International Journal of Veterinary Sciences and Animal Husbandry

ISSN: 2456-2912
VET 2024; SP-9(1): 250-254

www.veterinarypaper.com
Received: 15-10-2023
Accepted: 18-11-2023

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Standardize a mechanized process in mechanized jacketed kettle for the manufacture of Mathura Peda

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Abstract
India had emerged as the world's largest producer of milk with half of its production being used for the manufacture of different traditional milk products. For achieving uniform quality for the manufacture of these products on large scale, mechanization in production, standardization of recipe and processing conditions are inevitable. The present study was under taken for process standardization and mechanization of Mathura Peda in Mechanized jacketed kettle. The proportion of various variables required for the preparation of Mathura Peda was optimized using Response Surface Methodology (RSM). Suggested solution obtained for the preparation of *Peda* was 0.66 Fat/SNF ratio, 7.0% sugar w/w of milk and 20 min. holding period. The performance of the mechanized jacketed kettle used in experiment was evaluated at different scraper speeds (S1=15 rpm, S2=20 rpm, S3=25 rpm) and operating steam pressures (P1=1.0 kg/cm^2, P2=1.5 kg/cm^2, P3=2.0 kg/cm^2) by adopting optimum process of the product. The Mathura Peda manufactured in the mechanized jacketed kettle using 1.5 kg/cm^2 steam pressure and 25 rpm scraper speed gave maximum overall acceptability score of the product. On the basis of the results obtained in the experiment, it is concluded that a good quality Mathura Peda could be prepared by using 1.5 kg/cm^2 steam pressure and 25 rpm scraper speed.

Keywords: Mathura Peda, mechanization, standardization, fat/SNF ratio, steam pressure, scraper speed

Introduction
Traditional dairy products not only have an established market in India but also have great export potential because of the strong presence of the Indian diaspora in many parts of the world (Rao and Raju, 2003) [10]. The small-scale technology adopted by halwais for the preparation of indigenous products cannot be exploited for industrial production. The market for traditional Indian milk products is very large, rapidly growing, and is likely to rise at an annual growth rate of about 20% compared to Western dairy products, which varies from 5-10% (Vaghela *et al*., 2016) [12]. The demand for safe, nutritious, healthy products that promote convenience of milk products is growing. India has made substantial economic growth of urban and semi-urban areas during last decade. The small-scale techniques used at present by different sweetmeat producers have several drawbacks such as small-scale production, non-uniform quality, limited shelf life of product and poor energy utilization. Hence, there is a need to adopt mechanization and use of technology which can produce uniform and better-quality product with enhanced shelf life.
The mechanization production of value-added dairy products will give the advantages like (a) economic production, (b) uniform quality, (c) hygienic production and better keeping quality, (d) scale-up production, (e) less laborious process, (f) less energy consumption, (g)better control over the process parameters to maintain standardized sensory and rheological attributes, and (h) promote exports of TIDP through small and medium entrepreneurs. It is also necessary to develop and standardize a commercial method of manufacture of Mathura Peda, which can be adopted at the industrial level.

Materials and Methods

Tentative basic process used for manufacture of Mathura Peda

Standardization of process for the manufacture of Mathura Peda

Fresh milk procured from Anubhav Dairy was strained, standardized to required fat (6.0% fat and 9.0% SNF, 7.5% fat and 9.0% SNF, and 9.0% fat and 9.0% SNF) SNF ratio. Then heating of standardized milk in batches of 2 kg was carried out and it was converted into Mathura Peda.

For converting milk into Mathura Peda, a stainless-steel direct heating karahi with thick iron plate bottom specially designed was used in the whole of the study. The heating of milk inside karahi was carried out by indirect heating of the bottom plate using LPG gas as fuel.

