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Formulation and characterization of novel dairy-based dip utilizing heat-acid-coagulated milk gel and whey

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Research Article

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Abstract

An attempt was made to develop a novel dairy-based dip-like product from heat-acid-induced milk gel and whey. Based upon preliminary trials, the combination of cream (15–35%), whey (60–70%) and common salt (0.8–1.0%, all three as weight of heat-acid-induced milk gel) was selected for optimization of the dairy dip through factorial design of response surface methodology (RSM). Addition of glycerol monostearate, trisodium citrate and sodium hexametaphosphate each at the rate of 0.3% (as weight of heat-acid-induced milk gel) in the formulation was previously standardized. The optimization was carried out by analysing the textural and sensorial parameters of the dairy-based dip. The sensorial parameters (flavour, body and texture, colour and appearance and overall acceptability) and textural parameters (firmness, stickiness, work of shear and work of adhesion) were significantly ($P < 0.05$) correlated with the ingredient formulation. RSM analysis suggested the use of cream, whey and common salt at amounts of 27.92, 60.26 and 0.8% of the weight of heat-acid-induced milk gel for preparing dairy-based dip with a desirability of 0.84. The formulated product contained a lower fat but higher protein and lactose content than cheese dip.

Heat-acid-induced milk gel (also known as *Chhana* in India) offers enormous scope in the development of new dairy products due to its popularity and nutritive value among all age groups. Several studies have sought to develop spread-like products from heat-acid-induced milk gel (Dixit, 2006; Chappalwar *et al*., 2010; Kumar *et al*., 2016) to meet the demand for both low fat but nutritious and diversified foods with ethnic flavour. However, no reference is available in the literature on the development of sauce or dip-like product from heat-acid-induced milk gel. Dip has a thinner consistency than spread but thicker than sauce. Dip is served in separate container in cold condition, while sauce can be served both in warm or cold conditions (IFIS, 2009). Demott *et al*. (1977) developed a chip dip (solids content of 13.1–13.3%) from cottage cheese whey by adding xanthan gum at the rate of 1.2–1.4% followed by slow blending and storage at 4°C. Saad *et al*. (2016) developed a processed cheese sauce (25% dry matter and 40% fat on dry matter basis) from ras cheese by blending it with milk protein, butter fat, nisin, stabilizer (admixture of guar gum and corn starch), NaCl and emulsifying salt. The effect of milk protein from different sources such as milk protein concentrate, total milk proteinate, ultrafiltrate–retentate curd, skim milk powder, and soy protein concentrate were evaluated. The final products were found acceptable in terms of sensorial properties and shelf life but the most acceptable was the product made using the retentate curd. Shalaby *et al*. (2017) developed plain processed cheese sauce by admixing whey protein concentrate and acid casein curd. The effect of essential oils was evaluated from different sources such as turnip, shallots, capsicum and cardamom on the sensorial quality of the cheese sauce with an aim of providing improved flavour to the product. Dixit (2006) reported the manufacturing process of heat-acid-induced milk gel spread by blending with salt, whey and preservatives, packaging and storage at 5 ± 1°C. Gamay *et al*. (2011) observed that whey protein contributes mouthfeel as well as texture of cheese sauce, while the viscosity and texture were largely influenced by the presence of gum-like stabilizers such as sodium alginate, guar gum and xanthan gum. Flavour and texture profile of the product was provided by phosphate salt and common salt. Hine (1994) observed that desired quality cheese sauce can be obtained by using either natural or unmodified food-grade starch (rice starch, tapioca starch and potato starch) as ingredient. Spanier (1986) suggested to use either maltodextrin or corn syrup solids as filler material for improving the texture of cheese sauce. Bansal *et al*. (2017) prepared a cheese dip using 8.8% protein blend (WPC-70: sodium caseinate = 80:20), 6% cheddar cheese and 9.7% cream. During preparation of cheese dip, trisodium citrate, carboxy methyl cellulose and glycerol monostearate were used.

