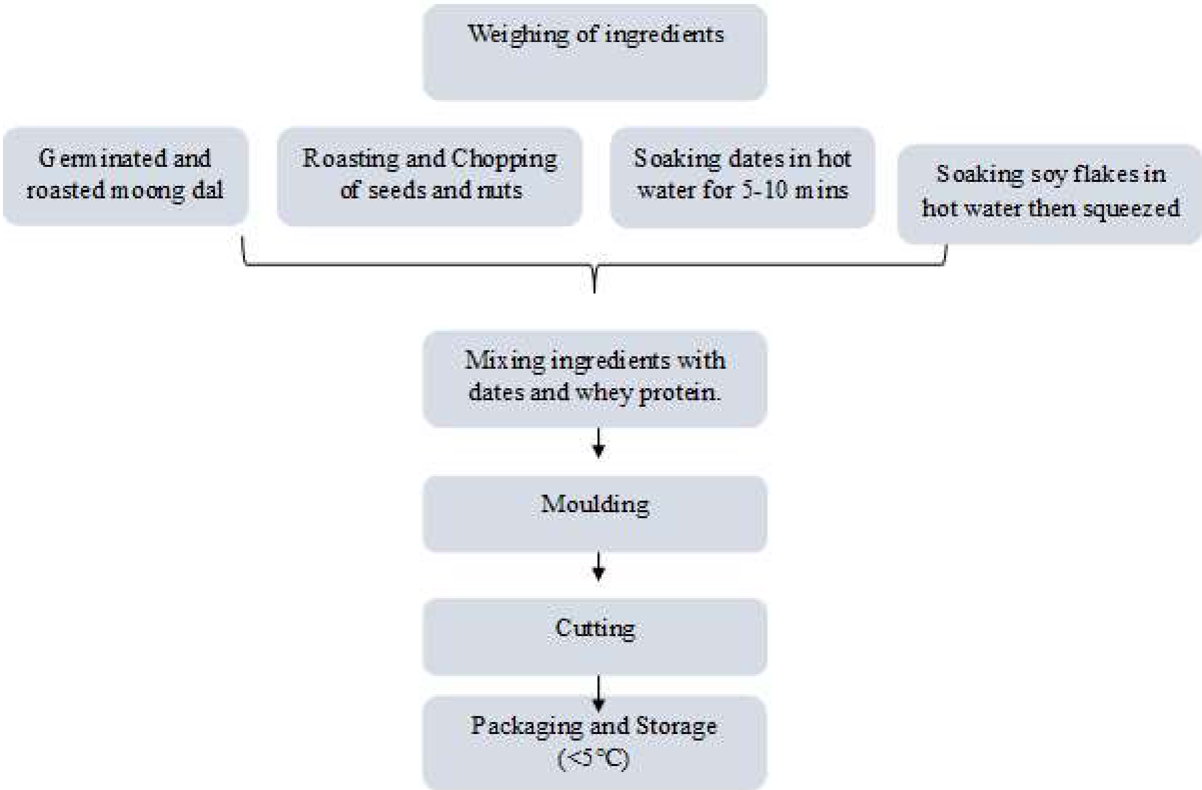

Fig. 1. Schematic diagram showing the basic steps for manufacturing of protein rich bar

preparation involves a series of steps aimed at ensuring uniformity, nutritional balance, and desirable sensory properties in the final product, a schematic diagram involving all the steps is given below as figure 1.

Experimental design

The final percentages of protein levels from three protein sources whey protein concentrate (WPC), Defatted soy flakes, and germinated moong dal, were optimized using Response Surface Methodology (RSM) through Minitab Software 2022 (Version 21.2). Preliminary sensory trials were conducted to determine the suitable range of ingredients, and based on these, the minimum and maximum levels were fixed for each protein source (as shown in Table 1). A Box-Behnken design was chosen to investigate the interactive effects and to fit a second-order polynomial model. This design included three independent variables: WPC (A), soy protein (B), and moong dal (C), each tested at three levels coded as -1, 0, and +1.

The design generated 15 experimental combinations (Table 2), allowing the study of linear, quadratic, and interaction effects of the protein sources on sensory attributes. Each experimental trial was conducted in triplicate, and the mean values of sensory and instrumental analysis were considered for statistical analysis to minimize the error due to human perception during sensory evaluation. The adequacy of the developed model was evaluated through analysis of variance (ANOVA), using the F-value and coefficient of determination (R^2). A model was considered significant if the F-value exceeded the table value at a 5% level of significance, and if R^2 was greater than 0.80. The influence of each factor and their interactions on sensory parameters was assessed, and the significance was interpreted at 1% and 5% level of confidence. The predicted responses were also compared with the actual responses using a t-test, ensuring the model's predictive accuracy and reliability.