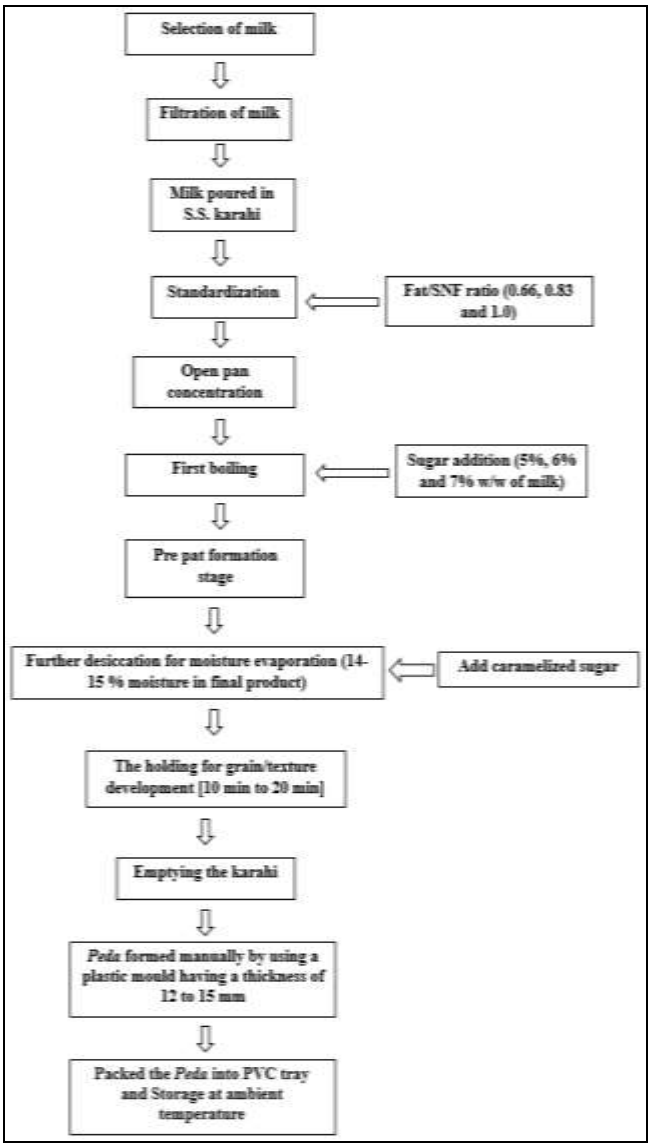

Fig 1: Flow diagram of tentative basic process used for Mathura Peda manufacture

Optimization method for manufacture of Mathura Peda

The main reason for mechanized Mathura Peda processing is to optimize the proportions of the main variables used in Mathura Peda preparation. The manufacture of Mathura Peda with various amounts of each variable includes multiple trials and evaluation of each trial's products in the experimental trials. The Response Surface Method (RSM) is a scientific way of improving the product formulation based on the software performance tests to be performed in such a situation. As a result, RSM was used to determine the experimental tests for product optimization using Design Expert 13.0.1 software. Preliminary trials were carried out and the product's quality was assessed before achieving the level range of different variable needed for RSM. Figure 1 shows the flow diagram for performing RSM-based laboratory trials.

The outcomes of the sensory attributes were used to select ranges of the three variables at various ratios, like Fat and SNF ratio (0.66 to 1.0), sugar (5 to 7% w/w of milk) and holding period (10 to 20 min.). These values were entered into a statistical tool Design Expert 13.0.1. The software's analysis, based on the input data, recommended treatments that included various variations or levels of the process parameters. Table 1 shows the details of the treatment variations that will be used as part of this experiment to optimize the formula for the manufacture of Mathura Peda.

The final products were manufactured using the process illustrated in Fig. 1 for the manufacture of Mathura Peda. The sensory attributes of the Mathura Peda, which was created by combining various factors, were assessed using a 100-point score card.

Mechanized jacketed hemi-spherical kettle

In the food industry, scraped surface heat exchangers (SSHEs) are often used for improved heat transfer, crystallization, freezing and other continuous methods. They're suitable for viscous, sticky, and particulate-containing materials. SSHEs are well suited for pumpable food products and they share these traits with the vast majority of packaged foods. To facilitate control over crucial manufacturing stages, heat-desiccated milk products such as *khoa, burfi, Peda, halwasan, halwa,* and others include batch-type SSHEs with conical or hemisphere-bottom kettle designs.