Response surface methodology (RSM) is a well-known optimization technique that has a wide range of applications in improving the formulations of food products since it can characterize the combined effects of ingredients and processing factors (independent variables) on the quality attributes (responses). Bansal *et al*. (2017) used RSM to optimize the levels of various ingredients in the preparation of the cheese dip just described.

In view of the opportunity of bringing diversification in food products through the use of heat-acid-induced milk gel and to cater to the need of health-conscious consumers, we attempted to develop a dip-like product using RSM. The utilization of dairy by-products (skim milk and whey) were also taken into focus.

Materials and methods

Materials

Fresh cow milk was acquired from the farm of West Bengal University of Animal and Fishery Sciences (Mohanpur Campus, West Bengal). Skim milk and cream were separated using a centrifugal cream separator. The fat percentage in skim milk and cream was standardized at 0.5 and 40%, respectively. Whey obtained during cow skim milk heat-acid-induced milk gel preparation was pasteurized to 72°C for 15 s and cooled to room temperature. Glycerol monostearate (GMS) was procured from Tripathi Products Pvt. Ltd., New Delhi. Common salt was procured from Tata chemicals Ltd., Mumbai. Food-grade citric acid and trisodium citrate (TSC) were procured from Urban Platter, New Delhi. Sodium hexametaphosphate (SHMP) was obtained from Choice Organochem LLP, Hyderabad.

Preparation of heat-acid-induced milk gel

The method for heat-acid-induced milk gel preparation of Kumar *et al*. (2016) was followed with some modification. The cow milk after receiving was filtered, separated and standardized to 0.5% fat and 8.5% SNF. The standardized skim milk was heated to 90°C followed by immediate cooling to coagulation temperature 65°C. The coagulation was done with citric acid solution of 2% strength till a clear whey separation. Finally, whey was drained out using a muslin cloth and rest part was hung for 30 min to obtain the heat-acid coagulum i.e., heat-acid-induced milk gel (60.55 ± 1.06% moisture, 4.28 ± 0.21% fat, 22.22 ± 0.91% protein, 3.85 ± 1.0% ash).

Preparation of dairy-based dip

The dairy-based dip was prepared using heat-acid-induced milk gel from cow skim milk and whey (Online Supplementary Fig. S1). Pasteurized whey, sodium hexametaphosphate, trisodium citrate and common salt were measured based on total weight of heat-acid-induced milk gel (60–70, 0.3, 0.3 and 0.8–1%, respectively, of the total weight of heat-acid-induced milk gel) and blended with heat-acid-induced milk gel thoroughly with a domestic hand blender (Philips Hand Mixer Model: HR3705, equipped with two kneading hooks) at speed control level 5 (1200 rpm). Pasteurized cream (40% fat) and glycerol monostearate were also measured on the basis of total weight of heat-acid-induced milk gel (15–35 and 0.3%, respectively of the total weight of heat-acid-induced milk gel) and added into that homogeneous slurry. The entire mixture was blended to obtain a product with homogeneous consistency. The product was heated for 5 min at 65°C. It was then cooled to room temperature. After that, the dairy-based dip was filled in a PET bottle and stored under refrigeration (4 ± 1°C) for further analysis.

Sensory analysis

A panel of 7 trained assessors from the Faculty of Dairy Technology having prior knowledge of the sensory evaluation of milk and milk products were trained for seven hours for this product. They then evaluated the dairy-based dip samples for sensory characteristics through 9-point hedonic scale. Flavour, body and texture (BT), colour and appearance (CA) and overall acceptability (OA) are the sensory attributes of dairy-based dip sample. Panel members carried out sensory evaluation in individual booths where 50 g of sample in a glass container was given to the assessor at 20°C.

