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ORIGINAL ARTICLE

Modelling and optimization of process parameters for production of desiccated *Chhana-murki* (Indian cottage cheese-based dessert)

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Abstract In the present study, process parameters were optimized for the production of desiccated *chhana-murki* (Indian cottage cheese-based dessert). Response Surface Methodology (RSM) was employed to explore the mutual effects of coagulation temperature (CT) of milk (70–90 °C), % fat level in milk (3.5%–5.5%), and sugar-to-*paneer* cube (SP) ratio (0.6–0.9) on instrumental hardness (N), water activity (a_w), yield (%), sensory sweetness and overall acceptability (on 100-point intensity scale) of *chhana-murki*. The resulted responses were evaluated by analysis of variance (ANOVA), and the second-order polynomial response surface equations were fitted using multiple regression analysis. Determination coefficients (R^2) were equal to 80% or higher for individual responses stated that the developed models were well fitted to the experimental results. The optimized product was prepared using CT 79.22 °C, milk fat 4.8%, and SP ratio 0.7. Confirmatory experiment values for instrument hardness, water activity (a_w), yield (%), sensory sweetness and overall acceptability were 105.05 N, 0.85, 115.2%, 61.2 and 78.8, respectively.

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Introduction

India is the world's largest producer (187.7 Million Tonnes, 2018–19) and consumer of milk (NDDB, 2020). Out of the total milk commercially processed, about 50%–55% is converted by the traditional sector into a variety of dairy products (Patil 2005). *Paneer* (heat and acid-coagulated product) commonly known as traditional cottage cheese made from buffalo milk, is one of the major processed dairy products consumed in India (USDA 2015). Similarly, *chhana,* Indian soft cottage cheese and *Khoa*, heat-desiccated products are the base or filler material for a variety of traditional Indian sweets (Aneja et al. 2002). Estimated volume of indigenous sweets in the Indian market was about 3 million tons that cost about 7,00,000 million rupees (Khanna and Gupta 2011; Gurditta et al. 2014).

Chhana-murki is sugar-coated *chhana/paneer* (Indian cottage cheese) based dessert originated from the northern and eastern region of India. The characteristic *chhana-murki* is marketed as bite-size cubes, white to creamy appearance, firm body, and unique, close-knit texture having sweet flavour notes. Conventionally, it is prepared by open pan heat desiccation of cubical to round pieces of 1–1.5 cm diameter *chhana/ paneer* cubes in sugar syrup followed by a coating of sugar on its surface. *Chhana-murki,* with partial heat desiccation of *panner* cubes and sugar coating, has fairly good shelf stability and longer keeping quality.

Two different varieties of *chhana-murki* are often marketed in India. One is desiccated/ hard/dry-type *chhana-*

murki (dry in outer and inner appearance) prepared from *paneer* (the milk coagulum obtained after acid coagulation is pressed to form block). The other variety is soft/ syrupy/ wet/ moist-type (inside texture resembles *rasgulla* wherein syrup is entrapped in the casein matrix while the outside surface is dry or wet in appearance) obtained from *chhana* (coagulum obtained after acid coagulation of milk is hanged till the entire (loose) moisture gets drained off). These two varieties marketed as *chhana-murki,* whether made from *paneer* or *chhana* are dissimilar in their physico-chemical, textural and sensory attributes (Arora 2011). The reason could be the quality of raw material and processing parameters critical to the finished product. The product is being prepared at small scale and limited to the unorganized dairy sector which utilizes conventional, ineffective methods of manufacturing where the sanitized surroundings are usually not maintained, and as a result, substandard product quality is obtained (Patil 2002).

The textural quality of any food product influences its consumer acceptability (Park 2007). The optimum firmness and sweetness are mainly the desired characteristics of *chhana-murki,* and it is mostly dependent on the quality characteristics of *paneer* and the amount of sugar used in product preparation. Therefore, there is a need to consider these factors during the product-process optimization of desiccated *chhana-murki*.