The development of suitable equipment for mechanized processing of Mathura Peda has necessitated sincere efforts in developing very good sensory and typical rheological properties. It would also be able to scale up the manufacturing process while maintaining better hygiene, using less labour, using less resources and providing a longer shelf life.

Heat transfer performance of SSHE was evaluated by determining the overall heat transfer coefficient (U-value) during the operation of SSHE under different operating conditions during the manufacture of several indigenous dairy products by several workers (Abichandani and Sarma, 1988; Punjrath *et al*., 1990; Dodeja *et al*., 1990; Patel, 1990; Christie and Shah, 1992; Bhadania, 1998; Patel, 2013; Dhotre, 2006) [1, 9, 6, 8, 5].

Fig 2: Mechanized Jacketed Kettle

Table 1: Specification of mechanized system

Sr. No.	Particulars	Specification
1.	Material of construction	SS AISI 304
2.	Volume of kettle	50 liters
3.	Outer diameter of inner shell	0.500 m
4.	Inner diameter of outer shell	0.505 m
5.	Thickness of the inner shell	0.005 m
6.	Height of the inner shell (hemisphere+ cylinder)	0.450 m
7.	Effective area of heat transfer	0.3925 m^2
8.	Thermal conductivity of SS AISI 304	16.2 W/m K
9.	Thickness of steam jacket (middle shell)	0.003 m

The SSHE principle is used to design the mechanized jacketed hemi spherical kettle. The obtained data was analyzed for the purpose of optimizing processing parameters and obtaining superior quality attributes of Mathura Peda in terms of its typical colour, body and texture. The highly insulated mechanized jacketed hemi spherical kettle with a volumetric size of 50 litres was used during experimentation. The kettle is made of stainless steel AISI 304. The kettle comes with all of the required attachments and mountings, including a steam pressure gauge, an air release valve, a safety valve, a steam regulating valve, a steam trap, a worm and worm wheel system for unloading hot processed products, and a lid to cover the kettle. The unit also includes a specially built scraper assembly with a Variable Frequency Drive (VFD) that allows for speed variations between 1 and 50 rpm to achieve the optimal rheological properties of the product. The scrapers are specially engineered to prevent the product from overheating and to have a higher rate of heat transfer to the desired granulations.

Process parameters for mechanized production of Mathura Peda

It was important to optimize processing variables in order to have mechanized output of Mathura Peda. To have greater control over the desired flavour, body and texture, colour and appearance of the mechanized system, process variables required to be optimized. In all of the experimental trials during the manufacture of Mathura Peda, the efficiency of the mechanized jacketed kettle was evaluated at various scraper speeds (S_1=15 rpm, S_2=20 rpm, S_3=25 rpm) and operating steam pressures (P_1=1.0 kg/cm², P_2=1.5 kg/cm², P_3=2.0 kg/cm²) with batch sizes of 10 litre milk. The study of energy analysis in terms of thermal and electrical calculation, overall heat transfer coefficient, energy input and output, energy losses and consumption were needed for the performance evaluation of the entire mechanized system.

Result and Discussion

Standardization of mechanized process technology for manufacture of Mathura Peda

It is necessary to standardize the Mathura Peda process so that mechanization can be implemented based on the standardized process for commercial-scale production of the commodity. This experiment aims to standardize the method of making Mathura Peda from milk, sugar, and caramelized sugar.

Standardization of level of Fat/SNF ratio, sugar and holding period for the Mathura Peda

Response Surface Methodology (RSM) was used to standardize the Fat/SNF ratio, sugar and holding period in comparison to each other. RSM is shown to be a useful tool for optimizing a number of food processes (Azoubel *et al*., 2003; Ozdemir *et al*., 2008; Singh *et al*., 2010) [2, 7, 11]. The RSM equations explain the effects of test variables on observed responses, assess test variable interrelationships, and show the cumulative influence of all test variables on observed responses, allowing the researcher to explore the process more efficiently. The key benefit of RSM is that it allows for a limited number of experimental trials to be conducted while also providing enough data for statistically valid results.

