

# Modelling and Optimizing Buttermilk Concentration and Coagulation Temperature for *Paneer* Production

Gaurav Chaudhary<sup>ac</sup>, Ameeta Salaria<sup>b</sup>, Yogeshkumar V. Vekariya<sup>c</sup>, Shalini Arora<sup>de</sup> (✉) and A.K. Singh<sup>e</sup>

Received: 27 July 2023 / Accepted: 06 October 2023 / Published online: 23 June 2024

© Indian Dairy Association (India) 2024

**Abstract:** This study explores the utilization of buttermilk, a significant byproduct of butter manufacture, in the production of *paneer*, a heat and acid-coagulated dairy product. Response Surface Methodology (RSM) was employed to investigate the impact of buttermilk addition (7.5-25.00%) and coagulation temperature (70-85°C) on various compositional parameters of *paneer*. The *paneer* yield ranged from 16% to 21%, while total solids, fat, protein, and lactose content varied from 40.5% to 50.5%, 21.0% to 32.5%, 10.1% to 18.8%, and 1.9% to 2.8%, respectively, at different buttermilk levels. Through optimization, it was found that replacing 13.99% of milk with buttermilk and coagulating at 85°C resulted in the production of *paneer* with enhanced nutritional quality. This study demonstrates an innovative and sustainable approach to improving the value of buttermilk and obtaining high-quality *paneer* with desirable nutritional attributes.

**Keywords:** Buttermilk; Coagulation temperature; Milk product; *Paneer*; Modelling

## Introduction

India holds the distinction of being the world's leading milk producer, with a substantial output of 209.96 million tons (MT) in 2020-21, surpassing the previous year's production of 198.44 MT (FAOSTAT, 2021). The traditional sector plays a pivotal

role, converting approximately 50-55% of processed milk into a diverse range of dairy products, contributing 20.17 percent to the sector (Arora, 2019). Amongst the cherished processed dairy products in India is *paneer*, a classic cottage cheese delicacy derived from buffalo milk, often used as a key ingredient in traditional Indian desserts (USDA, 2015; Arora et al. 2019; Arora et al. 2022; Gurditta et al. 2019). The Indian market witnesses a significant consumption of approximately 3 million tonnes of locally produced sweets, further showcasing the popularity of *paneer* in Indian cuisine (Gurditta, et al. 2014).

During the butter-making process, an essential byproduct known as buttermilk is produced. Buttermilk constitutes the liquid phase resulting from churning cream into butter. On a global scale, around 6.5%–7.0% of milk production is utilized for butter production, leading to the substantial generation of buttermilk as a byproduct (3.2 million tonnes annually). Additionally, the process of making butter and curd produces sour buttermilk, also known as *lassi* (Kumar et al. 2015).

Buttermilk boasts emulsifying and flavor-enhancing properties, making it a crucial dairy ingredient in various culinary applications. Both sweet and cultured buttermilk share a chemical composition akin to skim milk, although natural buttermilk exhibits compositional variations depending on the type of milk used for curd preparation and the amount of water added during churning. On average, it contains approximately 4% total solids, 3% to 4% lactose, 1.2% lactic acid, 1.3% protein, and 0.8% fat. Notably, buttermilk is a rich source of calcium, providing about 28% of the body's daily calcium requirement in one cup of low-fat buttermilk (Sodini et al. 2006). Consumption of around 500 ml of buttermilk can fulfill the body's entire daily calcium needs. Furthermore, well-packaged buttermilk typically possesses a pH of 4.5 and a smooth, thick consistency. Its consumption contributes to increased protein intake (approx. 3.73% in sweet cream buttermilk), making it a popular domestic beverage in India, prized for its high nutritive value. Its mild acidity also makes it an excellent thirst quencher. Buttermilk contains up to seven times higher concentrations (about 0.89 mg/g) of phospholipids than whole milk (Barukëia et al. 2019).