Table 1: Un-coded values for maximum and minimum levels of the protein sources

Variables	Level of ingredients (%)		
	Maximum	Central point	Minimum
WPC	20	18	16
Soy flakes	15	12.5	10
Moong bean	6	5	4

Sensory evaluation

Sensory evaluation of the prepared protein bar of experimental design (15 in number) was conducted using a semi-trained panel using a modified version of 9-point hedonic scale, comprising 10 panellists aged between 22 to 45 years, all of whom were either postgraduate students or faculty members with a background in food/dairy technology. The panellists were selected based on their availability, interest, and sensory acuity. The evaluation was carried out in a well-ventilated room with uniform lighting and minimal distractions, providing 3 samples at a time. Additionally, each sample was provided 3 times individually, without any reference or any product with which it can be compared. Each sample was coded to avoid biasness and was presented in randomized order to eliminate positional effects.

The experiment design with values of variables is shown in Table 2. Before optimization, goals were set for each independent variable (Table 3) wherein the criteria were based on the sensory responses and instrumental analysis.

Results and Discussion

Findings derived from the experimental trials carried out on the development and optimization of protein bars. The results are presented along with statistical analysis, including model fitting, regression coefficients, and significance levels. Each parameter such as color, sweetness, flavour, texture, and overall acceptability has been interpreted in light of the response surface methodology (RSM) design. The interactions between different ingredients and their effects on sensory and physical attributes are also discussed to understand the formulation's impact on product's quality.

Effect of ingredients on quality of protein bar

Colour

The colour scores of the protein bars ranged between 7.12 and 8.20, indicating that the products were generally well accepted by the panellists (Table 4). The highest score (8.20) was obtained in Run 13 containing 12.5 g soy, 18 g WPC and 5 g moong, which imparted a uniform golden-brown colour and enhanced visual appeal. In contrast, the lowest score (7.12) was observed in Run 3 with lower levels of soy and moong, resulting in a lighter shade and comparatively less attractive appearance. Bars prepared with higher levels of WPC (20 g) exhibited slightly reduced colour scores. This may be attributed to the natural whiteness of WPC, which diluted the intensity of browning and produced a paler product.

The regression model for colour showed $R^2 = 0.81$, suggesting that 81% of the variation in sensory scores could be explained by the experimental factors. Linear effects of soy, moong, and WPC were positive but statistically non-significant ($p \geq 0.05$). However, the quadratic effects of soy and moong were significant ($p \leq 0.05$) with negative coefficients, indicating that moderate levels of these ingredients promoted desirable browning, but excessive addition reduced acceptability. Similar trends have been reported in protein- and legume-based products, where controlled levels of soy and cereal proteins enhanced colour through Maillard reactions, while higher levels resulted in darker or less appealing products (Omah et al. 2022; Solanki et al. 2023). Overall, the findings demonstrate that balanced incorporation of soy, moong, and WPC is critical for achieving consumer-preferred colour in protein bars.

Texture

The texture scores of protein bars varied between 6.94 and 8.12, reflecting moderate to high acceptability (Table 4). The highest score (8.12) was recorded in the central formulation (12.5 g soy, 18 g WPC, 5 g moong), suggesting that a balanced ratio of soy and WPC with moderate moong content produced the most desirable texture. Bars containing WPC in the range of 18–20% and moong at 5% were found to have optimum binding and elasticity, resulting in a chewy yet soft structure. In contrast, low levels of soy and moong (10% and 4%, respectively) led to weaker

Table 2: The uncoded values of variables and sensory responses* (n=10)

Run Order	Soy	WPC	Moong	Color	Texture	Sweetness	Flavor	Overall Acceptability
1	12.5	18	5	8.00	8.00	8.00	8.10	8.10
2	12.5	20	6	7.43	7.06	7.43	7.43	7.25
3	10.0	18	4	7.12	6.75	7.25	7.37	6.87
4	12.5	20	4	7.50	7.20	7.20	7.75	7.75
5	15.0	18	6	7.75	7.56	6.93	7.00	7.00
6	12.5	16	6	7.50	6.94	7.25	6.75	6.87
7	10.0	20	5	7.75	7.37	7.00	7.25	7.50
8	15.0	20	5	7.81	7.18	7.50	7.37	7.37
9	10.0	18	6	7.25	7.43	7.25	7.00	7.12
10	12.5	16	4	7.75	7.25	7.50	7.25	7.75
11	10.0	16	5	7.50	7.75	7.00	7.25	7.50
12	12.5	18	5	8.10	8.12	7.80	8.00	8.20
13	12.5	18	5	8.20	8.10	7.95	7.90	8.00
14	15.0	16	5	7.56	7.63	7.37	7.25	7.37
15	15.0	18	4	7.50	7.12	7.87	6.87	7.00

*each value is an average of 3 values.

structural integrity and reduced textural scores. Excessive moong (6%) caused dryness and grittiness, which negatively affected mouthfeel.