For the preparation of Mathura Peda, preliminary trials were performed by varying the Fat/SNF ratio, sugar and holding period. For sensory evaluation, the product samples should be given to a semi-trained panel of judges. The selection of these variables was set based on these preliminary trials, which forms the foundation for RSM. For this study, Fat/SNF ratio ranging from 0.66 to 1.0, sugar levels ranging from 5 to 7% (w/w of milk) and holding period ranging from 10 to 20 minutes were specified. The data collected during the investigation was statistically analyzed and the findings were interpreted using the advanced statistical software programme Design Expert 13.0.1. The sensory properties of these treatment samples, such as flavour, body and texture, colour and appearance, as well as overall acceptability scores, were evaluated.

Table 2: Experimental Design Matrix for levels of factors: Fat/SNF ratio, sugar (%) by w/w of milk and holding period (min.)

Run Order	A: Fat/SNF ratio	B: Sugar (%)	C: Holding Period (min.)
1	0.83	6	15
2	0.66	5	10
3	0.66	6	15
4	0.83	6	15
5	0.66	5	20
6	0.66	7	20
7	0.83	7	15
8	1	5	10
9	0.83	6	15
10	1	7	10
11	0.83	6	10
12	1	6	15
13	0.83	6	20
14	0.83	6	15
15	0.83	5	15
16	0.83	6	15
17	1	5	20
18	1	7	20
19	0.83	6	15
20	0.66	7	10

The Mathura Peda was prepared with different levels of Fat/SNF ratio, sugar and holding period as shown in the design matrix of three factors Faced Central Composite Rotatable Design (FCCRD) (Table. 2). All the 20 Mathura Peda prepared using the varying proportion of levels of Fat/SNF ratio, sugar and holding period were evaluated for sensory characteristics and the data was analyzed using RSM.

Influence of varying the level of Fat/SNF ratio, sugar and holding period on the sensory properties of Mathura Peda

Sensory attributes are important for determining whether the product is acceptable or not. These attributes are more significant in the development of new products. Flavour, body and texture, colour and appearance and overall acceptability

were the sensory parameters used to evaluate the quality of Mathura Peda. The semi-trained panelists were evaluated the Mathura Peda on a 100-point scale, which can be found in Annexure.

Table 3: Experimental design matrix and sensory characteristics of Mathura Peda

Run Order	A: Fat/SNF ratio	B: Sugar (%)	C: Holding Period (min.)	Flavour Score (Out of 45)	B & T* Score (Out of 35)	C & A$ Score (Out of 20)	OA# Score (out of 100)
1	0.83	6	15	40.5	31.33	16.83	88.66
2	0.66	5	10	38.16	29.5	14.33	82
3	0.66	6	15	38.83	31.16	15.83	85.83
4	0.83	6	15	41.33	30.83	16.5	88.66
5	0.66	5	20	41.33	30.83	16.33	88.5
6	0.66	7	20	42	31.83	17.83	91.66
7	0.83	7	15	42.33	31.5	17.33	91.16
8	1	5	10	37.16	28.66	14.16	80
9	0.83	6	15	41.16	31.5	17.33	90
10	1	7	10	39.66	30.33	15.33	85.33
11	0.83	6	10	40.16	30.16	15.5	85.83
12	1	6	15	38	29.83	15.83	83.66
13	0.83	6	20	41.83	32.83	18.16	92.83
14	0.83	6	15	40.83	31.83	17.5	90.16
15	0.83	5	15	40.16	30.66	16.66	87.5
16	0.83	6	15	41.83	30.83	17.16	89.83
17	1	5	20	38.33	27.33	16.5	82.16
18	1	7	20	39.83	30.66	17.5	88
19	0.83	6	15	41.66	31.16	17.33	90.16
20	0.66	7	10	41.83	30.16	15.33	87.33

Flavour; Colour and Appearance$; Body and texture* and overall acceptability# score

Preliminary trials were conducted before employing the process parameters for the manufacture of acceptable quality Mathura Peda using a tentative process for the manufacture of Mathura Peda as shown in Figure 1. Three factors *viz*. the Fat/SNF ratio (0.66 to 1.0), sugar (5 to 7% w/w of milk) and holding period (10 to 20 min.) designated as A, B, and C respectively were optimized by adopting a Faced Central Composite Rotatable Design (FCCRD) consisting of total 20 experiments.