Textural attributes

Textural attributes of the dairy-based dip were measured using TA.HD Plus C texture analyser (Stable Micro Systems, Godalming, Surrey, UK) fitted with a 50 kg load cell. The TTC spreadability fixture was a set of precisely matched male and female Perspex 90° cones. The sample of dairy-based dip was placed into a female cone and pressed down to eliminate air pockets. The product was subjected to applied force to a strain of 10% by a male cone in the HDP/spreadability rig probe attached with texture analyser and was evaluated for textural properties, viz. firmness, work of shear (WOS), stickiness and work of adhesion (WOA) using the Exponent Connect Lite software (Stable Micro System). Five replications for each sample were evaluated for the textural attributes at 20°C.

Compositional analysis

The moisture and protein content of the optimized product were determined using AOAC (1995). Total fat, ash and salt content were determined using IS:SP:18 (1981).

Experimental design and statistical analysis

Three levels for each of the three factors cream amount (A), whey amount (B) and common salt amount (C) were selected for optimization. The selected variables were optimized using 3-level factorial design. On the basis of sensorial and textural properties, the effect of different parameters was investigated using a 3-level factorial design of RSM. A set of factors with all possible combinations were contained in a full factorial design. A systematic investigation was carried out into the responses to know all factor influences and interaction effects. Online Supplementary Table S1 shows the lists of independent variables with their coded and actual levels.

Experimental results were analysed using a second order polynomial equation. The effects of process variables (A, B, C) and their interactions on response variables are represented using this model. The following is a representation of the model's general form:

$$Y = b_0 + b_1A + b_2B + b_3C + b_{12}AB + b_{13}AC + b_{23}BC + b_{11}A^2 + b_{22}B^2 + b_{33}C^2$$

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Where Y denotes the predicted response, b_0 denotes the model constant, b_1, b_2, and b_3 denote linear coefficients, b_{12}, b_{13}, and b_{23} denote cross product coefficients, and b_{11}, b_{22}, and b_{33} denote quadratic coefficients. The validity of the models was established on the basis of analysis of variance (ANOVA) using Statistical Stat-Ease Design Expert software version 7.0. The experimental investigation involved a total of 32 tests, including 5 control experiments at centre points. Construction of empirical models was done on the basis of actual data which represents flavour, BT, CA, OA, firmness, stickiness, WOS and WOA as responds to the variables. The validation of the results obtained from 3-level factorial design of RSM for comparison of the predicted values of sensory and textural parameters were assessed by Student's t test using IBM SPSS Statistics 20 software package.

Results and discussion

The variations in the quality of the dairy-based dip due to changing the independent variables cream, whey and salt were evaluated. The pronounced effect of each variable as well as their combinations was noticed during experiments. The sensorial score and textural parameters obtained from different experimental design are presented in Online Supplementary Tables S2 and S3, respectively. All the sensory and textural parameters of dairy-based dip were subjected to evaluation through quadratic model and the results of ANOVA regression analysis are presented in Table 1. The developed model equations could reliably and adequately predict the scores for all the sensory (flavour, BT, CA and OA) as well as textural (firmness, stickiness, WOS and WOA) attributes as a function of variables. Online Supplementary Fig. S2 represents the response surface plot of flavour (a, b, c), BT (d, e, f), CA (g, h, i) and OA (j, k, l). Online Supplementary Fig. S3 depicts firmness (a, b, c), stickiness (d, e, f), WOS (g, h, i) and WOA (j, k, l).

