Indian J Dairy Sci 78(6): 502-510
https://doi.org/10.33785/IJDS.2025.v78i06.002

RESEARCH ARTICLE

Optimization of mass of *rasogolla* ball and cooking time in an indirectly heated cum conveying machine for *rasogolla* preparation

Parameswari P L[1], Priyanka[1], Pradyuman Barnwal[1] (✉), Ankit Deep[1], Shilpa Vij[2] and Writdhama Prasad[3]

Received: 29 May 2025 / Accepted: 04 September 2025 / Published online: 23 December 2025

Abstract: *Rasogolla* is a popular traditional Indian spongy product made from *chhana*. In spite of the demand of the product, its making process lacks mechanization. A cooking cum conveying system for *rasogolla* was fabricated and feasibility studies were done for the developed system. Thermic fluid was used as the secondary heating medium. Optimization of the developed mechanized cooking unit for processing parameters was done. The performance evaluation of the fabricated system was conducted based on the design obtained from response surface methodology using design expert software. The effect of mass of ball (6, 9, 12 g) and screw speed (5, 10, 15 rpm) on cooking time, sphericity, L^*, whiteness index, springiness, expansion ratio, percentage absorbed sugar, overall acceptability was found significant. The cooking time, sphericity, L^*, whiteness index, springiness and overall acceptability of product were 18.00±1.15 min., 0.97±0.005, 77.76±1.40, 73.98±1.61, 0.19±0.03 and 8.00±0.00 respectively at optimized solution (mass of the ball as 6 g and screw speed 5 rpm). Microbial studies indicated better hygiene conditions with the developed system in terms of total colony count and yeast and mold count. *Rasogolla* prepared with the developed system was analysed for physico-chemical, textural properties and overall acceptability and no significant difference was found.

Keywords: *Rasogolla*, screw conveyor, thermic fluid, response surface methodology, mechanized, microbial

Abbreviation Full name
TIDP: Traditional Indian Dairy Products
DAHD: Department of Animal Husbandry and Dairying
SS: Stainless steel
AISI: American Iron and Steel Institute
SNF: Solids not fat
FCCD:Face-centered Central Composite Design
AOAC: Association of Official Analytical Chemists
rpm: Revolutions Per Minute

Introduction

India ranks first in total milk production with an annual production of over 236.35 million tonnes during 2023-24, showing an annual growth of 2.5% (DAHD, 2023). The consumption of traditional Indian dairy products (TIDP) is growing at an annual rate of 20%. The production of TIDPs is limited by several factors such as unavailability of quality milk, lack of standardization and mechanized procedures, intensive energy requirement, non-availability of standards for most of the TIDPs and lack of appropriate packaging technology. The manufacture of these products involves various unit operations which require technological innovations suitable to each product characteristics.

Chhana is a heat acid coagulated product, which forms base for preparation of various indigenous sweetmeats especially in eastern parts of India. It is prepared by acidification of hot milk and subsequent destabilization of casein micelles. About 6% of total milk produced in India is utilized for *chhana* (Sahu and Das, 2009). Mechanization of various steps in *chhana* production has been reported by various researchers in published literature (Aneja et al. 1977; Sahu and Das 2009).

A large proportion of milk is converted to *khoa* and *chhana* based sweets. *Rasogolla*, *sandesh*, and *rasomalai* are the popular *chhana* based sweets available in Indian market. Estimated market size of *khoa* and *chhana* based sweets is Rs. 520 billion (Aggarwal et al. 2018). Therefore, intervention of mechanization is much needed for large scale production of the products.

---

[1]Dairy Engineering Division ;[2]Dairy Microbiology Division; [3]Dairy Technology Division
ICAR-National Dairy Research Institute, Karnal, India

P. Barnwal (✉)
ICAR-National Dairy Research Institute, Karnal-132 001, Haryana, INDIA
Phone: +91-184-2259419(O), +91-8397833349 (M)
Email: pbarnwal@rediffmail.com,pbndri@gmail.com

Rasogolla, a syrupy sweet delicacy popular in South Asia, is prepared by cooking *chhana* balls in sugar syrup. Manual kneading and ball formation of *chhana*, practiced in conventional methods is laborious, unhygienic and produce non-uniform balls. Optimum kneading is required for adequate air incorporation into *chhana* dough. Attempts were made by various researchers to mechanize different steps in *rasogolla* preparation (Choudhary et al. 2002; Karunanithy et al. 2007; Subhash 2017). The cooking step is time consuming, laboursome and causes the major changes in physical and textural properties of *rasogolla*. An increase in weight, volume expansion, chewiness and springiness are found after cooking of *chhana* balls. Therefore, the cooking step is of critical importance in the preparation of *rasogolla*.

The conventional method for cooking of *rasogolla* is based on either stove or indirect heating by steam. Cooking on stove systems is unsafe and unhygienic. Thus, these systems are not suitable for small or medium scale industries. Indirect heating using thermic fluids helps in uniform heating of liquids e.g. sugar syrup. Temperature control of other fluids is precise with thermic fluids and they require less maintenance than steam systems. Therminol-55 (thermic fluid) is used in low pressure or non-pressurized system at moderate temperatures. It is non-corrosive, less sensitive to thermal oxidation and had high flash point. It has a long life even at higher temperatures. Therefore therminol-55 was selected for present study as the secondary heating medium and a mechanized process unit for cooking and conveying of *rasogolla* was developed.