Response Surface Methodology (RSM) is an efficient statistical tool for optimizing multivariable and their interaction by using experimental design (Henika 1982). Several workers have applied RSM in their research and used it for optimization of different process variables in dairy products such as fermentation condition in yoghurt (Bansal et al. 2016), *burfi* (Chetana et al. 2010), pearl millet-based dairy dessert (Jha et al. 2013), *paneer* (Rao and Patil 2001), mango soy fortified yoghurt (Kumar and Mishra 2003), cheese (Ling and Hui-ping 2013) and traditional dairy desserts like soft-serve ice-cream (Softy) (Sharma et al. 2003). So far, no attempt has been made to study the process parameters critical for the production of desiccated *chhana-murki*. Therefore, the present work was conceded to observe the effect of process variables viz., *paneer* making conditions and sugar-to-*paneer* cube (SP) ratio on instrument hardness, water activity, yield (%), sensory sweetness and overall acceptability characteristics of desiccated *chhana-murki* using response surface methodology (RSM).

Material and methods

Freshly pooled buffalo milk (7%–8% Fat content and 8.5%–9% SNF) was procured from the Experimental Dairy Plant, Dairy Technology Division, ICAR-National Dairy Research Institute, Karnal, India in steam-sterilized aluminium can. pH of milk for *paneer* preparation was adjusted using commercial-grade (SQ grade) citric acid. Cane sugar was obtained from the experimental dairy store for production of *chhana-murki.*

Experimental design

Response Surface Methodology (RSM) was used to study the optimum condition for product preparation (Henika 1982). For the production of desiccated *chhana-murki,* the experimental design and statistical analysis were executed using Design Expert software (Trial version 12, Stat-Ease, Inc., MN, USA). A five level-three factor central composite rotatable design (CCRD) was used to assess the mutual effect of three process variables viz., coagulation temperature (CT) of milk, % milk fat and sugar-to-*paneer* cube (SP) ratio coded as A, B and C, respectively (Table 1). The complete design consisted of 20 combinations including eight factorial points, six axial points and six central point (replicates). The actual value of three process variables and the experiment results of the studied responses (instrumental Hardness (N), yield (%), water activity (a_w), sensory sweetness and overall acceptability (on a 100-Point descriptive scale) were coded as Y_1, Y_2, Y_3, Y_4 and Y_5, respectively (Table 2). The experimental data were fitted using a quadratic polynomial model as per the Eq. (1) given below:

$$Y = \beta 0 + \sum_{i=1}^{k} \beta i X i + \sum_{i=1}^{k} \beta ii X2i + \sum_{i=1}^{k-1} \sum_{j=i+1}^{k} \beta ij Xi Xj \qquad (1)$$

where Y is the dependant variable (Y_1, Y_2,..Y_5) and k is the number of independent variables. Xi and Xj represents three independent variables (A, B and C) in coded form and β_0 is constant. β_i, β_{ii}, and β_{ij} represent the linear, quadratic and interaction regression coefficients, respectively.

Preparation of desiccated *chhana-murki*

Preparation of paneer and sugar syrup

Preparation of *paneer* was carried out following the method of Sachdeva and Singh (1988) and Arora et al (2019) with slight modification. Buffalo milk with the desired fat content was standardized according to RSM design (Table 1) while the SNF was kept constant (8.5%). The standardized buffalo milk was pre-heated to 90 °C (except run no-18, Table 2) without holding (at temperature 90 °C or above, the whey proteins (β-Lg) gets denatured. There is irreversible interaction between whey proteins and

Table 1 Levels of different variables in coded and actual form for production of desiccated *chhana-murki*

Independent variables	Units	Symbols	Coded level				
Factor			Axial point −1.682	Factorial point −1	Centre coordinate 0	Factorial point + 1	Axial point + 1.682
Coagulation temperature	(°C)	A	63.18	70	80	90	96.82
Milk Fat	(%)	B	2.82	3.5	4.5	5.5	6.18
Sugar-to-*paneer* cube ratio		C	0.50	0.6	0.75	0.9	1.00

Table 2 The central composite rotatable design (CCRD) for desiccated *chhana-murki* with process variables and experimental results of responses