<sup>a</sup>Department of Food Science and Technology, Chaudhary Charan Singh University, Meerut (UP), (India)

<sup>b</sup>Faculty of Dairy Technology, Sher-e-Kashmir University of Agricultural Sciences and Technology, RS Pura, Jammu, J&K, (India)

<sup>c</sup>Dairy Engineering Department, SMC College of Dairy Science, Kamdhenu University, Gandhinagar, Gujarat (India)

<sup>d</sup>Department of Dairy Technology, CoDST, Lala Lajpat Rai University of Veterinary and Animal Sciences, (Hisar), Haryana (India)

<sup>e</sup>Dairy Technology Division, National Dairy Research Institute (NDRI), Karnal, Haryana (India)

(✉)

Email: shaliniarora.luv@gmail.com

In dairy product development, Response Surface Methodology (RSM) stands as a powerful statistical tool to optimize various process variables through experimental design (Henika, 1982). Researchers have effectively employed RSM to optimize process variables in diverse dairy products such as pearl millet-based dairy desserts, desiccated *chhana-murki* and low-calorie high-fiber *chhana* balls (Singh et al. 2019; Jha et al. 2013; Arora et al. 2021). However, the application of RSM to determine optimal *paneer* production parameters, specifically related to buttermilk addition and coagulation temperature, remains unexplored. The main objective of the numerical optimization in this study was to produce a *paneer* product with a high level of acceptance or quality. To achieve this goal, various constraints and parameters were taken into consideration. This study aims to investigate the impact of these variables on the compositional properties of *paneer* using Response Surface Methodology (RSM).

## Materials and Methods

### Raw materials

Freshly pooled mixed milk (6-7% 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 a steam-sterilized aluminium can. The citric acid (SQ grade, Qualigens Fine chemicals, Mumbai) was used to adjust milk pH for *paneer* preparation. Buttermilk produced during the process of butter making was used, with fat content varying from 0.1-0.5% and total solids ranged from 2.6-3.2%.

### Experimental Design

RSM was used to study the optimum condition for producing buttermilk-added *paneer*. The experimental design and statistical analysis were executed using Stat-Ease software (Design-Expert 13 Trial, Stat-Ease, Inc., MN, USA). A five-level-two factor central composite rotatable design (CCRD) was used to assess the mutual effect of two process variables (%) buttermilk and coagulation temperature (CT) of milk, coded as A, and B respectively. The minimum and maximum values for A, and B was 7.5-25% and 70-85°C, respectively. Table 1 represents the codes and values of the process variables for *paneer* making experiment. The complete design consisted of 13 combinations. The actual value of two process variables and the experiment results of the studied responses' such as proximate composition and yield is shown in Table 2.

### Preparation of paneer

The 13 different *paneer* samples were prepared using different combinations of buttermilk level and coagulated at different coagulation temperature to ascertain the optimized solution.

The preparation of *paneer* was carried out following the method of Sachdeva and Singh (1988). Desired quantity of buttermilk (as

per RSM) was added in the standardized mixed milk (4.5% fat and 8.5% SNF) and it was heated to 90°C without holding and coagulated at the desired temperature as per RSM design. The milk solids were pressed by weight corresponding with a weight of 4 kg placed over planks measuring 35×28×10 cm sitting over the filled hoops for 25-30 minutes. Cooling was done with chilled water (4-5°C) for 2 hours.

### Analytical procedures

The moisture, fat, protein and ash content of *paneer* samples was estimated using moisture analyzer, Gerber method, Kjeldahl assembly, and Muffle furnace, respectively as per methods described by IS: SP18 (Part XI). Lactose content was estimated by Lane Eynon method as described by Ranganna (1986). The yield of the *paneer* obtained by mixing buttermilk with milk was calculated. This was done by weighing the total milk amount before *paneer* making and then weighing the product obtained. Then yield percentage was calculated using formula given below:

$$\text{Yield (\%)} = \frac{100 \times W_1}{W_2}$$

Where,  $W_1$  = Weight of the product (*paneer*) obtained

$W_2$  = Weight of milk taken for *paneer* preparation including buttermilk

### 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 and  $p < 0.01$  and  $p < 0.05$  was taken as significant.

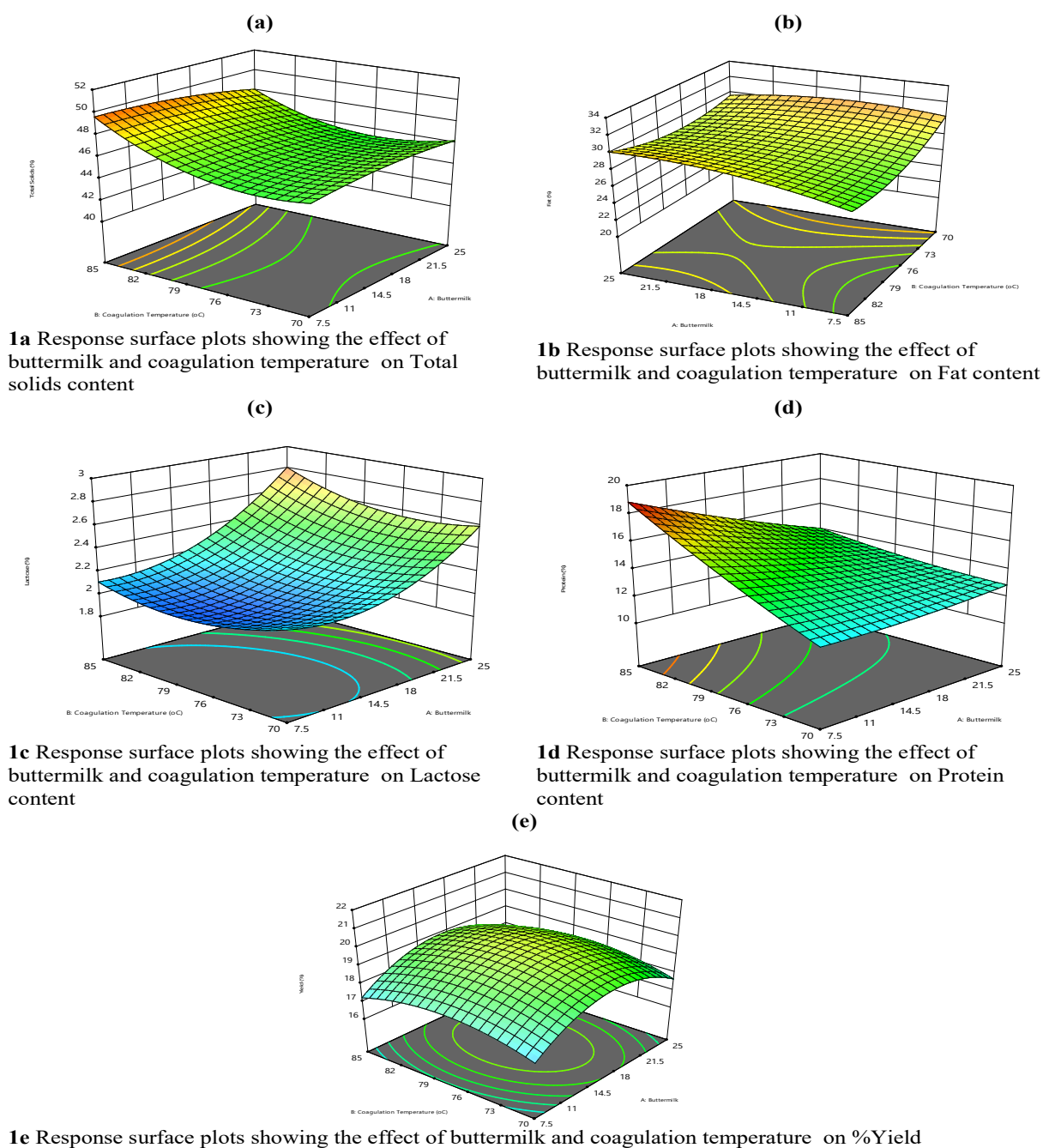
## Result and Discussion

### Total Solids content

The findings, presented in Table 2, Table 3, and Fig. 1a, revealed that the total solid content of the *paneer* samples exhibited a range from 40.55% to 50.58%.

The *paneer* prepared using 16.66% buttermilk at a coagulation temperature of 66.89°C displayed the lowest total solid content. This can be attributed to the combination of a lower coagulation temperature and a relatively higher buttermilk concentration, which resulted in a substantial entrapment of water within the casein structure. Consequently, the entrapped water led to a reduction in the overall solid content of the *paneer*.

Conversely, the highest total solids (50.58%) content was observed in the *paneer* sample produced with 16.25% buttermilk



**Fig 1.** Response surface plots showing the effect of buttermilk and coagulation temperature

at a higher coagulation temperature of 88.11°C. The elevated coagulation temperature facilitated maximum casein coagulation, resulting in a significant enhancement of the total solid concentration in the *paneer*:

The results provide valuable insights for optimizing the *paneer* production process to achieve desired solid concentrations. The results are also following earlier reports of Deshmukh et al. (2009); Kantha and Kanawjia (2009) and Bhatt (2013).