The present study therefore aimed to optimize the process parameters of mechanized system for cooking and conveying of *rasogolla*. The objective was to have final product comparable in quality to the available product in the market. The performance of cooking cum conveying system for *rasogolla* was evaluated using different physico-chemical, textural attributes and microbial qualities of the product (*rasogolla*) compared with market sample to document the advantages of mechanized system over the conventional methods.

Materials and methods

Cooking Cum Conveying System for *Rasogolla*

The cooking cum conveying system for *rasogolla* was developed in Research and Development (R & D) workshop, Dairy Engineering Division, ICAR-NDRI, Karnal, Haryana, India (Figure 1). The system consists of a U-shaped (cross-section) semi-cylindrical trough having 103 cm length and 21 cm diameter, made of 2 mm thick stainless steel (SS 304 / AISI 304) sheet. An outer thermic fluid jacket of 87 cm length and 29 cm diameter was welded to bottom of the trough. A radial gap of 4 cm between trough and jacket was provided for filling of thermic fluid. Stainless steel valve was fitted at bottom of the jacket. Glass wool insulation (1.2 cm thick) was provided for reducing the heat losses. Removable closure was made with inlet for *chhana* balls. A conveying auger was used to transfer cooked *rasogolla* balls to the discharge chute. Electric heating elements (0.5 kW and 2 kW) were installed at the both sides of thermic fluid jacket. The heat transfer fluid (Therminol-55; Procured from M/s Technotex Sales Corporation, Surat, Gujarat, India) was selected owing to its high thermal capacity, low viscosity, low-cost, non-toxic, non – corrosiveness and chemically inertness.

Preparation of *Rasogolla*

For preparation of *rasogolla*, cow milk (4.1% Fat, 8.11% SNF) was procured from Experimental Dairy, ICAR-NDRI, Karnal, India. *Chhana* was prepared from cow milk using acid coagulation method with 1.5% citric acid at 80 °C (De 1980). Once optimum pH was reached (pH=5.4), the coagulum was immediately strained using muslin cloth and hanged for 1 h to obtain *chhana*. *Rasogolla* was prepared following the standard method (Suryawanshi 2020) with slight modifications. The ingredients used were *chhana*, 2% refined flour/all-purpose flour and 0.15% baking powder. The ingredients were kneaded properly into a smooth paste, portioned and rolled between hand palms to form balls of desired weight (6, 9 and 12 g). These *rasogolla* balls were cooked in 50-54 °Brix sugar syrup for 14-15 min. (time varied according to the size of balls). Heating was regulated to maintain the stability of the balls. During cooking, small amount of water was continuously added at the rate of 2.46 ml/kg.min to maintain constant syrup concentration. After cooking, *rasogolla* balls were transferred to dilute sugar syrup (40 °Brix) at 60 °C for texture stabilization and colour improvement. Stabilized balls were then transferred into 60 °Brix syrup for overnight (Mishra et al. 2021).

Quality Evaluation of *Rasogolla*

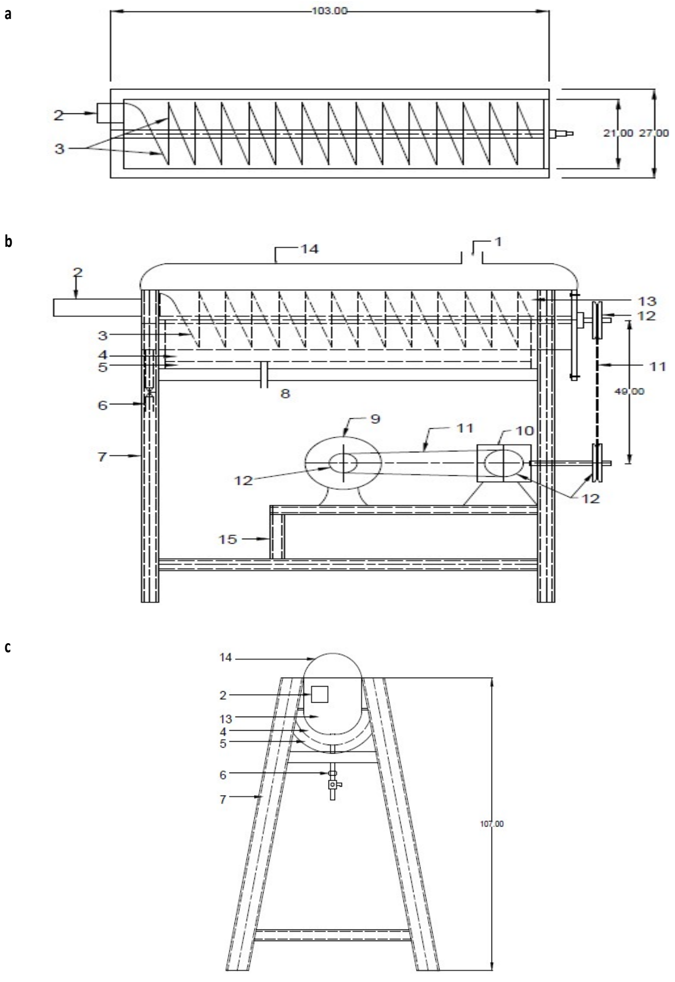
The cooking cum conveying system was employed for *rasogolla* preparation. The *rasogolla* samples were evaluated for physico-chemical (fat, moisture, titrable acidity, ash, carbohydrate and crude protein), textural and microbial (yeast and mold, coliform, total count) attributes. The sphericity, colour attributes, % absorbed sugar and expansion ratio of the *rasogolla* samples were also determined.