Run	A	B	C	Y_1	Y_2	Y_3	Y_4	Y_5
1	70.00	3.50	0.90	151.2	0.83	132.0	80.2	78.8
2	80.00	4.50	0.50	95.5	0.9	95.2	60.4	79.5
3	70.00	5.50	0.90	133.3	0.87	136.4	85.4	78.9
4	80.00	2.82	0.75	114.5	0.84	133.6	65.2	77.7
5	70.00	3.50	0.60	80.63	0.87	86.0	65.0	78.7
6	63.18	4.50	0.75	70.11	0.88	134.4	72.0	73.3
7	80.00	4.50	0.75	108.5	0.83	116.4	65.0	78.8
8	90.00	3.50	0.90	160.0	0.82	112.8	82.5	71.1
9	90.00	3.50	0.60	137.3	0.84	114.4	62.0	74.4
10	80.00	6.18	0.75	73.3	0.88	128.0	65.5	77.7
11	80.00	4.50	0.75	124.9	0.85	104.4	67.0	81.1
12	90.00	5.50	0.60	78.07	0.87	95.6	60.0	78.8
13	80.00	4.50	1.00	156.5	0.81	115.6	88.8	76.6
14	80.00	4.50	0.75	114.5	0.84	123.2	66.0	82.2
15	70.00	5.50	0.60	70.45	0.89	85.6	62.5	76.6
16	90.00	5.50	0.90	110.2	0.83	106.8	82.6	75.5
17	80.00	4.50	0.75	104.5	0.84	118.4	67.0	77.7
18	96.82	4.50	0.75	115.5	0.82	114.4	72.5	71.5
19	80.00	4.50	0.75	114.9	0.85	116	68.0	81.1
20	80.00	4.50	0.75	107.1	0.85	120	71.4	80.0

A Coagulation temperature, ***B*** % Milk Fat and ***C*** Sugar -to-*Paneer* cube (SP) Ratio, Y_1 Instrument Hardness (N); Y_2 Water Activity (a_W); % Y_3 Yield (%); Y_4 Sweetness (100-point scale); Y_5 overall acceptability (OA)(100-point scale)

K-casein, and this increases the casein micellar size (Anema and Li 2003) which in turn affect the yield of the coagulum) and coagulated at the desired temperature (Table 2). The *panner* block was pressed using 0.047 kg/cm^2 pressure for 15–20 min. The block thus obtained was kept in chilled water (at 4 °C –5 °C) for 2 h to increase the firmness and ease in cutting.

The sugar syrup was prepared by dissolving the calculated quantity of sugar (Table 1) in the calculated amount of water (1/3rd of sugar) and brought to boil. It was clarified by adding a few millilitres of skim milk in the boiling syrup and removing scum by filtration.

Production of desiccated chhana-murki

One kg *paneer* cubes of approx. 1 cm size was immersed in boiling sugar syrup (103 ± 1 °C temperature, 76–77° Bx sugar in solution) and stirred slowly. As the heating progresses, the loose whey/moisture expelled out of the *paneer* pieces (generally it takes 12–15 min for 1 kg *panner* cubes or depending upon the lot size). When the surface of the cubes becomes shiny and translucent (after 5–6 min), the cubes were removed from the syrup by using dry clean stainless-steel sieve. The syrup was allowed to concentrate (usually 10–12 min) till sugar begins to crystallize on the pan surface. The *paneer* cubes were again dipped in the syrup and heating is continued for 5–6 min followed by slow agitation of *paneer*-sugar syrup mixture. No further heating was required at this stage and with constant scraping and stirring the *paneer* cubes gets coated with sugar. The product thus obtained was equilibrated under ambient temperature and studied for instrumental hardness, water activity (a_w), % yield and sensory properties.

Physical analysis

Water activity (a_w)

Water activity meter (CxT-2, Aqua Lab, WA, USA) was used for determining the water activity (a_w) of the samples. The grounded sample of *chhana-murki* was placed in the sample cup, which is then sealed within the sample chamber of water activity meter for measurement. The instrument was initially calibrated, and all observations were carried out when the temperature of the samples stabilized at 25 °C.

Product yield (%)

For the preparation of *chhana-murki*, one kg of *paneer* cubes was used in each experiment. The product obtained from 1 kg *paneer* is presented as yield (%) according to the following equation:

$$Percent(\%)yield = \frac{Weight\ of\ chhana\ murki\ obtained}{Initial\ weight\ of\ paneer\ cubes\ taken} \times 100 \quad (2)$$

Instrumental texture profile analysis (TPA)

The texture profile includes instrumental hardness (N) of *chhana-murki* was studied using TA-XT2i Texture Analyzer (Stable Micro Systems, UK). 25 kg load cell and compression platen (P/75) probe was used for performing the texture analysis. Samples with equal dimensions were compressed twice to 70 per cent of its original height. The pre-test, test and post-test speed of 2.0 mm/sec were used throughout the study. All measurements were carried out at 25±1 °C. The data on instrument texture parameter was interpreted using Texture Expert Exceed software recommended by Bourne (1982).