Sensory parameters of dairy-based dip

Regression analysis data are in Table 1 and all mentions of statistical significance are at $P < 0.05$ unless otherwise stated. The regression analysis of flavour score demonstrated that at the linear level, cream significantly and positively influenced the flavour score of the dairy-based dip, whilst whey showed a significant negative correlation with flavour score. The interaction of cream with whey significantly and negatively affected the product's flavour score (Online Supplementary Fig. S2a). With increased level of cream, the negative effect of whey decreased. A significant effect of cream on flavour score was observed at quadratic level, specifically, the flavour score increased initially with amount of cream, and then decreased upon further addition. A similar trend in the effect of milk fat was observed by Bansal *et al.* (2017) during preparation of cheese dip which shows higher milk fat content in final product due to the increase in amount of cream. The enhancement of perceived fattiness with increase in milk fat content might be the reason of augmentation of flavour score. The research study carried out by Kähkönen *et al.* (1995) revealed that the perceived fattiness, thickness and flavour of cheese soup increased due to the increase in fat content. It was also noticed that with the increase in the amount of added cream, the percentage of emulsifier in the final product and ratio of emulsifier and emulsifying salt to milk fat decreased. It was reported that an increase in the amount of TSC increased the acid-induced gel's water-holding capacity (Li *et al.*, 2018). Lowering of water-holding capacity at higher level of cream might be the reason of lowering of thickness, perceived creaminess or mouth feel of the product. GMS decreased the rate of creaming in recombined dairy cream having low fat content by developing stability to oil in water emulsion (Wu *et al.*, 2016). Lowering the GMS to cream ratio might decrease the creaming stability and, consequently, decrease the flavour score. Ghanshyambhai

Table 1. Regression coefficient of independent variables on sensorial and textural attributes of dairy-based dip

Factors	Flavour	BT	CA	OA	Firmness	Stickiness	WOS	WOA
Intercept	8.67	8.65	8.64	8.65	193.95	183.47	180.44	68.74
A	0.09*	0.10	0.11*	0.09*	−27.19*	−38.49*	−26.70*	−7.46*
B	−0.21*	0.11	−0.12*	−0.09*	−12.31*	−12.20*	−13.12*	−3.53*
C	−0.04	−0.04	0.091*	0.01	3.59*	5.13*	4.10	0.39
AB	−0.13*	−0.29*	−0.26*	−0.25*	7.95*	10.96*	9.83*	0.48
AC	0.01	0.19*	−0.01	0.08*	−1.60	−1.96	−3.11	−0.20
BC	−0.00	0.58*	0.01	0.20*	−0.92	−0.39	−3.82	−0.29
A^2	−0.52*	−0.25*	−0.47*	−0.46*	5.31	12.63*	−2.23	−0.86
B^2	0.09	−0.82*	0.00	−0.24*	5.64*	7.79*	11.28*	3.89*
C^2	−0.04	−0.09	0.07	−0.01	0.66*	1.62	2.83	−0.67
Model F value	11.04	16.06	7.48	20.27	48.47	50.81	16.27	9.41
Model P value ($P > F$)	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Lack of fit (F value)	0.08	4.04	0.09	0.25	0.50	0.78	1.16	0.87
R^2	0.82	0.87	0.75	0.89	0.95	0.95	0.87	0.79
PRESS	1.08	4.76	1.59	0.91	1856.07	3129.26	6846.16	740.50
Adequate precision	10.30	14.86	8.67	15.13	24.83	24.76	16.029	10.75

BT, body and texture; CA, colour and appearance; OA, overall acceptability; WOS, work of shear; WOA, work of adhesion.
*Significant at $P < 0.05$.

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et al. (2015) during preparation of cultured buttermilk using *dahi* and unfermented paneer whey observed that addition of unfermented paneer whey decreased flavour score.