Texture analysis

Texture profile of the *rasogolla* samples was analysed by using texture analyser (TA-XT2i; M/s Stable micro systems, Godalming, England; Software: Texture Expert Exceed, Version: 2.55), fitted with a 25 kg load cell and calibrated with 5 kg standard dead weight prior to use. *Rasogolla* was compressed twice in a reciprocating motion to give a two-bite texture profile curve. Compression probe (P-75) was used to compress the whole, uncut *rasogolla* sample up to 80% of its strain, using a double compression test. The various test parameters for the whole, uncut *rasogolla* sample were 2 mm/s pre-test speed, 2 mm/s test speed, 10 mm/s post-test speed, 5.00 s and 25±1 °C testing temperature.

Sphericity

Sphericity is the ratio of volume of solid to the volume of a sphere that has a diameter equal to the major diameter of the object so that it can circumscribe the solid sample. The major, intermediate and minor dimensions of *rasogolla* samples were measured as a, b and c, respectively by using the digital Vernier calliper (Brand: Mitutoyo, manufacturer: M/s Parashar Micro Measurement (P) Ltd, Noida, India, range: 0-150 mm, least count: 0.1 cm). Sphericity was calculated using standard relationship (Mohsenin 1970).



All dimensions in cm

1. Rasogolla ball inlet
2. Rasogolla ball outlet
3. Screw with shaft
4. Thermic fluid jacket
5. Insulation
6. Sugar syrup outlet
7. Stand
8. Thermic fluid outlet
9. Motor
10. Speed reduction gear box
11. V-belt
12. Pulleys
13. Semicylindrical trough
14. Semicylindrical closure
15. Supporting stand for motor and reduction gear

Fig.1 Schematic diagram of cooking cum conveying system for *rasogolla* (a) Top View (b) Front View and (c) Side View

$$\text{Sphericity}, \phi = \frac{\sqrt[3]{abc}}{a} \tag{1}$$

Whiteness index

Hunter Colour Lab (Hunter associated laboratory Inc., VA, USA) was employed to measure L^*, a^*, and b^* values. The sample for colour analysis was prepared by following the standard procedure (Kaur and Goswami 2018). It was expressed as follows:

$$\text{Whiteness index} = 100 - \sqrt{(100 - L^*)^2 + a^{*2} + b^{*2}} \tag{2}$$

Percentage absorbed sugar

Initial weight of *rasogolla* was measured. After this, it was placed on a plate. Five kg weight was placed on the *rasogolla* and the final weight of pressed *rasogolla* was taken after 5 min. Volume of sugar syrup expressed was measured and percentage absorbed sugar was calculated using following standard formula (Mohanta and Shrivastava 2014):

$$\text{Percentage absorbed sugar (\%)} = \frac{\text{Amount of sugar syrup released}}{\text{weight of rasogolla}} \times 100 \tag{3}$$

Expansion ratio

Expansion ratio was measured by taking the ratio of cross-sectional area of *rasogolla* after soaking to the cross-sectional area of *chhana* ball (Franklin et al. 2017). The major, intermediate and minor diameters of *rasogolla* and *chhana* ball samples were measured. The expansion ratio was computed using following equation:

$$\text{Expansion ratio} = \frac{\text{Cross sectional area of rasogolla}}{\text{Cross sectional area of chhana ball}} \tag{4}$$

Overall Acceptability

The *rasogolla* samples were subjected to sensory evaluation by a panel of five judges selected from Dairy Engineering Division, ICAR-NDRI, Karnal, India. A nine-point hedonic scale was used for the sensory attributes like flavour, body and texture, colour and appearance, and overall acceptability (Kumar et al. 2015).

Modelling of responses

Response surface methodology (Design expert v.13.0.5.0, Stat-Ease Inc., Minneapolis, USA) was applied to optimize the processing conditions for *rasogolla* manufacturing. A face-centered central composite design (FCCD) with two independent variables and their responses (dependent variables) was used to optimize cooking cum conveying conditions for *rasogolla*. The independent variables selected for the experimental design (based on preliminary trials) were mass of ball (6, 9 and 12g) and screw speed (5, 10 and 15 rpm). It was assumed that independent variables affect the performance responses. There may be effect of unexpected variability in performance responses due to extraneous factors, so experiments were performed in random order. The responses considered in this study were cooking time, sphericity, *L**, *a**, *b**, whiteness index, hardness, chewiness, springiness, expansion ratio, percentage sugar absorption and overall acceptability. In response surface method, the relation between responses (Y) and independent variables (X) was assumed to be a non-linear equation given by $y = f(x) + \varepsilon$ (Lawson 2014).

The general quadratic equation is expressed by following equation:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_{11} X_1^2 + \beta_{22} X_2^2 + \beta_{12} X_1 X_2 + \varepsilon$$
(5)

where, Y is the response; β_0 is the intercept (constant); β_1, β_2 are linear coefficients; β_{11}, β_{22} are squared coefficients; β_{12} is the interaction coefficient; X_1, X_2 are the independent variables (X_1 = mass of ball and X_2= screw speed) and ε is the error.

Optimization of Processing Conditions and its Experimental Validation

Numerical optimization was performed using response surface methodology to obtain the optimized solution based on suitable criteria (minimize cooking time, maximize sphericity, maximize L*, maximize whiteness index, maximize springiness and maximize overall acceptability) and desirability values. Validation of the optimized solution was executed by experimental trials on the obtained optimized parameters. The experiments were conducted in triplicates at optimized conditions. To test the significance difference between the experimental and predicted value at optimum parameters, student's t-test ($p<0.05$) was used. Mean relative percentage deviation modulus (% P) was used to evaluate the goodness of fit between experimental values and predicted values. The value of % P less than 5 indicates an extremely good fit of the model, while a value less than 10 shows a reasonably good fit and above 10 is a poorly fitted model.