The regression model for texture showed an R^2 value of 0.79, indicating that nearly 80% of the variation could be explained by the experimental factors. While the linear and interaction effects of soy, WPC, and moong were statistically non-significant ($p > 0.05$), the quadratic effect of moong was significant ($p = 0.001$). This indicated a non-linear response, where texture improved up to moderate levels of moong but declined with further increase (Fig. 2b). Similar observations were reported by Wani et al. (2015) in WPC-enriched cookies and by Siegwein et al. (2011), who noted optimal protein–carbohydrate ratios for desirable textural properties.

Sweetness

The sweetness scores of the protein bars ranged from 6.93 to 8.00, indicating moderate to high acceptability among panellists (Table 4). The regression model for sweetness showed good fit with an R^2 value of 0.89, suggesting that nearly 90% of the variation could be explained by the formulation variables. Among the linear effects, moong showed a negative but statistically non-significant influence ($p > 0.05$), reflecting that higher moong levels slightly masked sweetness due to its characteristic earthy notes (Fig. 2c).

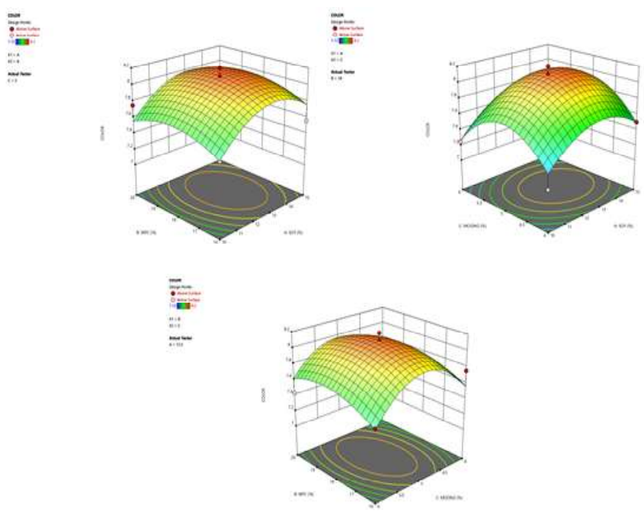

Fig. 2a

The quadratic effects of soy and WPC were statistically significant ($p < 0.05$), indicating that sweetness improved up to moderate inclusion levels but declined at higher concentrations. This may be attributed to increased protein intensity or a mouth-drying effect that suppressed the perception of sweetness. Since the amount of dates (natural sweetener) was constant across formulations, variations in sweetness were mainly due to protein–matrix interactions affecting flavour release during mastication. The interaction effect of soy and moong was also significant, indicating that higher levels of these components together could suppress sweetness perception.

Table 3: The target set for responses for optimization in RSM

Ingredient	Goal	Desired Target
Colour	Target	7.85
Texture	Target	7.80
Sweetness	Max	8.00
Flavour	Target	7.70
Overall acceptability	Max	8.20

Table 4: Coefficient of full second order polynomial model for sensory responses

FACTOR	COLOUR	TEXTURE	SWEETNESS	FLAVOUR	OVERALL ACCEPTABILITY
INTERCEPT	8.1	8.073	7.917	8	8.1
A=SOY	0.125	0.024	0.1463	-0.0475	-0.0313
B=WPC	0.0225	-0.095	0.0012	0.1625	0.0475
C=MOONG	0.0075	0.084	-0.12	-0.1325	-0.1412
A^2	-0.292	-0.244	-0.3596	-0.477	-0.536
B^2	-0.152	-0.347	-0.3396	-0.243	-0.129
C^2	-0.402	-0.614	-0.2321	-0.462	-0.566
A. B	0	-0.018	0.0325	0.03	0
A.C	0.03	-0.06	-0.235	0.125	-0.062
B.C	0.045	0.042	0.12	0.045	0.095
Residual SE	0.217	0.316	0.187	0.223	0.275
R^2	81.31%	79.98%	89.70%	89.22%	86.01%
R^2 (adj.)	47.66%	43.95%	71.16%	69.82	60.83%

*The regression coefficients obtained from the Response Surface Methodology (RSM) model for the effects of soy (A), whey protein concentrate (B), and moong (C) on the selected response variable are presented. The table includes the linear, quadratic, and interaction terms, along with the model fit statistics (R^2, adjusted R^2) and residual standard error.