The following response surface equation was attained to predict the change in flavour score with change in level of different factors in terms of actual factors:

$$\begin{aligned}\text{Flavour} =& 16.53 + (0.43 \times \text{Cream}) - (0.47 \times \text{Whey}) \\ &+ (8.09 \times \text{Salt}) - (2.62 \times 10^{-3} \times \text{Cream} \times \text{Whey}) \\ &+ (0.015 \times \text{Cream} \times \text{Salt}) - (0.012 \times \text{Whey} \times \text{Salt}) \\ &- (5.21 \times 10^{-3} \times \text{Cream}^2) \\ &+ (3.91 \times 10^{-3} \times \text{Whey}^2) - (4.51 \times \text{Salt}^2)\end{aligned}$$

dy and texture (BT) data are in Table 1. The effects of varying ingredient composition were non-significant ($P > 0.05$) at the linear level. However, at the quadratic level both cream and whey exhibited significant negative correlation with BT score, meaning that at an intermediate level of each of cream and whey, BT score was a its greatest. Wu *et al.* (2016) reported that emulsion stability decreased and creaming rate increased in recombined low fat dairy cream with decrease in the level of GMS. We observed that creaming rate was increased with increase in fat owing to the decrease of emulsifier to cream ratio in the final product. At very high levels of cream, the increase in rate of creaming from that emulsion might be responsible for lower BT score. Increase in amount of whey decreases the ratio of emulsifying salt to whey, which might decrease the BT score of the product at a much higher level of whey. The decrease in the amount of water holding in acid-induced gel with a lowering of the amount of TSC was observed by Li *et al.* (2018). During a study of the effect of interaction between, firstly, cream and salt and, secondly, whey and salt, it was observed that the negative effect of salt increased significantly with increase in amount of added whey and cream (Online Supplementary Fig. S2e and f). However, the interaction of cream and whey exhibited negative correlation with BT score of dairy-based dip, which means an increase in the added cream decreased the positive influence of whey on BT score (Online Supplementary Fig. S21d). To forecast the change in BT score with change in level for different factors in terms of actual factors, the response surface equation shown below was obtained:

$$\begin{aligned}\text{Body and Texture} =& -77.52 + (0.33 \times \text{Cream}) + (3.39 \times \text{Whey}) \\ &- (64.82 \times \text{Salt}) - (5.83 \times 10^{-3} \times \text{Cream} \times \text{Whey}) \\ &+ (0.19643 \times \text{Cream} \times \text{Salt}) + (1.16667 \times \text{Whey} \times \text{Salt}) \\ &- (2.45 \times 10^{-3} \times \text{Cream}^2) - (0.03 \times \text{Whey}^2) - (9.10 \times \text{Salt}^2)\end{aligned}$$

Colour and appearance (CA) data are in Table 1. Similar relationships to those for flavour were observed: at linear level a significant positive correlation of the level of added cream was seen, whilst at the quadratic level the effect of cream was negative, since the CA of the product increased to a maximum as eam was added and then decreased with further addition. Whilst salt and CA score had a significant positive correlation, whey had a significant negative correlation at the linear level. The cream and whey interaction was as for flavour: additional cream decreased the negative influence of whey (Online Supplementary Fig. S2g). The increase in cream content increased the lightness and sheen of product and thereby increased the CA score of dairy-based dip. At very high levels of cream the separation of cream from the dip due to lower emulsifier might cause reduction in CA score. Sołowiej *et al.* (2010) reported that the sheen of the processed cheese analogue was reduced by addition of WPC. Bansal *et al.* (2017) suspected that lactose in WPC-70 might have undergone Maillard's reaction and darkened the cheese dip colour. The lowering of sheen with addition of whey might cause the reduction of CA score.

To forecast the change in CA score with change in level of various factors in terms of actual factors, the following response surface equation was obtained:

$$\begin{aligned}\text{Colour and Appearance} =& 5.15 + (0.59 \times \text{Cream}) \\ &+ (0.05\,\text{Whey}) - (12.05 \times \text{Salt}) - (5.24 \times 10^{-3} \times \text{Cream} \times \text{Whey}) \\ &- (8.94 \times 10^{-3} \times \text{Cream} \times \text{Salt}) + (0.02 \times \text{Whey} \times \text{Salt}) \\ &- (4.69 \times 10^{-3} \times \text{Cream}^2) + (2.92 \times 10^{-4} \times \text{Whey}^2) \\ &+ (6.68 \times \text{Salt}^2)\end{aligned}$$