Physico-chemical analysis

The product prepared at the optimized parameters was tested for physico-chemical parameters including fat, protein, titrable acidity, total solids and ash etc. according to standard method (AOAC 2012). Sucrose content of *rasogolla* balls were determined by difference by subtracting protein, fat, lactose and ash from total solids.

Microbial analysis

The microbial analysis of the samples prepared at optimized conditions was done in terms of total count (IS:5402 2021), coliform count (IS:5401 2012) and yeast and mold count (IS:5403 1999). Similar tests were conducted for the market samples and the results were compared to analyse the efficacy of the developed system to provide hygienic conditions.

Results and Discussion

Rasogolla was prepared in the cooking cum conveying system (Figure 1) with an indirect heating medium (Therminol-55), maintained at 145±5 °C temperatures. The various performance responses (cooking time, sphericity, *L**, whiteness index, percent sugar absorption, springiness, expansion ratio and overall acceptability) were studied using the quadratic response model (equation 5) for independent variables i.e. mass of ball (g) and screw conveyor speed (rpm) and regression equations are presented in Table 2.

Cooking Time

Depending on the various parametrical run combinations, the cooking time of *rasogolla* varied from 15 to 47 min at various levels of independent variables. The effect of mass and screw speed on cooking time are represented by corresponding regression coefficients in fitted quadratic model (Table 2). The interaction effect of process variables were statistically significant ($p<0.01$). The coefficient of determination ($R^2 = 0.99$) of cooking time indicated that the fitted quadratic model was able to explain 99% of variation in cooking time of *rasogolla* in the fabricated system. Regression coefficients showed a strong correlation between cooking time and the independent variables. The non-significant lack of fit for cooking time indicated that the model was sufficiently accurate for predicting the cooking time of *rasogolla* for any combination of factors within the evaluated range. The response surface plot (Figure 2a) of cooking time indicated direct correlation of mass of the ball with cooking time. Sengupta and Bhowal (2017) reported 10-15 min cooking time for 8 g *chhana* balls. For balls weighing 10.46g, 20 min cooking time was reported by Acharya and Kanth (2005).

Sphericity

Size and shape, which contributes to the appearance of the product, had a profound role in consumer preferences. Table 2 showed the regression model fitted to the experimental data. The model indicated that the mass of ball had significant ($p<0.01$)

effect on sphericity of *rasogolla*. Sphericity of the prepared *rasogolla* varied from 0.89 to 0.98 at different mass and screw speed. Sukre et al. (2021) reported similar results for market samples of *gulabjamun* where sphericity varied from 0.94 to 0.97. It could be interpreted from Figure 2b that the sphericity decreased with increase in mass of ball. The smaller balls had higher sugar absorption rate and this helped to hold the shape of the ball. The top portion of *chhana* balls flattened slightly at higher screw speed. This could be due to reduced foaming of syrup and collision of balls at higher screw speed. Maximum sphericity (0.98) was obtained for 6g ball at 10 rpm screw speed. Any product, having a sphericity value closer to 1, could be considered as sphere (Kumar, 2018). So, the product obtained in the present study was spherical in shape. The regression equation ($R^2 = 0.92$) was able to explain 92% changes in sphericity (Table 2).

Whiteness index

The whiteness index varied from 63.79 (12g *chhana* ball) to 76.98 (for 9g balls). The corresponding L^* value ranged from 66.87 to 79.48. The 12g *chhana* balls exhibited higher whiteness index even though the cooking time was more for it. A similar whiteness index of 70.92 was found for *paneer* prepared from high pressure treated milk (Kapoor et al. 2021). The effect of squared value of mass of ball was significant ($p<0.01$) for both whiteness index and L^* values. So, variation of L^* and whiteness index with mass of ball showed a parabolic curve (Figure 2 c, d). It showed a decrease in whiteness index when mass is increased from 6 to 9g. Further, an increase in the whiteness index was found when mass was increased to 12g. This could be attributed to mixing up of sugar syrup and movement of balls in the syrup even at higher cooking time. Balls swell in sugar syrup, exposing the pores and thus increase the surface area. At 15 rpm, the foaming reduced the swelling of ball, which kept a constant exposed area of ball in contact with syrup. Srinivasa et al. (2017) reported that the whiteness index of market samples of *rasogolla* was 56.69 to 72.72. The coefficient of determination signifies that the predicted model could able to explain 85% and 89% of variability in the L^* and whiteness index, respectively. The quadratic model for a^* and b^* values was found to be non-significant.

Texture attributes

The effect of mass of ball and screw speed on hardness and chewiness of ball was non-significant ($p>0.05$). However, the quadratic model for springiness was found to be significant ($p<0.05$) with a non-significant lack of fit. The quadratic term of mass of *chhana* ball significantly ($p<0.01$) affect springiness of the product (Table 1). The regression coefficients in the quadratic model for springiness indicated that the mass of ball had a positive correlation with springiness (Table 2). Springiness of *rasogolla* samples ranged from 0.13-0.26 mm and showed maximum value for 9g balls. The decrease in springiness for 12g ball might be

Table 1: F-value and ANOVA results for significant responses using quadratic response model