Similar observations were reported by Thapa Magar et al. (2021), who noted that legume proteins may reduce sweetness intensity, while Brewer et al. (1992) described a decline in sweetness when beany flavours became dominant. Overall, balanced levels of soy, WPC, and moong were essential to achieve optimal sweetness in protein bars.

Flavour

The flavour scores of protein bars varied from 6.75 to 8.10, indicating that most formulations were acceptable to highly acceptable (Table 4). Lower flavour scores were generally associated with higher levels of soy and moong, likely due to the development of bitter or beany notes characteristic of these ingredients. In contrast, formulations with balanced levels of soy, WPC, and moong achieved better flavour acceptability.

The regression model for flavour showed good fit with an R^2 value of 0.89, explaining 89% of the variability. The quadratic effects of soy ($p = 0.009$) and moong ($p = 0.011$) were statistically significant with negative coefficients, indicating that flavour improved up to a moderate level of inclusion but declined when their levels were further increased (Fig. 2d). The linear effects of soy and moong were negative but non-significant ($p > 0.05$), while WPC showed a positive but non-significant effect on flavour, suggesting that its mild, creamy taste may balance undesirable notes from legumes.

These findings align with earlier reports where increased legume proteins reduced flavour acceptability due to beany characteristics (Thapa Magar et al. 2021; Brewer et al. 1992). Overall, the results suggest that moderation in soy and moong levels, complemented by WPC, is essential for achieving desirable flavour in protein bars.

Overall Acceptability

The overall acceptability scores of protein bars ranged from 6.87 to 8.20, reflecting that all formulations were at least moderately liked by panellists (Table 4). The highest score (8.20) was recorded at the central level of all three ingredients, suggesting that a balanced ratio of soy, moong, and WPC provided the most desirable sensory profile. Formulations at extreme low or high levels of these ingredients showed reduced acceptability, indicating the need for moderation in their inclusion.

The regression model for overall acceptability showed good fit ($R^2 = 0.86$), explaining 86% of the variation in scores. Linear effects of soy and moong were negative but statistically non-significant ($p > 0.05$), while WPC showed a mild positive effect. Significant quadratic effects ($p < 0.05$) were observed for soy and moong, both with negative coefficients, indicating that acceptability improved up to a certain inclusion level but declined beyond it due to increased hardness, dryness, or beany flavour (Fig. 2e).

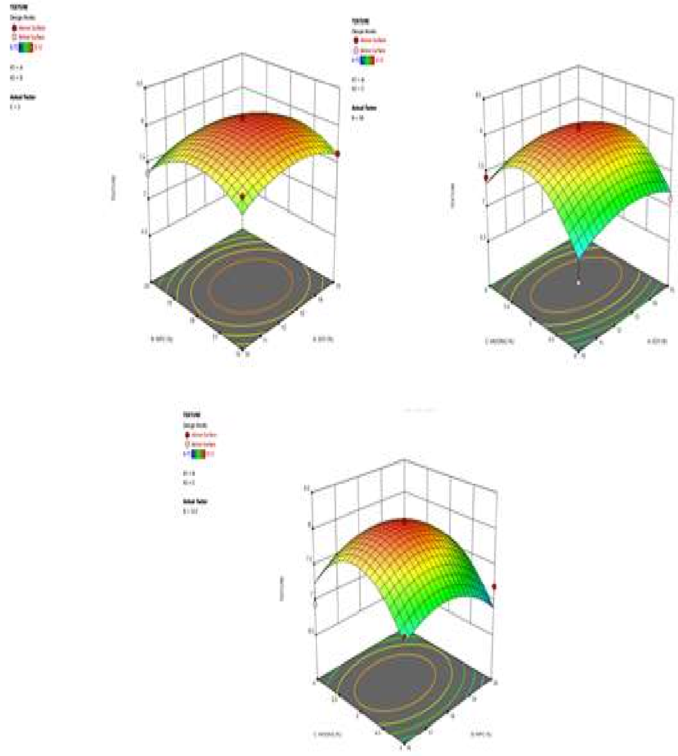

Fig. 2 b

Similar patterns have been reported in other protein-rich foods. Shree et al. (2017) observed reduced acceptability in misti dahi with excess WPC, while Solanki et al. (2023) noted that sensory scores in extruded paneer increased with WPC addition only up to an optimum level. These findings reinforce that balanced ingredient levels are crucial for maximizing overall consumer acceptance of protein bars.