Overall acceptability (OA) data are in Table 1. The effects of cream and whey were positive and negative respectively, as for flavour and CA, whilst in this case the interaction was positive rather than negative (Online Supplementary Fig. S2j). The interactions between cream and salt, and whey and salt also exhibited significant positive correlations (Online Supplementary Fig. S2k and Table l). At the quadratic level, cream addition initially increased the OA score to a maximum which then declined, as before. Whey exhibited a significant negative effect on OA score of the product at the quadratic level. Gautam *et al.* (2024) reported that medium-fat milk ricotta cheese spread (11.55% fat) obtained highest OA score than no fat (7.71%), low fat (9.80%) and full fat (13.06) ricotta cheese spread in their study. They suspected that the observed variation was due to the balance in moisture, fat and protein content in medium fat milk ricotta cheese spread in their study. Furthermore, Chatziantoniou *et al.* (2015) found that increase of fat content or decrease of protein coent (*via* adjusting the ratios of whey cheese to cream) in spreadable processed whey cheeses produced uniform, solid, less viscous and highly spreadable spread that obtained higher OA in sensory score. The observed effect of OA in the current study could be attributed to the balance in the proportion of cream and moisture content in the dairy-based dip samples.

The following response surface equation was attained to predict the change in OA score with change in level of different factors in terms of actual factors:

$$\begin{aligned}\text{Overall acceptability} =& -16.78 + (0.49 \times \text{Cream}) + (0.97 \times \text{Whey}) \\ &- (26.19 \times \text{Salt}) - (4.95 \times 10^{-3} \times \text{Cream} \times \text{Whey}) \\ &+ (0.081 \times \text{Cream} \times \text{Salt}) + (0.40 \times \text{Whey} \times \text{Salt}) \\ &- (4.58 \times 10^{-3} \times \text{Cream}^2) - (9.45 \times 10^{-3} \times \text{Whey}^2) \\ &- (1.14 \times \text{Salt}^2)\end{aligned}$$

Texture parameters of dairy-based dip

Firmness data are in Table 1. As per Gautam *et al.* (2024), firmness is the maximum depth of penetration during compression of the sample. At linear level, significant negative correlation of cream, whey and salt with firmness of dairy-based dip was observed from regression analysis (Table 1; Online Supplementary Fig S3a–c). A significant effect of whey on stiffness was perceived at the quadratic level. The higher value of

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firmness both at lower and higher level of whey was observed as compared to the firmness at intermediate level of whey. A similar pattern was also seen in the case of cream. The percentage of emulsifier and ratio of emulsifier to milk fat decreased with an increase in the amount of added cream, which might cause the decreased firmness of the products. It was also reported from previous studies that TSC have the ability to increase firmness and water-holding capacity of acid induced, transglutaminase-treated micellar casein gel (Li *et al.*, 2018) and hardness of process cheese (Shirashoji *et al.*, 2006). Lynch and Griffin (1974) reported that substituting a portion of the continuous phase with an equal amount of fat caused stiffness to decrease at very high levels of fat content.

The following response surface equation was attained to predict the change in firmness with change in level of different factors in terms of actual factors:

$$\begin{aligned}\text{Firmness} = {} & 1544.14 - (14.26 \times \text{Cream}) - (34.10 \times \text{Whey}) \\ & + (76.08 \times \text{Salt}) + (0.16 \times \text{Cream} \times \text{Whey}) \\ & - (1.60 \times \text{Cream} \times \text{Salt}) - (1.84 \times \text{Whey} \times \text{Salt}) \\ & + (0.053 \times \text{Cream}^2) + (0.22 \times \text{Whey}^2) \\ & + (66.39 \times \text{Salt}^2)\end{aligned}$$