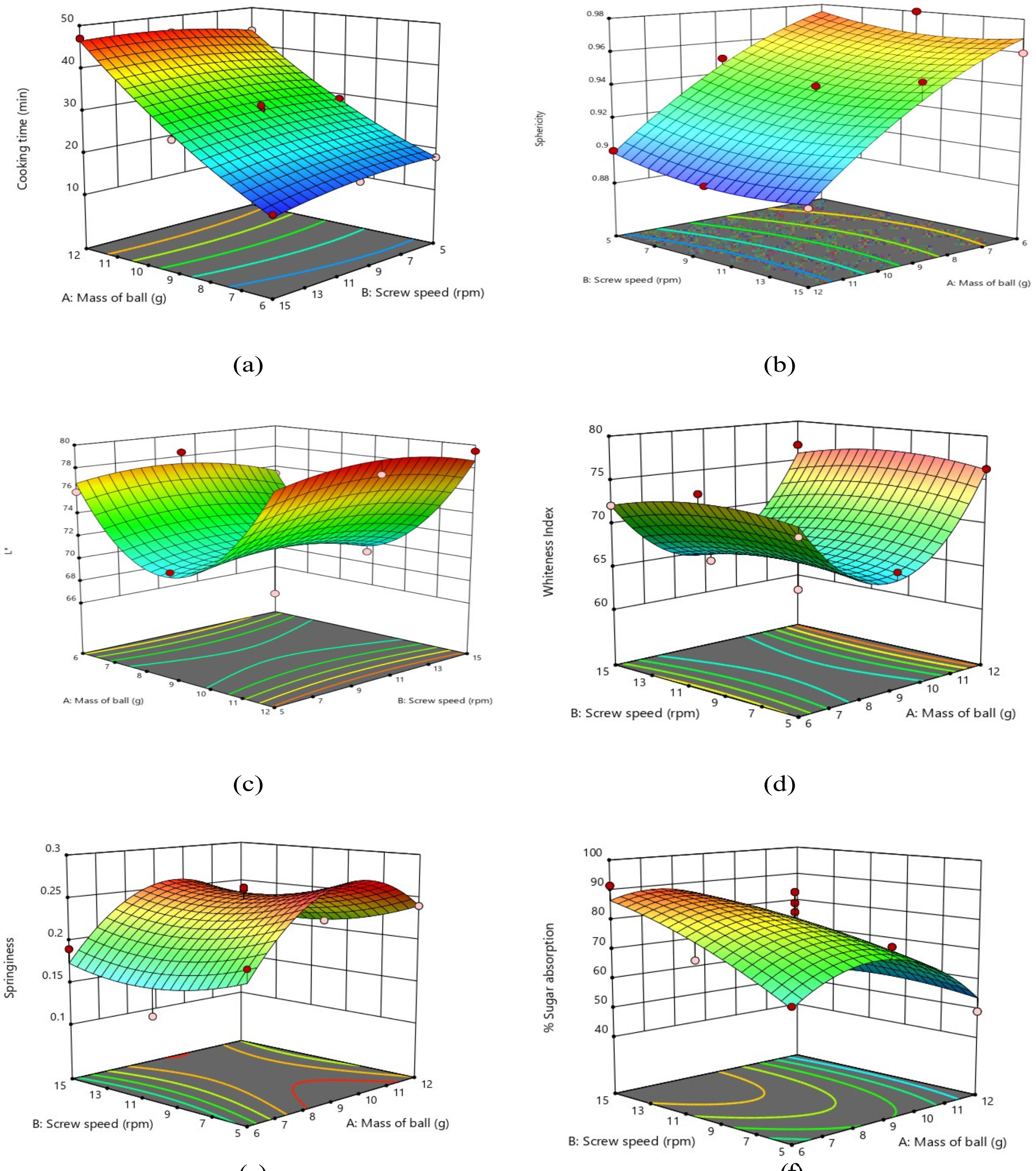
Variable/Factors	DF	Cooking Time	Sphericity	L^*	Whiteness Index	% Sugar Absorption	Springiness	Expansion Ratio	Overall Acceptability
Quadratic model	5	368.39**	16.17**	8.14**	12.8**	6.42*	6.81**	6.12*	7.49**
X_1 = mass of ball	1	1807.66**	78.04**	1.98^{NS}	4.27^{NS}	11.01*	8.58*	7.12*	27.19**
X_2 = screw speed	1	0.95^{NS}	0.59^{NS}	0.058^{NS}	0.10^{NS}	4.61^{NS}	0.99^{NS}	0.32^{NS}	9.79*
$X_1 X_2$	1	12.90**	0.00^{NS}	0.09^{NS}	0.01^{NS}	2.74^{NS}	0.05^{NS}	1.78^{NS}	0.40^{NS}
X_1^2	1	19.58**	2.4^{NS}	36.5**	52.88**	9.88*	24.15**	8.65*	0.01^{NS}
X_2^2	1	6.44**	0.84^{NS}	0.94^{NS}	1.02^{NS}	0.37^{NS}	1.97^{NS}	4.73^{NS}	0.01^{NS}
R^2		0.99	0.92	0.85	0.89	0.83	0.82	0.81	0.84
C.V. percent		2.76	1.14	2.79	2.98	9.17	10.08	6.19	2.06
Lack of Fit	3	1.92^{NS}	1.96^{NS}	0.23^{NS}	0.37^{NS}	0.79^{NS}	3.87^{NS}	1.05^{NS}	1.27^{NS}

**significant ($p<0.01$); *significant ($p<0.05$); NS: non-significant; x_1 = mass of ball and x_2 = screw speed

*Note-DF: degree of freedom, NS: Non-Significant; ** (p<0.01); *(p<0.05* due to the lesser sugar absorption at the core. It was observed in the response surface plot (Figure 2e) that springiness was highest at 9g mass of ball and it decreased at either side. The springiness values reported for market *rasogolla* was 5 mm (Adhikari et al. 1992) and that for low fat *rasogolla* was 5.72 mm (Chavan et al. 2011). The coefficient of determination was 0.83, which indicated that 83% variability in springiness could be explained by the model.