Sensory analysis

Two most critical sensory attributes viz., sweetness and overall acceptability corresponding to the present study were chosen on a descriptive intensity scale of 100 points for reporting and evaluation of sensory results. A 10 cm line was drawn representing 100-point structured line scale and descriptors were mentioned at an interval of 25. Both responses were taken with the suitable semantic descriptor, ranging from 0, denoting not much perceived (e.g. too low), to 100, denoting pronounced (e.g. excessive sweetness) to evaluate the sweetness attribute. For evaluation of overall acceptability, the semantic descriptor ranging from 0 denoting most disliked imaginable (disliked extremely) to 100 most liked imaginable (liked extremely) was considered (Bartoshuk et al. 2002). Seven trained and experienced panel members were selected to participate in the descriptive sensory test for the desiccated *chhana-murki*. A score sheet with line scale was provided to the panel member for evaluation. Luke warm water (25^0C) was provided to cleanse the palate, before and in between samples evaluation. All the samples serving and evaluation were carried out as per the method given by Hootman (1992).

Statistical analysis

Analysis of variance (ANOVA) was used to evaluate the effect of independent variables on responses. All trials were carried out in triplicate, and the statistical significance was evaluated using independent t-test, and $p \leq 0.01$ and $p \leq 0.05$ were taken as significant.

Result and discussion

Diagnostic check of the quadratic model

The experimental variables in actual form and the corresponding value of the response generated are presented in Table 2. The quadratic models for instrument hardness, water activity, yield (%), sensory sweetness and overall acceptability were achieved through subsequent regression analysis, and the coefficients estimates are presented in Table 3. The numerical analysis specifies that the suggested model was adequate with satisfactory values of the regression (R^2) for all the responses. The R^2 values were equal to 0.80 or higher for the individual responses stated that the fitted quadratic model could thoroughly explain more than 80 per cent of the variation of the resultant data (Erdem et al. 2014). R^2 closer to unity, suggests that the experimental models well fit with the actual data. Alternatively, the lower value of R^2 indicates that the fitted quadratic model explains the higher variation in empirical data. The probability (p) values for quadratic model were significant at 1% level for hardness (N), water activity, sweetness and overall acceptability attribute, and at 5% level for yield (%) parameter for desiccated *chhana-murki*. The effects of independent variables on the studied responses were also presented graphically using 3-D surface plots (Fig. 1 and 2). The lack of fit test (check the fitness of the model), was non-significant relative to the pure error for all responses demonstrating that the applied models were adequately precise for estimating the responses of desiccated *chhana-murki* prepared with any combinations of levels of independent factor within the range evaluated.

Effect on instrument hardness

Hardness depicts the force needed to attain a given extent of deformation, and it is the peak force obtained after the first compression of the product (Kumar and Mishra 2003). The instrumental hardness of desiccated *chhana-murki* ranged from 70.11(N) to 156.5 (N) (Table 2).

The increase in CT ($\beta = +9.22$) and SP ($\beta = +21.32$) ratio had significant positive effect and % milk fat ($\beta = -15.13$) had a significant indirect effect ($p \leq 0.01$) on the textural hardness of the product at the linear level. This might be due expulsion of moisture at a higher rate at higher CT of milk that tends to increase the hardness of *chhana-murki*. The decrease in hardness with the increase in % milk fat from 3.50 to 5.50 may be due entrapment of a large number of fat globules in the casein micelles that tend to make the product comparatively

Table 3 Estimated regression coefficients of the fitted second-order polynomial and their significance