Stickiness data are in Table 1. The maximum negative peak force indicates the stickiness of a sample, which is a tactile sensation detectable by the tongue and palate (Bayarri *et al.*, 2012). Stickiness behaved in the same way as firmness. At the linear level cream, whey and salt all showed a significant negative correlation (Table 1; Online Supplementary Fig. S3d–f) and at the quadratic level higher stickiness values were seen at low and high levels of both whey and cream. With increase in the amount of cream and whey the content of heat-acid-induced milk gel decreased in the final product. The decrease in the amount of heat-acid-induced milk gel might be responsible for lower stickiness. Kumar *et al.* (2016) reported that increase in the amount of heat-acid-induced milk gel and skim milk powder significantly influenced the stickiness of low-fat, dairy-based dairy spread. Moreover, Gautam *et al.* (2024) also observed that stickiness value was significantly decreased with increase in fat content in ricotta cheese spread.

The following response surface equation was attained to predict the change in stickiness with change in level of different factors in terms of actual factors:

$$\begin{aligned}\text{Stickiness} = {} & 2185.52 - (22.65 \times \text{Cream}) - (47.74 \times \text{Whey}) \\ & - (140.01 \times \text{Salt}) + (0.22 \times \text{Cream} \times \text{Whey}) \\ & - (1.96 \times \text{Cream} \times \text{Salt}) - (0.78 \times \text{Whey} \times \text{Salt}) \\ & + (0.13 \times \text{Cream}^2) + (0.32 \times \text{Whey}^2) \\ & + (161.61 \times \text{Salt}^2)\end{aligned}$$

The work of shear (WOS) data are in Table 1. WOS indicates the energy necessary to carry out the shearing process. This parameter is regarded as an effective instrumental measurement of spreadability in spreadable products (Bayarri *et al.*, 2012). Once again, at the linear level WOS behaved as for firmness (significant negative correlations). However, whey showed a positive correlation with WOS at the quadratic level. Gautam *et al.* (2024) reported that WOS value was decreased significantly with the increase of fat content in ricotta cheese spread, so the observed variation in WOS of dairy-based dip in current study could be due to variation of cream and whey content as it directly alters the fat content of the dip.

The following response surface equation was attained to predict the change in WOS with change in level of different factors in terms of actual factors:

$$\begin{aligned}\text{Work of Shear} = {} & 2304.89 - (11.53 \times \text{Cream}) - (59.32 \times \text{Whey}) \\ & + (106.29 \times \text{Salt}) + (0.19 \times \text{Cream} \times \text{Whey}) \\ & - (3.11 \times \text{Cream} \times \text{Salt}) - (7.65 \times \text{Whey} \times \text{Salt}) \\ & - (0.02 \times \text{Cream}^2) + (0.45 \times \text{Whey}^2) \\ & + (283.21 \times \text{Salt}^2)\end{aligned}$$

Work of adhesion (WOA) data are in Table 1. WOA can be described as the effort needed to counteract the attractive forces between the probe's surface and the sample's surface (Gautam *et al.*, 2024). WOA varied in the same way as WOS: significant negative correlations at linear level and a positive correlation of whey at quadratic level (Table 1: Online Supplementary Fig S3j). Gautam *et al.* (2024) reported that WOA significantly decreased in ricotta cheese spread with increase in fat content. Here, the observed variation could be attributed to the development of strong gel matrix in the dairy-based dip during the alteration of whey and cream content.