Percentage sugar absorption

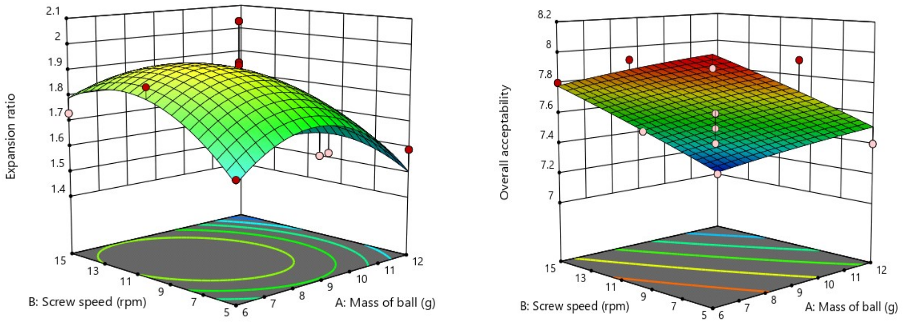
The percentage sugar absorption varied from 49.01 to 91.44%. Under the studied range of mass of ball, 12g balls had least percentage sugar absorption. It was observed that the linear and quadratic terms of mass of ball negatively affected the sugar absorption of *rasogolla* (Table 2). The balls travelled gently in the sugar syrup and subsequently the syrup diffused into its pores. The percentage sugar absorption was maximum for 6g ball and minimum for 12g ball. Central portion (core) of large balls could be hard, which reduced the sugar syrup diffusion, whereas



(a) (b)

(c) (d)

(e) (f)



(g) (h)

Fig.2 Effect of mass of ball and screw speed on (a) cooking time and (b) sphericity (c) *L** and (d) whiteness index (e) springiness and (f) % sugar absorption (g) expansion ratio and (h) overall acceptability

Table 2: Regression model equations for significant responses

Sl. No.	Regression model equation	R^2
1	Cooking time= $29.79 + 14.5\ X_1 + 1.5\ X_1 X_2 + 2.2\ X_1^2 - 1.28\ X_2^2$	0.99
2	Sphericity = $0.94 - 0.04\ X_1$	0.92
3	$L^* = 71.4 + 7.51\ X_1^2$	0.85
4	Whiteness index = $66.41 + 9.15\ X_1^2$	0.89
5	Springiness = $0.25 + 0.02\ X_1 - 0.06\ X_1^2$	0.83
6	% Sugar absorption = $80.59 - 9.95\ X_1 - 13.89\ X_1^2$	0.82
7	Expansion Ratio = $1.91 - 0.12\ X_1 - 0.19\ X_1^2$	0.81
8	Overall acceptability = $7.62 - 0.33\ X_1 - 0.2\ X_2$	0.84

Note: X_1 *= mass of ball and* X_2*= screw speed*

6g balls were more porous and softer at the core. The sugar absorption as a quadratic function of mass was indicated by the response surface plot (Figure 2f). The model regression equation (R^2=0.82) adequately predicts percentage sugar absorption as a function mass of ball i.e. 82% variation in percentage sugar absorption could be explained by the model. Srinivasa et al. (2017) reported that the market samples of *rasogolla* had a percentage sugar absorption in the range of 44.3 to 64.4%.

Expansion ratio

The effect of independent variables in expansion ratio of rasogolla was represented using regression coefficients in quadratic models (Table 2). The reliability of models (R^2=0.81) confirms that the equation may be effectively used to predict response as a function of mass of ball and 81% changes in expansion ratio could be explained by the model. The effect of screw speed on the expansion ratio of *rasogolla* was non-significant ($p>0.05$). The effect of mass of ball on expansion ratio showed a similar nature of trend as observed in percentage sugar absorption. The regression coefficients showed that the expansion ratio was in significant negative correlation ($p<0.05$) with linear and quadratic terms of mass of *chhana* ball (Tables 1-2, Figure 2g). During cooking, moisture in the *chhana* balls diffused out and forms pores and void spaces. This space was occupied by the sugar syrup by diffusion and thus increasing the juiciness of the product. The expansion ratio of *rasogolla* varied from 1.42 to 1.93. Kumar (2018) reported expansion ratios of 1.195, 1.205 and 1.231 for *pantua* at different temperatures of frying.

Overall Acceptability

The fitted regression model (Table 2) showed a negative correlation of mass of ball with the processing variables. The overall acceptability varied from 7 to 8. The overall acceptability decreased linearly with increase in mass and screw speed (Table 2, Figure 2h). Reduction in foam formation at higher screw speed affected sensorial attributes of *rasogolla*. Begum et al. (2020) reported that sensory characteristics of *rasogolla* improved with foaming characteristics of medium. Adhering of foam to the balls caused swelling of *chhana* balls. Karunanithy et al. (2007) also observed that the variation in overall acceptability scores was due to reduction in sponginess and juiciness of *rasogolla* under various operating conditions. The coefficient of determination (R^2=0.84) showed sufficient fitting of the model. The statistical model could predict 84% of variation in overall acceptability.

Optimization of Processing Conditions and its Experimental Validation

The process variable (screw speed) and product variable (mass of ball) at three levels were optimized for production of acceptable quality *rasogolla*. Numerical optimization was executed using response surface methodology to obtain the optimized solution based on suitable criteria. The optimized solution was 6g mass of ball and 5 rpm screw speed with a maximum desirability of 0.80.