Factor	Y_1	Y_2	Y_3	Y_4	Y_5
Intercept	112.06	0.8434	116.78	67.35	80.16
A	9.22**	−0.0147**	−3.22	−0.377	−1.17**
B	−15.13**	0.0122**	−2.21	0.095	0.569
C	21.32**	−0.0199**	10.30**	9.44**	−0.517
A^2	−4.53	0.0017	0.3530	2.05**	−2.63**
B^2	−4.19	0.0052	2.62	−0.389	−0.669
C^2	7.21*	0.0034	−6.36*	2.88**	−0.669
AB	−10.09*	−0.0025	−3.60	−0.575	1.25**
AC	−9.80*	0.00001	−10.90**	0.625	−1.25**
BC	0.1800	0.00001	2.20	1.22	0.1389
R^2	0.92	0.90	0.80	0.97	0.87
Adequate Precision	14.08	12.6	8.9	20.3	9.03
PRESS	6528.2	0.0068	5571.45	225.6	82.72
Model F value	13.95**	11.09**	4.30*	32.22**	8**
Lack of Fit	NS	NS	NS	NS	NS

*Significant at $p \leq 0.05$, **Significant at $p \leq 0.01$

NS Non-significant, ***A*** Coagulation temperature, ***B*** % Milk Fat and ***C*** Sugar -to-*Paneer* cube (SP) Ratio, Y_1 Instrument Hardness (N); Y_2 Water Activity (a_W); Y_3 Yield (%); Y_4 Sweetness (100-point scale); Y_5 Overall acceptability (OA) (100-point scale)

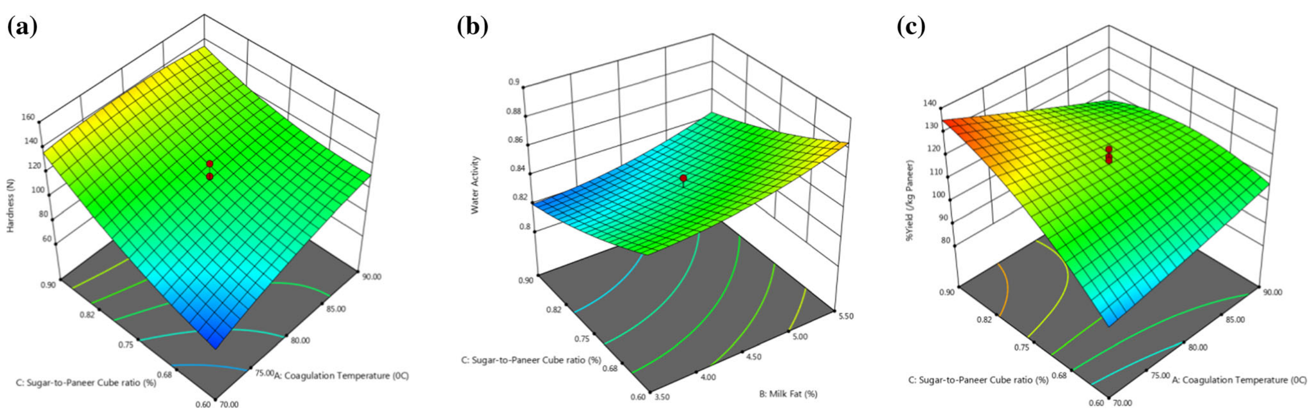

Fig. 1 Response plots showing the effect of **a** Coagulation temperature (CT), sugar-to-paneer cube (SP) ratio and their mutual effect on Hardness (N). Other variable is constant: Milk Fat % −4.5%, **b** Milk fat %, sugar-to-paneer cube (SP) Ratio and their mutual effect on Water Activity (a_w). Other variable is constant: Coagulation temperature (CT)−80 °C, **c** Coagulation temperature (CT), sugar-to-paneer cube (SP) Ratio and their mutual effect on Yield (%). Other variable is constant: Milk Fat−4.5%

softer. This study was in agreement that large size of the casein micelles and high-fat content in milk (5%–6%) is desirable for preparation of good quality *paneer* with a soft spongy body and smooth texture (Khan and Pal 2011; Kumar et al. 2008). In another study, *paneer* made from cow or buffalo milk with 3.5 or less fat content lack typical flavour and desirable texture (lack smoothness) (Arya and Bhaik 1992). The quadratic terms of SP ratio was significant ($p \leq 0.05$) and its interaction with fat was non-significant. CT showed significant ($p \leq 0.05$) negative interaction effect with the other two variables (Table 3). The response surface plots (3-D plots) for the effect of CT and SP ratio on instrument hardness of desiccated *chhana-murki* are shown in Fig. 1(a). The negative quadratic term of CT signify the convex-upward type of the 3-D plot, wherein the maximum hardness was observed at or near centre point, and further increase or drop of CT consequently decrease the hardness (Fig. 1a). The hardness of desiccated *chhana-murki* could well be predicted by the Eq. 3

$$Hardness(coded\ value\ of\ the\ factors) = +112.06 + 9.22A - 15.13B + 21.32C + 7.21C^2 - 10.09AB - 9.80AC \quad (3)$$