Optimization of variables and its validation

During optimization goals and targets of different variables were fed in the RSM model (Table 4). The desired target of different variables like overall acceptability, flavour, texture, colour and sweetness were 8.2, 7.7, 7.8, 7.85, and 8, respectively. RSM provided an optimized combination of WPC, soy, and moong dal that best met these targets, resulting in a high composite desirability of 0.859. The desired targets for different responses and their predicted values are given in the Table 3.

The optimized formulation consisted of 11.40% soy protein, 18.79% whey protein concentrate, and 5.57% moong dal. This combination yielded predicted sensory scores of 7.78 (OA), 7.70 (flavour), 7.66 (sweetness), 7.80 (texture), and 7.85 (colour) shown in Table 3. The sensory analysis was done and the average sensory scores for different attributes were used as observed value of the responses in order to assess whether there is significant discrepancy between the observed and the predicted

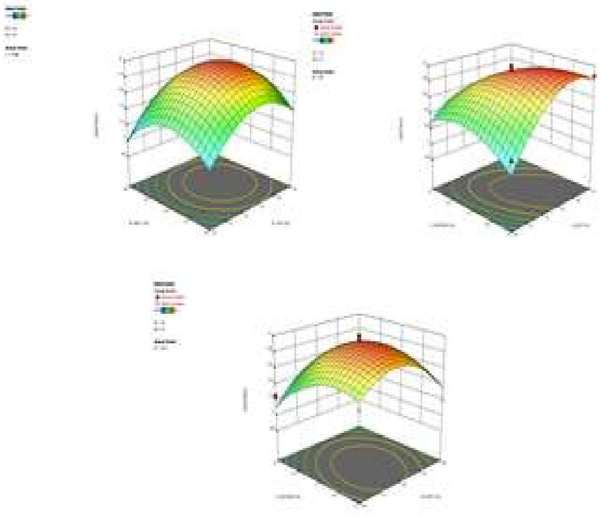

Fig. 2c

values. Using t-test (test of significance) these values were compared. The test showed that there was no significant difference between the sensory values predicted by RSM and the values which were observed as calculated t values were less than table value (2.30) (Table 5).

Physico-chemical analysis of the optimized product

The optimized whey protein composite bar was evaluated for sensory, physico-chemical, microbiological, textural, and instrumental colour attributes, with mean values (n = 3) presented in Table 6. Physico-chemical analysis confirmed satisfactory compositional balance, with proximate composition of fat, protein, moisture, ash and carbohydrates of 10.98 ± 1.86, 27.436 ± 0.32, 19.17 ± 0.76, 0.983 ± 0.01 and 38.82 ± 6.11 percent, respectively. These values are consistent with earlier reports for similar high-protein bars (Szydłowska et al. 2020; AlJaloudi et al. 2024). Water activity (a_w) was 0.752, categorizing the product as intermediate-moisture food with good microbial stability. The relatively lower water activity compared to AlJaloudi et al. (2024) may be attributed to higher proportions of protein- and lipid-rich components and the hygroscopic nature of dates, which effectively bind water (Etemad et al. 2009; Peter et al. 2017). Crude fibre was 3.10 ± 1.92%, comparable to values reported by Jovanov et al. (2021). The slightly elevated fat content reflects inclusion of nuts, seeds, and ghee, yet remains close to the ~10% reported by Kumar et al. (2018)

Instrumental colour analysis yielded L* (34.49), a* (5.60), and b* (16.78), indicating a relatively dark product with mild reddish and golden tones. The reduced L*, a*, and b* values compared to Małecki et al. (2022) likely result from Maillard browning, inclusion of dark ingredients (dates, moong dal), and absence of pigmented