**Fat concentration**

The study investigated the fat percentage in *paneer* produced using different combinations of buttermilk concentration and coagulation temperatures. The results, presented in Table 2, Table 3, and Fig. 1b, revealed that the fat content of the *paneer* samples varied in the range of 21.00% to 32.50%.

The *paneer* sample prepared with 7.5% buttermilk and a coagulation temperature of 70°C exhibited the highest fat percentage (32.50%). This can be attributed to the relatively lower buttermilk concentration and the consequent reduction in fat losses during the whey-draining process. The lower buttermilk concentration allowed for a higher retention of fat within the *paneer* structure.

On the other hand, the *paneer* sample made with 16.25% buttermilk and a coagulation temperature of 66.89°C had the lowest fat percentage (21.00%). The higher buttermilk concentration and lower coagulation temperature in this case led to increased fat loss in the whey, which was drained off during the *paneer*-making

process. The resulting *paneer* had higher moisture content, contributing to the reduced fat level and a very soft texture.

These findings are in line with earlier reports by Chandan (2007), Deshmukh et al. (2009), Kantha and Kanawjia (2009), and Bhatt (2013), further supporting the consistency and validity of the study's results.

**Protein concentration**

The study focused on analyzing the protein concentration in *paneer* produced using different combinations of buttermilk concentrations and coagulation temperatures. The results,

**Table 1:** Experimental variables for *paneer* making using milk admixed with buttermilk (coded and actual values)

Independent Variable	Coded Values	Coded Level				
		-1.7 <sup>a</sup>	-1	0 <sup>b</sup>	+1	+1.7 <sup>a</sup>
Buttermilk (%)	A	3.88	7.5	16.25	25.0	28.62
Coagulation Temperature (°C)	B	66.89	70	77.50	85	88.11

a = ± á, b = centre point

**Table 2:** Chemical composition and yield of *paneer* made with different levels of buttermilk and coagulation temperature

Run	A: Buttermilk (%)	B: Coagulation Temperature °C	Total Solids (%)	Fat (%)	Protein (%)	Lactose (%)	Yield (%)
1.	16.25	77.50	47.40	30.50	13.67	2.10	18.00
2.	7.50	70.00	46.02	32.50	10.11	2.38	17.40
3.	16.25	77.50	47.82	31.50	13.16	2.06	21.34
4.	16.25	77.50	47.81	31.50	13.16	2.14	21.30
5.	16.25	77.50	47.40	30.50	13.74	2.18	18.00
6.	28.62	77.50	44.32	28.25	12.19	2.86	17.20
7.	3.88	77.50	45.45	25.00	17.46	1.91	16.00
8.	25.00	85.00	49.03	29.50	15.63	2.80	17.80
9.	25.00	70.00	46.64	30.50	12.29	2.71	17.60
10.	16.25	77.50	47.40	30.50	13.81	2.09	18.00
11.	7.50	85.00	50.32	28.25	18.77	2.21	17.60
12.	16.25	88.11	50.58	31.00	16.12	2.38	18.00
13.	16.25	66.89	40.55	21.00	16.66	1.95	19.80

**Table 3:** Coefficients of quadratic models for the response variables as a function of process variables

	Total Solids	p-values	Fat	p-values	Protein	p-values	Lactose	p-values	Yield	p-values
Intercept	46.20		29.00		14.11		2.08		19.69	
A	-0.28	0.76	0.48	0.72	-1.05	0.15	0.28	0.00	0.26	0.58
B	1.40	0.15	-0.57	0.67	1.93	0.02	0.04	0.50	0.05	0.92
A <sup>2</sup>	-0.39	0.69	-0.81	0.58	0.19	0.79	0.20	0.01	-1.47	0.02
B <sup>2</sup>	1.66	0.12	1.25	0.40	0.23	0.75	0.13	0.06	-0.77	0.16
AB	-0.48	0.71	0.81	0.67	-1.33	0.19	0.07	0.43	0.00	1.00
R <sup>2</sup>	0.67		0.7		0.66		0.86		0.66	

Highlighted significant value p<0.05

**Table 4:** Goals set for constraints to get an optimum combination of the process variables

Name	Goal	Lower Limit	Upper Limit	Lower Weight	Upper Weight	Importance
A:Buttermilk	is in range	7.5	25	1	1	3
B:Coagulation Temperature	is in range	70	85	1	1	3
Total Solids	maximize	40.55	50.58	1	1	3
Fat	is in range	21	32.5	1	1	3
Protein	maximize	10.11	18.77	1	1	3
Lactose	is in range	1.91	2.86	1	1	3
Yield	maximize	16	21.34	1	1	3

presented in Table 2, Table 3, and Fig. 1c, demonstrated that the protein content of the *paneer* samples varied between 10.11% and 18.77%.