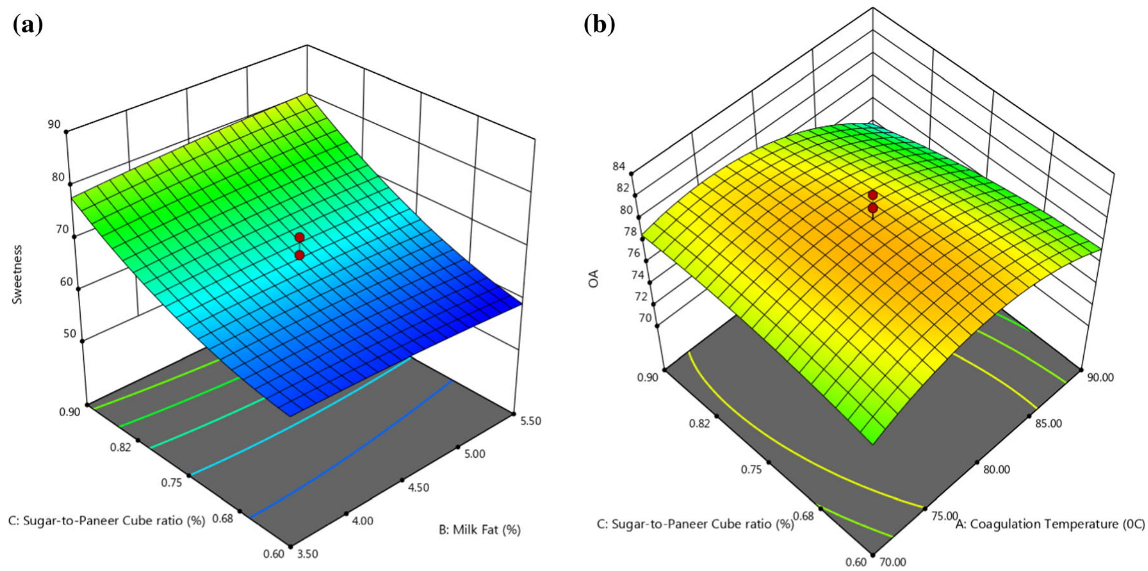

Fig. 2 Response plots showing the effect of **a** Milk fat %, sugar-to-*paneer* cube (SP) Ratio and their mutual effect on sweetness. Other variable is constant: Coagulation temperature (CT)−80 °C, **b** Coagulation temperature (CT), sugar-to-*paneer* cube (SP) ratio and their mutual effect on Overall Acceptability (OA). Other variable is constant: Milk Fat −4.5%

The coefficient of determination (R^2) for hardness was 0.92, and the adequate precision ratio (APR) was 14.08 (Table 3) substantially high than the desirable value (4) used for predicting the model.

Effect on water activity (a_w)

The water activity is the strength by which water is associated to the non-aqueous components of food (Damodaran and Perkin 1996) and most importantly, the food bacteria (especially spoilage bacteria) will not grow a_w below 0.9. The a_w of desiccated *chhana-murki* varied from 0.81 to 0.9 (Table 2).

The coefficient estimates for a_w model (Table 3) illustrates that the % milk fat had a direct effect ($p \leq 0.01$) and CT and SP had significant ($p \leq 0.01$) indirect influence on a_w of the developed *chhana-murki* at linear level. Our results are similar to panta (2009) findings who reported that processing conditions of *paneer* influence the water activity of the resultant product. Similarly, Goula et al. (2008) reported that exposing food to different temperatures influences the mobility of water molecules and establishment of dynamic equilibrium between vapour phase and adsorbed phase resulted in a change in water activity. However, all three parameters didn't show significance at quadratic and interaction level. The 3-D plot indicated that an increase in fat with a simultaneous decrease in SP ratio tends to raise the a_w of desiccated *chhana-murki* (Fig. 1b). The equation for predicting a_w is presented in Eq. 4.

$$\begin{aligned} &\textit{Water Activity}(\textit{coded value of the factors}) \\ &= +0.8434 - 0.0147A + 0.0122B - 0.0199C \end{aligned} \tag{4}$$

The coefficient of determination (R^2), adequate precision ratio (APR) and model F value was 0.90, 12.6 and 11.09, respectively, inferred that the model is significant.