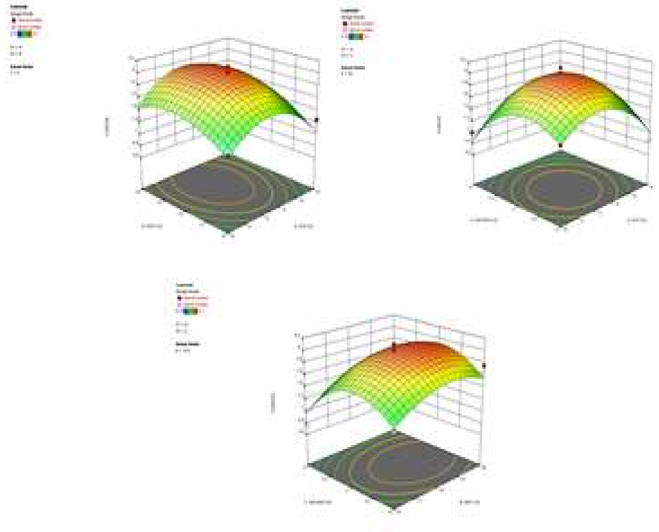

Fig. 2 d

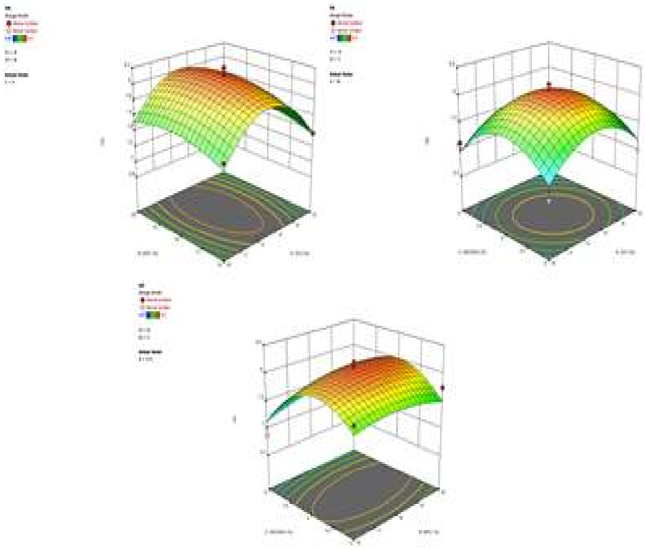

Fig. 2 e

Fig. 2a-e: **fig. 2a** Surface plots showing effect of concentration of WPC, Soy and Moong. Bean on colour sensory scores**. fig. 2b** Surface plots showing effect of concentration of WPC, Soy and Moong Bean on texture sensory scores. **fig. 2c** Surface plots showing effect of concentration of WPC, Soy and Moong Bean on sweetness sensory scores. **fig. 2d** Surface plots showing effect of concentration of WPC, Soy and Moong Bean on flavour sensory scores. **fig. 2e** Surface plots showing effect of concentration of WPC, Soy and Moong Bean on overall acceptance scores.

cereals or high-temperature baking (Bourne, 2002; Pathare et al. 2013). The moderate b* value contributed to a subtle golden hue, potentially enhancing consumer appeal.

Table 5: Comparison of predicted values from RSM and observed values of sensory scores with help of t-test (0.05)

Responses	Predicted values *	Obtained values **	Calculated t value	Level of significance
Colour	7.84	8.05 ± 0.276	2.12	NS
Texture	7.79	8.04 ± 0.312	2.29	NS
Sweetness	7.67	7.85 ± 0.240	2.14	NS
Flavour	7.70	7.93 ± 0.299	2.13	NS
Overall Acceptability	7.78	8.01 ± 0.344	1.91	NS

*Predicted values of Minitab RSM
**Actual values of the optimized product (average of 3)
Table t value (0.05) = 2.306. NS means Non-significant.

Table 6: Sensory, physico-chemical and microbiological characteristics of optimized product

Parameters	Values for optimized product(n=3)
Sensory Analysis	
Colour & Appearance	8.05 ± 0.276
Texture	8.04 ± 0.312
Sweetness	7.85 ± 0.240
Flavour	7.93 ± 0.299
Overall Acceptability	8.01 ± 0.344
Physico-chemical Analysis	
Moisture (percent)	19.17 ± 0.76
Fat (percent)	10.98 ± 1.86
Protein (percent)	27.43 ± 0.32
Total carbohydrates (percent)	38.82 ± 6.11
Water activity	0.752 ± 0.0008
Ash (percent)	0.98 ± 0.01
Fibre content (percent)	3.10 ± 1.92
Instrumental Colour Analysis	
L*	34.49 ± 1.8
a*	5.68 ± 0.24
b*	16.78 ± 0.42
Minerals (mg / 100 g)	
Calcium	437.15 ± 0.78
Sodium	171.78 ± 0.83
Magnesium	63.45 ± 0.93
Phosphorus	113.82 ± 0.55
Microbiological Analysis: (cfu/ml)	
SPC	1 X 10^3
Yeast and Mould	Nil
TPC	1 X 10^2
Texture Profile Analysis	
Hardness	1182.78 ± 146.68
Adhesiveness	-146.90 ± 88.06
Springiness	0.71 ± 0.048
Cohesiveness	0.12 ± 0.04
Chewiness	108.76 ± 55.26
Gumminess	148.32 ± 67.68

Sensory evaluation showed acceptable organoleptic attributes (appearance, flavour, texture, overall acceptability), comparable to those reported by AlJaloudi et al. (2024). Carbohydrate content (38.82%) was lower than Kumar et al. (2018), reflecting substitution of sucrose with dates, while protein content (27.5%) was slightly higher and aligned with AlJaloudi et al. (2024).