The *paneer* sample prepared with 7.5% buttermilk and a coagulation temperature of 70°C exhibited the lowest protein percentage (10.11%). This can be attributed to the coagulation of casein particles, the major milk protein responsible for the formation of *paneer*. The coagulam formed at 70°C are relatively softer due to the gentle coagulation process. The softer curds retain more moisture, and as a result, the protein content in the curds might be relatively lower because of the higher water content.

Conversely, the *paneer* sample made with 7.5% buttermilk and a coagulation temperature of 85°C displayed the highest protein percentage (18.77%). The higher temperature leads to more whey expulsion, concentrating the proteins in the curds. As a result, the protein content in the curds formed at 85°C is likely to be higher compared to curds formed at 70°C. Further due to denaturation, whey protein also get entrapped with the casein particles leading to higher protein content in the resultant product.

These findings align with earlier research by Chandan (2007), Deshmukh et al. (2009), Kantha and Kanawjia (2009), and Bhatt (2013), providing further support for the consistency and validity of the study’s results.

**Lactose concentration**

The study investigated the lactose concentration in *paneer* produced using different combinations of buttermilk concentrations and coagulation temperatures. The results, presented in Table 2, Table 3, and Fig. 1d, revealed that the lactose content of the *paneer* samples varied between 1.912% and 2.86%.

The highest lactose percentage (2.86%) was found in the *paneer* sample made from 18.62% buttermilk and a coagulation temperature of 77.5°C. This can be attributed to the fact that buttermilk is a good source of lactose, and the higher

concentration of buttermilk in this case led to an increase in the lactose content of the resulting *paneer*.

Conversely, the *paneer* sample prepared with 3.88% buttermilk and a coagulation temperature of 77.5°C displayed the lowest lactose percentage (1.91%). Most of the lactose is lost in the whey during the *paneer*-making process. The lower buttermilk concentration in this sample resulted in a reduced lactose content in the final product.

These findings align with previous studies conducted by Chandan (2007), Kantha and Kanawjia (2009), and Bhatt (2013), providing further support for the consistency and validity of the study’s results.

**Yield of the *paneer***

The study examined the yield of *paneer* produced using different combinations of buttermilk concentrations and coagulation temperatures. The results, presented in Table 2, Table 3, and Fig. 1e, revealed that the yield of the *paneer* samples varied between 16.00% and 21.34%.

The highest yield of *paneer* (21.34%) was obtained from the sample prepared with 16.25% buttermilk at a coagulation temperature of 77.5°C. This higher yield can be attributed to the better retention of moisture and other constituents during the *paneer*-making process. The optimal combination of buttermilk concentration and coagulation temperature allowed for the maximum incorporation of water and other components, resulting in a higher yield of *paneer*.

Conversely, the *paneer* sample made with 3.88% buttermilk and a coagulation temperature of 77.5°C displayed the lowest yield percentage (16.00%). The lower buttermilk concentration in this case led to reduced moisture retention during the *paneer*-making process, resulting in a lower yield of the final product.

These findings are consistent with previous reports by Chandan (2007), Kantha and Kanawjia (2009), and Bhatt (2013), further reinforcing the validity and reliability of the study’s results.

## Optimization

Table 4 provides a summary of these constraints that were applied during the optimization process to attain the highest value for each parameter.

By maximizing the objectives for each parameter, the researchers were able to determine the optimal combination of buttermilk concentration and coagulation temperature that would result in a *paneer* product with the best overall quality. According to the numerical optimization results, the ratio of 13.99% buttermilk to 85°C coagulation temperature was identified as the ideal combination, producing a *paneer* of optimum quality. This was determined based on a desirability value of 0.79. This specific combination resulted in *paneer* with the following composition: 49.03% total solids, 29.50% fat, 17.1% protein, and 2.10% lactose, a higher *paneer* yield of up to 18.7%, indicating that the selected settings of the manufacturing procedure were highly favorable for achieving good results.