The following response surface equation was attained to predict the change in work of adhesion with change in level of different factors in terms of actual factors:

$$\begin{aligned}\text{Work of Adhesion} = {} & 703.85 - (0.76 \times \text{Cream}) - (20.65 \times \text{Whey}) \\ & + (168.96 \times \text{Salt}) + (9.65 \times 10^{-3} \times \text{Cream} \times \text{Whey}) \\ & - (0.20 \times \text{Cream} \times \text{Salt}) - (0.59 \times \text{Whey} \times \text{Salt}) \\ & - (8.67 \times 10^{-3} \times \text{Cream}^2) + (0.15 \times \text{Whey}^2) - (67.24 \times \text{Salt}^2)\end{aligned}$$

Optimization of level of ingredients

The levels of cream, whey and common salt were optimized through numerical optimization procedure of Design Expert 8.0 software for the development of dairy-based dip. The levels of ingredients were kept in the experimental range and maximized according to the score of the different sensory attributes (flavour, BT, CA, OA score) whilst the values of the different textural attributes (firmness, stickiness, WOS and WOA) were kept in range (Table 2). The optimization procedure predicted that adding cream, whey, and common salt to the weight of the heat-acid-induced milk gel at rates of 27.9, 60.3 and 0.8% would result in a dip with the maximum desirability of 0.84. The predicted score for sensorial attributes of optimized product was 8.97, 8.34, 8.81 and 8.73 for flavour, BT, CA and OA, respectively and the values of firmness, stickiness, WOS and WOA were 197.67 g, 185.54 g, 188.33 g.s, and 71.16 g.s, respectively (Table 3).

The dairy-based dip was prepared in triplicate in order to compare the predicted values by applying an independent sample *t* test. The actual values of sensorial and textural attributes differed non significantly ($P > 0.05$) with predicted values (Table 3). The optimized product contained 72.6 ± 0.3% moisture, 8.4 ± 0.1% fat, 12.2 ± 0.1% protein, 0.71 ± 0.01% salt, 6.0 ± 0.4% lactose and 0.11 ± 0.002% ash (Online Supplementary Table S4).

In conclusion, a good quality of dairy-based dip could be prepared using heat-acid-induced milk gel, cream, whey, common

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Table 2. Criteria for optimization of different constraints for selection of optimized dairy-based dip

Name	Goal	Lower limit	Upper limit	Importance
Cream	Is in range	15	35	3
Whey	Is in range	60	70	3
Salt	Is in range	0.8	1	3
Flavour	Maximize	7.928571	9	3
BT	Maximize	6.5	9	3
CA	Maximize	7.75	9	3
OA	Maximize	7.5	8.93	3
Firmness	Is in range	165.0055	266.95	3
Stickiness	Is in range	138.0675	279.1025	3
WOS	Is in range	146.4385	262.823	3
WOA	Is in range	55.813	86.4955	3

BT, body and texture; CA, colour and appearance; OA, overall acceptability; WOS, work of shear; WOA, work of adhesion.

Table 3. Independent sample t-test to compare predicted value with observed value

Parameter	Predicted value	Observed value	*P* value (2 tailed)*
Flavour	8.97	8.9 ± 0.06	0.374
BT	8.34	8.67 ± 0.17	0.186
CA	8.81	8.9 ± 0.06	0.266
OA	8.73	8.83 ± 0.08	0.348
Firmness (g)	197.67	203.33 ± 6.51	0.476
Stickiness (g)	185.54	202.30 ± 13.20	0.332
WOS (g.s)	188.33	183.03 ± 2.47	0.165
WOA (g s)	71.16	68.96 ± 2.09	0.293

BT, body and texture; CA, colour and appearance; OA, overall acceptability; WOS, work of shear; WOA, work of adhesion.
Mean ± SE. ($n = 3$); * non-significant ($P > 0.05$) difference at 5% level of significance.

salt, trisodium citrate, sodium hexametaphosphate and glycerol monostearate at levels of 52.7, 14.7, 31.7, 0.42, 0.16, 0.16 and 0.16%, respectively. The study showed a significant ($P < 0.05$) effect of cream, whey and salt on sensorial as well as textural properties of the product. Increased cream content improved the flavour of the dairy-based dip with a decrease in the firmness value, whereas increased whey content created a firmer product. Common salt imparted a positive effect on the sensorial parameters.

Supplementary material. The supplementary material for this article can be found at https://doi.org/10.1017/S0022029924000621.

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