Microbiological analysis confirmed safety: Standard Plate Count (SPC) was 1 × 10^3 CFU/ml (3.00 log € CFU/ml), Total Plate Count (TPC) was 1 × 10^2 CFU/ml (2.00 log € CFU/ml), and yeast/mould were undetectable, all within ICMSF (2011) permissible limits. The low microbial load was attributed to reduced water activity, mild thermal processing, protein–polyphenol interactions, and protective packaging (Padmashree et al. 2012; Kumari et al. 2023; Kumar et al. 2022), ensuring extended stability and safety.

Conclusion

Formulating bars using natural ingredients such as WPC, soy flakes, moong bean, nuts, seeds, and dates, not only enhanced the nutritional content but also aligned with sensory preferences. Response Surface Methodology (RSM) provide valuable insight into optimizing ingredient levels. The box design was applied and experimental design was carried out which yielded upon optimization the result with maximum desirability (0.859) involving 11.40, 18.79, and 5.57 (%) soy flakes, WPC, and moong bean, respectively. The calculated values (t-calculated) for all the attributes were less than the table value indicating that there was no significant difference (t value < 2.30) between the observed values and the predicted values. Thus, protein bars can serve as effective functional food, combining sensory appeal with health benefits. The optimized formulation demonstrated appreciable protein content, along with acceptable sensory scores with numerous health benefits, making it a promising product for health-conscious consumers like athletes, and individuals seeking convenient, on-the-go nutrition.

References

Adsule RN, Kadam SS, Salunkhe DK, Luh BS (1986). Chemistry and technology of green gram (Vigna radiata [L.] Wilczek). Critical Rev Food Sci Nutri 25(1): 73-105

Al-Farsi MA, Lee CY (2011). Usage of date (Phoenix dactylifera L.) seeds in human health and animal feed. *Nuts and seeds in health and disease prevention* (447-452). Academic Press.

AlJaloudi R, Al-Dabbas MM, Hamad HJ, Amara RA, Al-Bashabsheh Z, Abughoush M, Choudhury IH, Al-Nawasrah BA, Iqbal S (2024). Development and characterization of high-energy protein bars with enhanced antioxidant, chemical, nutritional, physical, and sensory properties. Foods 13(2): 259. https://doi.org/10.3390/foods13020259

Arya A, Mendiratta SK, Singh TP, Agarwal R, Bharti SK (2017) Development of sweet and sour chicken meat spread based on sensory attributes: process optimization using response surface methodology. J Food Sci Technol 54(13):4220-4228

Baþ D, Boyacý ÝH (2007) Modeling and optimization I: Usability of response surface methodology. J Food Eng 7*8*(3): 836-845

Bourne MC (2002) Relationship between rheology and food texture. In *Engineering and Food for the 21st Century* (pp. 321-336). CRC Press

Brewer MS, Floyd KM, Kristi Britt (1992) Fat, soy and carrageenan effects on sensory and physical characteristics of ground beef patties." J Food Sci 57: 1051-1055

Chattopadhyay S, Raychaudhuri U, Chakraborty R (2013) Optimization of soy dessert on sensory, color, and rheological parameters using response surface methodology. Food Sci Biotechnol 22(1): 47-54

Deliza R, Rosenthal A, Silva ALS. (2003) Consumer attitude towards information on non-conventional technology. Trends Food Sci Technol 14(1-2): 43-49

Devalekar SK, Udachan IS (2025) Process optimization of vegan prebiotic ice cream by response surface methodology. Discover Food *5*(1):13

Etemad B, Fellows A, Kwambana B, Kamat A, Feng Y, Lee S, Sagar M (2009) Human immunodeficiency virus type 1 V1-to-V5 envelope variants from the chronic phase of infection use CCR5 and fuse more efficiently than those from early after infection. J Virol 83(19): 9694-9708

Jovanov P, Sakač M, Jurdana M, Pražnikar ZJ, Kenig S, Hadnađev M, Miroslav J, Tadeja P, Ana D, Marić A (2021). High-protein bar as a meal replacement in elite sports nutrition: a pilot study. Foods 10(11): 2628