## Conclusion

In conclusion, the results of the present experiments suggest that the optimal combination of buttermilk concentration and coagulation temperature for producing nutritionally high-quality *paneer* is achieved. This specific combination resulted in *paneer* with the following composition: 49.03% total solids, 29.50% fat, 17.1% protein, and 2.10% lactose. Additionally, the use of 13.99% buttermilk and 85°C coagulation temperature led to a higher *paneer* yield of up to 18.7%.

The findings indicate that *paneer* prepared with this combination has a desirable nutrient profile, with significant levels of total solids, fat, and protein. Moreover, the higher yield obtained from this combination is advantageous from both a nutritional and economic standpoint.

## References

- Arora S (2019) Food safety issues and strategies to improve trade of Indian livestock products. *Ind Dairyman* 10:60-67
- Arora S, Gurditta H, Patel AA, Singh U, Singh RRB, Rekha (2021) Modelling and optimization of process parameters for production of desiccated Chhana-murki (Indian cottage cheese-based dessert). *J Food Sci Technol* 56:3043-3054 <https://doi.org/10.1007/s13197-020-04920-6>
- Arora S, Patel AA, Gurditta H, Yadav U, Mahajan S (2019) Estimation of production cost for hard-variant of Chhana-murki (Indian cottage cheese based cheese-based dessert). *Haryana Vet* 58: 174-180
- Arora S, Patel AA, Sindhu R, Yadav U, Singh TP, Chaudhary G (2022) Studies on the organoleptic perception of different flavours and consumer acceptance of desiccated Chhana-murki. *Indian Dairy Sci* 75:125-132
- Barukèià I, Lisak Jakopovià, K, Božanià, R (2019) Valorisation of whey and buttermilk for production of functional beverages - An overview of current possibilities. *Food Technol Biotechnol* 57:448-460
- Chandan RC (2007) Cheese varieties made by direct acidification of hot milk. In Hui YH (eds) *Handbook of food products manufacturing* Vol.-I. Wiley-Inter Science, John Eiley and Sons Inc. Pub., p 645-650
- Deshmukh DS, Zanjad PN, Pawar VD, Machewad GM (2009) Studies on the use of acidified and cultured whey as coagulant in the manufacture of *paneer*. *Int J Dairy Technol* 6:174-181
- FAOSTAT (2021) Food and Agriculture Organization of the United Nations Statistics Division. Food and Agriculture Organization of the United Nations
- Gurditta H, Patel AA, Arora S (2014) Optimisation of sweetener and bulking agent levels for the preparation of functional *chhana-murki*. *Int J Dairy Technol* 67:1-8
- Gurditta H, Patel AA, Arora S (2019) Selection of dietary fibres for sucrose replacement in functional *Chhana-murki* (Indian Cottage cheese-based dessert) and their effect on sensory, physical and instrumental texture parameters. *Int J Dairy Technol* 72: 633-642. <https://doi.org/10.1111/1471-0307.12624>
- Henika RG (1982) Use of response surface methodology in sensory evaluation. *Food Technol* 36:96-101
- Jha A, Tripathi AD, Alam T, Yadav R (2013) Process optimization for manufacture of pearl millet-based dairy dessert by using response surface methodology. *J Food Sci Technol* 50:367-373
- Kantha KL, Kanawjia SK (2009) Response surface analysis of sensory attributes and yield of low fat *paneer* enriched with soy fiber. *Indian J Dairy Sci* 60:230-238
- Kumar R, Kaur M, Garsa AK, Shrivastava B, Reddy VP, Tyagi A (2015) Natural and cultured buttermilk. Chapter: Editors: AK Puniya, Natural and Cultured Buttermilk Publisher: CRC Press/ Taylor and Francis, 203-225
- Ranganna S (1986) *Handbook of analysis and quality control for fruit and vegetable products*, 2nd Edition, McGraw-Hill Publishing Co. Ltd., New Delhi
- Sachdeva S, Singh S (1988) Optimisation of processing parameters in the manufacture of *paneer*. *J Food Sci Technol* 25:142-145
- Singh TP, Chauhan G, Mendiratta SK, Agrawal RK, Arora S (2019) Optimization of ingredients for preparation of low calorie fiber enriched *chhana* balls-Sandesh like product. *J Food Sci Technol* 5:3043-3054
- Sodini I, Morin P, Olabi A, Jiménez-Flores R (2006) Compositional and functional properties of buttermilk: a comparison between sweet, sour, and whey buttermilk. *J Dairy Sci* 89:525- 536
- USDA (2015) Foreign Agricultural Service Dairy and Products Annual GAIN Report No IN5131 October