The model was experimentally validated by conducting experiments (in triplicates) on cooking cum conveying system for *rasogolla* with the optimum solution. The predicted responses' values were measured experimentally and validated by student's t-test and found non-significant (pe”0.05). The mean relative percentage deviation modulus (% P) was found less than 5 per cent for all the responses which indicated an extremely good fit of the model.

Physico-chemical analysis

The product prepared at the optimized parameters (6g mass of ball and 5 rpm screw speed) was analysed for physico-chemical properties. The results of the analysis are shown in Table 3. Comparison of different components revealed that the two samples (market and lab prepared) had similar ($p>0.05$) ash, content. On the other hand, fat, protein, and carbohydrate content in the two samples were found to be significantly different ($p<0.05$). Machine made sample was found to have fat content of 1.46 % which was significantly lower ($p<0.05$) than the fat content in the market sample (5.09%). Sarkar et al. (2021) reported that fat content in *rasogolla* ranges from 2.47 to 7.58%. Lower fat content in the lab made sample could be attributed to the differences in the size of *chhana* balls used for *rasogolla* preparation. Market *rasogolla* sample was prepared by cooking the balls of 12-15g, while the machine sample was prepared by cooking the balls of 6g. Difference in size of the balls contributes to difference in the radius (and thus distance) that the fat has to travel to come to surface of the ball and get into the cooking syrup. Cooking of *rasogolla* balls is performed at a temperature of about 105±2 °C along with continuous agitation, these results into complete liquefaction of fat and its migration to the cooking medium (i.e., sugar syrup). In addition to this, fat content in the raw milk used for *rasogolla* preparation could also result into differences in the fat content of the product. Bhattacharya and Des (1980) reported that use of high fat milk resulted in *rasogolla* having higher fat content.

Microbial analysis of *rasogolla*

The microbial analysis of the samples prepared at optimized criteria was done in terms of total count (IS:5402 2021), coliform count (IS:5401 2012) and yeast and mold count (IS:5403 1999). Similar tests were done for the market samples and the results were compared to analyse the efficacy of the developed system to provide hygienic conditions (Table 4). It was observed that total count in market samples (1.22×10^3 cfu/ml) was much higher than the product obtained from the developed system (3×10^1 cfu/ml). Yeast and mold count were not detected in machine developed system while there was presence of yeast and mold count in the market sample (3×10^1 cfu/ml). The results indicated the possibility of better hygienic conditions of preparing *rasogolla* using the developed system as compared to the market sample.

Conclusion

Table 3: Physico-chemical analysis of *rasogolla* under optimized condition

Rasogolla Sample	Moisture	Fat	Titrable acidity	Ash	Carbohydrate	Crude protein
	(%, wt. basis)	(%, wt. basis)	(% lactic acid)	(%, wt. basis)	(%, by difference)	(%, wt. basis)
Machine made	47.55 ± 0.51^b	1.46 ± 0.09^b	0.38 ± 0.03^b	0.98 ± 0.01^a	43.02 ± 0.56^b	6.99 ± 0.23^b
Market sample	36.16 ± 0.25^a	5.09 ± 0.09^a	0.15 ± 0.02^a	0.99 ± 0.01^a	53.25 ± 0.81^a	4.13 ± 0.40^a

Values are mean±SE (n=3); Means with different superscript (a,b) in the same column differ significantly ($p<0.05$) for different sample

Table 4 : Microbial analysis of *rasogolla* and comparison with market sample

Rasogolla Sample	Total count		Coliform count		Yeast and mold count	
	(CFU/ml)	(log CFU/ml)	(CFU/ml)	(log CFU/ml)	(CFU/ml)	(log CFU/ml)
Machine made	3×10^1	1.477	nd	nd	nd	nd
Market sample	1.22×10^3	3.08636	nd	nd	3×10^1	1.477

nd: not detected

Performance of the cooking cum conveying system for *rasogolla* was carried out with varying product and process parameters including mass of *chhana* ball and screw speed. The significance of mass of *chhana* ball and screw speed was found on various parameters like cooking time, sphericity, colour, textural attributes, expansion ratio, percentage absorbed sugar and overall acceptability. Cooking time and percentage sugar absorption had a stronger correlation with mass of ball. The interaction effect of mass of ball and screw was significant in cooking time of *rasogolla*. Foaming of sugar syrup was affected by screw speed, which in turn determined the juiciness and overall acceptability of the final product. Whiteness index of the product was significantly affected ($p<0.01$) by mass of *chhana* ball. The cooking time, sphericity, L^*, whiteness index, springiness and overall acceptability of product at optimized solution (6 g, 5 rpm) were 18.00±1.15 min, 0.97±0.005, 77.76±1.40, 73.98±1.61, 0.19±0.03 and 8.00±0.00, respectively. It was found that there was no significant difference between experimental and predicted values ($p >0.05$). Physico-chemical analysis results coincided with the standard values. Microbial analysis and comparison with the market samples indicated better hygienic condition in terms of total count and yeast and mold count.

Acknowledgement

Research was supported by the Indian Council of Agricultural Research, Department of Agricultural Research and Education, Government of India.

References

Acharya PP, Kanth SK (2005) Utilization of whey as a cooking syrup medium in the preparation of *chhana* based sweet-'*Rasogolla*'. Tribhuvan University J 25(1): 149-158. doi:10.3126/tuj.v25i1.3757.

Adhikari AK, Mathur ON, Patil GR (1992) Texture and microstructure of *chhana* and *rasogolla* made from cows' milk. J Dairy Res 59:413-424. doi:10.1017/S0022029900030685.