Effect on product yield (%)

C*hhana-murki* yield (%) was estimated at one kg *paneer,* and it varied from 85.6% -136.4% (Table 2). The minimum and the maximum yield was obtained with the same level of 5.5% milk fat, and 70 °C CT when the SP ratio varied from 0.6 (minimum % yield) to 0.9 (maximum % yield).

The magnitude of p-value indicated that SP ratio had a higher positive effect (β = + 10.30) at a linear level while the effect was negative and significant at quadratic (β= -6.36) and interaction with CT (β = −10.90) (Table 3). Thus, with raising SP ratio, the yield of the product improved but at a lower rate within the range of milk fat evaluated. However, the yield of *chhana-murki* improved as SP ratio increased from 0.6 to 0.9 but only at lower CT, and the effect was not observed at higher CT (Fig. 1c). The 3-D response surface curve for yield response was convex upward as depicted by the negative coefficient terms for SP ratio ($p \leq 0.05$). Similar results were given by Panta (2009), who observed that increasing level of sugar raises the yield of chocolate *chhana-murki* to a significant extent because of an increase in coating thickness. However, Gurditta (2011) observed that replacing sugar with sweeteners decrease the yield of functional *chhana-murki.* The yield of desiccated *chhana-murki* could be calculated by Eq. (5):

$$\%Yield(coded\ value\ of\ the\ factors) = +116.78 + 10.30C - 6.36C^2 - 10.90AC \quad (5)$$

The coefficient of determination (R^2), model F-value and adequate precision ratio (APR) for yield were 0.80, 4.3 and 8.9, respectively, after performing regression analysis of the experimental data (Table 2) suggested that the model was accurate for prediction.

Effect on the sensory sweetness

The score for the sensory sweetness of desiccated *chhana-murki* varied from 60 and 88.8. (Table 2). The maximum score for sweetness was perceived for *chhana-murki* from run no. 13 (excessive sweet) and the minimum score was registered for a run no. 2 (optimum sweetness). The coefficient estimates for sweetness (Table 3) explained that SP ratio had significant ($p \leq 0.01$) positive effect on sweetness perception at the linear and quadratic level. While, CT had a negative effect on the sweetness perception scores at linear level, specifying that reducing CT from 90 to 70 °C, the perception of sweetness decreased, though the effect was non-significant. There is an increase in hardness and decrease in the moisture content of *panner* as the milk CT increased (Sachdeva and Singh 1988) that might affect the migration of sugar syrup inside the *panner* cubes and decreased binding of sugar during cooking (Arora 2011). Further, replacing sugar with alternative sweeteners or bulking agents like guar gum and microcrystalline cellulose tend to decrease the sweetness perception (Lawless et al. 1996). The effect of another parameter viz., % milk fat on sweetness perception was non-significant at a linear, quadratic and interactive level. Although the response surface (3D) plot showed by convex upward graph indicated the curvilinear relationships between % milk fat and SP ratio (Fig. 2a). It shows the maximum sweetness perception was observed at the central level of CT and % milk fat but at the highest SP ratio (Run no. 13, Table 2).

The changes in sensory sweetness could be predictive by the following Eq. 6.

$$Sweetness(coded\ value\ of\ the\ factors) = +67.35 + 9.44C + 2.05A^2 + 2.88C^2 \quad (6)$$

The R^2 value after performing the regression analysis of the experimental data for sweetness was 0.97 predicting the adequacy of the model (Table 3). The adequate precision ratio (APR) was found to be 20.3, and model F value was 32.22, ensuring a high degree of reliability.

Effect on overall acceptability (OA)

Overall acceptability (OA) is the average of all desirable sensory attributes defining the overall quality of the product in terms of colour, texture (hardness), sweetness and flavour, etc.