Kahyaoglu T, Kaya S (2006). Determination of optimum processing conditions for hot air roasting of hulled sesame seeds using response surface methodology. J Sci Food Agric 86(10):1452-1459

Kumar A, Mohanty V, Yashaswini P (2018). Development of high protein nutrition bar enriched with Spirulina plantensis for undernourished children. Current Res Nutri Food Sci J 6(3): 835-844

Kumari A, Patel S, Sudesh SN, Yadav SK (2023). Development of shelf stable protein enriched energy bars from defatted groundnut (Arachis hypogaea L.), sesame (Sesamum indicum L.) and soybean (Glycine max L.) seeds.

Lawless HT, Heymann H (2010). *Sensory evaluation of food: principles and practices*. Springer Science & Business Media.

Li J, Hussain I, Azam M, Khan MA, Akram MT, Naveed K, Liu H (2023) Hot water treatment improves date drying and maintains phytochemicals and fruit quality characteristics of date palm (*Phoenix dactylifera*). Foods 12(12): 2405

Małecki J, Terpiłowski K, Nastaj M, Sołowiej BG (2022) Physicochemical, nutritional, microstructural, surface and sensory properties of a model high-protein bars intended for athletes depending on the type of protein and syrup used. Int J Environ Res Public Health 19(7):3923

Monteiro CA, Cannon G, Levy RB, Moubarac JC, Louzada ML, Rauber F, Khandpur N, Cediel G, Neri D, Martinez-Steele E, Baraldi LG, Jaime PC (2019). Ultra-processed foods: what they are and how to identify them. Public Health Nutrition 22(5): 936-941

Munoz AM (2002) Sensory evaluation in quality control: an overview, new developments and future opportunities. Food Quality and Preference 13(6): 329-339

Omah EC, Eze CO, Eze CR, Umego EC, Anchang MM (2022) Processing and optimisation of complementary food blends from roasted pearl millet (Pennisetum glaucum) and soybean (Glycine max) using response surface modeling. J Food Sci Technol 59(11): 4273-4287

Padmashree A, Sharma GK, Srihari KA, Bawa AS (2012) Development of shelf stable protein rich composite cereal bar. J Food Sci Technol 49(3): 335-341

Pathare PB, Opara UL, Al-Said FAJ (2013) Colour measurement and analysis in fresh and processed foods: A review. Food Bioprocess Technol 6(1): 36-60

Peter Ikechukwu A, Okafor DC, Kabuo NO, Ibeabuchi JC, Odimegwu EN, Alagbaoso SO, Njideka NE, Mbah RN (2017) Production and evaluation of cookies from whole wheat and date palm fruit pulp as sugar substitute. Int J Advancement Eng Technol, Manage Appl Sci 4(4): 1-31

Shree TC, Venkatesh MM, Praveen AR, Teja V (2017) Effect of whey protein concentrate and fruit juice on sensory quality of enriched misti dahi. Asian J Dairy Food Res 36*(*1): 21-25

Siegwein AM, Vodovotz Y, Fisher EL (2011) Concentration of soy protein isolate affects starch based confections' texture, sensory, and storage properties. J Food Sci 76(6): E422-E428

Solanki K, Arunkumar H (2024) Evaluation of nutritional and sensory quality of functional extruded paneer produced from soy flour blended with reconstituted skim milk paneer. European J Nutri Food Safety 16(2): 109–116

Stone H, Sidel J, Oliver S, Woolsey A, Singleton RC (2004). Sensory evaluation by quantitative descriptive analysis. *Descriptive sensory analysis in practice*, 23-34.

Szydłowska A, Zielińska D, Łepecka A, Trząskowska M, Neffe-Skocińska K, Kołożyn-Krajewska D (2020). Development of functional high-protein organic bars with the addition of whey protein concentrate and bioactive ingredients. *Agriculture*, *10*(9), 390.

Thapa Magar B, Katawal SB, Niroula A (2021). Enhancement of sensory and nutritional quality of Sel roti by the incorporation of soy flour. Food Sci Nutri 9(11): 6078-6088

Wani SH, Gull A, Allaie F, Safapuri TA (2015) Effects of incorporation of whey protein concentrate on physicochemical, texture, and microbial evaluation of developed cookies. Cogent Food Agric 1(1): 1092406

Yolmeh M, Jafari SM (2017) Applications of response surface methodology in the food industry processes. Food Bioprocess Technol 10(3): 413-433