Aggarwal D, Raju PN, Alam T, SabikhiL, Arora B (2018) Advances in processing of heat desiccated traditional dairy foods of Indian sub-continent and their marketing potential. J Food Nutr Res 3:172. doi:10.29011/2575-7091.100072.

Aneja VP, Rajorhia GS, Makker SK (1977) Design and development of continuous *chhana* making machine. J Instit Engrs (India) 58:11

AOAC (2012) Official Methods of Analysis. Washington DC, USA: Association of Official Analytical Chemists

Begum M, Islam N, Harun-ur-Rashid M, Islam MZ, Haque MR, Siddiki MSR (2020) Effects of different concentrations of cooking and soaking sugar syrup on the physico-chemical quality of *rasogolla*. Dairy and Vet Sci J 14:77-81. doi: 10.19080/JDVS.2020.14.555890.

Bhattacharya DC, Des R (1980) Studies on production of rasogolla. Part - I. Traditional method. Indian J Dairy Sci 33: 237–43.

Chavan RS, Prajapati PS, Chavan SR (2011) Low fat sweet syrup cheese ball (*Rosogolla*) manufacturing and effect of lowering fat in quality. Sens Instrumen. Food Qual 5(1): 33-42. doi: 10.1007/s11694-011-9109-5.

Choudhary RL, Makkar SK, Narasaiah K (2002) Development of *chhana* ball forming system. Annual Report 2001-02: NDRI, Karnal.

DAHD (2023) Annual Report 2022-2023; Department of Animal Husbandry and Dairying, New Delhi. https://dahd.nic.in/sites/default/filess/AnnualEnglish.pdf. (Accessed on April 11, 2023)

De S (1980). Outlines of Dairy Technology Oxford Univ. Press New Delhi; pp.517

IS:5401 (2012) Microbiology of food and animal feeding stuffs - Horizontal method for the detection and enumeration of coliforms: Part 1 colony count technique (Second Revision). Bureau of Indian Standards Manak Bhavan; New Delhi

IS:5402 (2021) Microbiology of the food chain - Horizontal method for the enumeration of microorganisms- Part 1: Colony count at 30 C by the pour plate technique. Bureau of Indian Standards Manak Bhavan; New Delhi

IS:5403 (1999) Method for yeast and mould count of foodstuffs and animal feeds (First Revision). Bureau of Indian Standards Manak Bhavan; New Delhi

Kapoor S, Singh, MP, Vatankhah H, Deshwal GK, Ramaswamy HS (2021) Production and quality improvement of Indian cottage cheese (*paneer*) using high pressure processing. Innov Food Sci Emerg Technol 72: 102746. doi:10.1016/j.ifset.2021.102746

Karunanithy C, Varadharaju, N, Kailappan R (2007) Studies on development of kneader and ball former for *chhana* in *rasogolla* production: Part I: Performance evaluation of *chhana* kneader. J Food Eng 81: 298-305. doi:10.1016/j.foodeng.2006.06.036

Kaur G, Goswami TK (2018) Effect of defatted soy flour and concentration of stevia on physico-chemical and sensory characteristics of *rasgulla*. Asian J. Dairy Food Res 37: 187-191. doi: 10.5555/20183343350.

Kumar J, Gupta, VK Kumar, S, Kumar S (2015) Effect of coagulants on the quality of *chhana* and *rasogolla* obtained from admixture of buffalo milk and butter milk. J Food Sci Technol 52: 1736–1741

Kumar, M (2018) Effect on physico-thermal properties of *Pantoa* during sub-baric frying. J Pharmacognosy Phytochem 7: 1100-1106

Lawson, J (2014). *Design and Analysis of Experiments with R*. United States: CRC Press; (pp 383-384).

Mishra K, Pinto S, Jambukiya H, Prajapati JP (2021) Rheological attributes of goat milk *chhana* and *rasogolla*. Pharma Innovation J 10:2727-2735

Mohanta B, Shrivastava SL (2014) Optimization of process parameters for preparation of *rasogolla*-an Indian dairy product at atmospheric pressure. Asia Pacific J Res 1:47-56

Mohsenin, NN (1970) Physical properties of plant and animal materials: structure, physical characteristics and mechanical properties. New York: Gordon and Breach Science Publishers; pp 87

Sahu JK, Das H (2009). A continuous heat-acid coagulation unit for continuous production of *chhana*. Assam University J Sci Technol 4:40-45

Sarkar T, Salauddin, M, Chakraborty R (2021). *Rasgulla*—the ethnic Indian sweetmeat delicacy and its evolutionary journey through contemporary research. J Ethnic Foods 8: 1-14.

Sengupta S, Bhowal J (2017) Studies on preparation of dietetic *rasgulla* (cheese ball) from edible quality flours and antioxidant rich vegetable oils. Lebensmittel-Wissenschaft und Technologie 86:473-482

Srinivasa K, Barnwal, P, Pritpal, S (2017). Selected physical, colour and textural characteristics of market *rasogolla*. Indian J Dairy Sci 70:155-161.

Subhash P (2017) Design and development of a mechanized *chhana* ball forming machine for medium scale applications. Bioved 28:439-448

Sukre VN, Barnwal P, Chavhan BB, Deep A, Bhagat PN (2021) Evaluation of selected physico-chemical, colour and textural characteristics of market *gulabjamun*. Indian J Dairy Sci 74:479-485

Suryawanshi DB (2020) Development of *Rasogolla* prepared by incorporating *Isabgol* (Plantago Ovata) powder. The Pharma Innovation J 9:5-12