The organoleptic scores for acceptability of desiccated *chhana-murki* ranged from 71.1 (run no. 8) to 82.2. (run no. 14) (Table 2). As shown in Table 2, the CT significantly affected the OA score of *chhana-murki* as explained by the regression coefficient of the fitted model wherein the linear ($\beta = -1.17$, $p \leq 0.01$), quadratic ($\beta = -2.63$, $p \leq 0.01$) and the interactions term with the other two independent variables were significant ($p \leq 0.01$, Table 3).

Generally, the OA scores increased with raising CT to a certain extent and then decreasing trend was observed at the higher ranges of temperature. CT influenced the moisture retention in *paneer,* and the resultant product (*chhana-murki*) was found hard at higher CT (Table 2). This might be the reason for decreased OA scores at higher CT and the desirable sensory characteristics of the product at or near the centre values of temperature. This drift was specifically established at higher milk fat % compared to low-fat milk, consequently a net increase in the OA scores, however, a net decline in the OA scores was observed at the maximum level of CT and SP ratio (Fig. 2b).

The OA scores of 'desiccated' *chhana-murki* could be explained by the Eq. 7.

$$OA(coded\ value\ of\ the\ factors) = +80.16 - 1.17A - 2.63A^2 + 1.25AB - 1.25AC \quad (7)$$

The R^2 value was 0.87, and the value for adequate precision ratio (APR) was 9.03, substantially high for predicting the model.

Optimization

The numerical optimization was targeted to obtain the product with high acceptability. In this view, the different constraints were set for obtaining the maximum desirability value, as summarized in Table 4. This is obtained by maximizing the goals for OA (relative importance = 3) and simultaneously keeping all other parameters viz., instrument hardness, yield, water activity and sweetness in range (relative importance = 3). The numerical optimization suggests that the 79.22 °C CT, 4.8% % milk fat, and 0.7 SP ratio resulted in an optimized product with a desirability value of 0.83. High desirability value indicated the suitability of process conditions for achieving favourable results in terms of responses. Experiments were performed under the predicted optimal conditions to verify

Table 4 Criteria and output of the numerical optimization of desiccated *chhana-murki*

Variables	Goal	Experimental range		Importance	Optimum value	Desirability
		Min	Max			
A	In range	70	90	3	79.2	0.833
B	In range	3.5	5.5	3	4.82	
C	In range	0.6	0.9	3	0.70	
Responses					Predicted value	Experiment value
Y1	In range	60.49	190.67	3	100.12	105.05^{NS}
Y2	In range	0.81	0.9	3	0.85	0.85 ^{NS}
Y3	In range	85.6	136.4	3	112.8	115.2^{NS}
Y4	In range	60	88.8	3	64.88	61.2 ^{NS}
Y5	Maximize	71.1	82.2	3	80.36	78.8^{NS}

Experiment values are means of 3 replicates

NS Non-significant, $\boldsymbol{Y_1}$ Instrument Hardness (N); $\boldsymbol{Y_2}$ Water Activity (a_W); $\boldsymbol{Y_3}$ Yield (%); $\boldsymbol{Y_4}$ Sweetness (100-point scale); $\boldsymbol{Y_5}$ Overall acceptability (100-point scale)

optimization results. The experimental results closely agreed with those obtained using RSM and validated by student t-test and p-values (greater than 0.05). The confirmatory experimental values being 105.05 N, 0.85, 115.2%, 61.2 and 78.8, for textural hardness, water activity, yield, sweetness and overall acceptability, respectively (Table 4). This depicts the appropriateness and accuracy of the model.

Conclusion

In this study, the central composite rotatable design (CCRD) of RSM is demonstrated to be efficient and reliable in the optimization of different process parameters and the relevant responses for the production of desiccated *chhaha-murki*. Model analysis and response surface plots for estimating the interactive effect revealed that the models were adequate in predicting the response studied. The selected independent variables markedly affected the responses and the product with high desirability (0.83) could be obtained by optimum combination of 79.22 °C CT of milk, 4.8% fat milk and 0.7 SP ratio for production of desiccated *chhana-murki*. The result of the confirmatory experimental value of high overall acceptability (78.8) deduces that the optimized conditions could be simulated to upgrade the technology of *chhana-murki* production at an organized sector.

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