Table 3 shows the sensory scores of Mathura Peda prepared with various combinations of Fat/SNF ratio, sugar and holding period as calculated by RSM, as well as formulations in their run order. The quadratic model fit the flavour, body and texture, colour and appearance and overall acceptability scores well.

The quadratic model for sensory parameters was obtained through successive regression analysis. For flavour, body and texture, colour and appearance, and overall acceptability, the model F values were 13.08, 8.10, 24.89, and 25.75, respectively, as seen in Table 4. At a 5% level of significance, the measured F values are greater than the table F values, indicating that the model terms are significant. Furthermore, for flavour, body and texture, colour and appearance and overall acceptability of experimental Mathura Peda, the coefficient of determination (R^2) was 0.9217, 0.8794, 0.9573, and 0.9586, respectively shown in Table 4, which represents the proportion of variability in data explained or accounted by the model. A better fit of the quadratic model is shown by larger (R^2) values. The adequate precision measures the signal to noise ratio, the value of which should be greater than 4.0. The adequate precision value for flavour, body and texture, colour and appearance and overall acceptability were 13.623, 10.617, 17.139, and 18.063, respectively, which were greater than 4, hence, it is considered to be supporting the suitability of the model to navigate the design.

Table 4: Coefficient of the full second-order polynomial model for coded sensory responses to different levels of variables of Mathura Peda

Terms		Sensory Attributes			
		Flavour (Out of 45)	Body and Texture (Out of 35)	Colour and Appearance (Out of 20)	Overall Acceptability (Out of 100)
Intercept		40.99	31.34	17.04	89.38
Linear Level	A: Fat/SNF ratio	- 0.9170@	- 0.6670@	- 0.0330ns	- 1.62@
	B: Sugar	1.05@	0.7500@	0.5340@	2.33@
	C: Holding Period	0.6350@	0.4670@	1.17@	2.27@
Interactive Effect	A × B	- 0.0425ns	0.4175ns	- 0.0413ns	0.3350ns
	A × C	- 0.2500ns	- 0.5000@	0.0013ns	- 0.7500ns
	B × C	- 0.5000@	0.2500ns	0.0413ns	- 0.2075ns
Quadratic Level	A^2	- 2.23@	- 0.9932@	- 1.11@	- 4.33@
	B^2	0.5973ns	- 0.4082ns	0.0595ns	0.2514ns
	C^2	0.3473ns	0.0068ns	- 0.1055ns	0.2514ns
R^2		0.9217	0.8794	0.9573	0.9586
Model F-value		13.08	8.10	24.89	25.75
APV		13.6231	10.6178	17.1394	18.0632
Suggested Model		Quadratic	Quadratic	Quadratic	Quadratic

@: $p<0.05$: significant; ns: non-significant; APV= Adequate Precision Value;
A=Fat/SNF ratio; B=Sugar; C=Holding Period; R^2 = Coefficient of determination

Optimization of product formulation for manufacture of Mathura Peda

The aim of process optimization for the production of Mathura Peda was to find the best possible combinations of different levels of factors, such as Fat/SNF ratio (A), sugar (B) and holding period (C), that would result in the most sensory-acceptable product.

Table 5: Criteria/responses chosen for process optimization of Mathura Peda Manufacture

Sr. No.	Parameter	Units	Goal	Lower Limit	Upper limit	Level of Importance
1	A: Fat/SNF ratio	Ratio	is in range	0.66	1.0	3
2	B: Sugar	%	is in range	5	7	3
3	C: Holding Period	Min.	is in range	10	20	3
4	Flavour	Score out of 45	Maximize	37.16	42.33	3
5	Body & Texture	Score out of 35	Maximize	27.33	32.83	3
6	Colour & Appearance	Score out of 20	Maximize	14.16	18.16	3
7	Overall Acceptability	Score out of 100	Maximize	80	92.83	3

Table 6: Suggested solution from RSM analysis for Mathura Peda

Solution No.	Solutions			Desirability
	Fat/SNF ratio	Sugar (%)	Holding Period (min.)	
1.	0.66	7.0	20	0.987

Table 5 shows the goals or responses that was set in order to achieve the best possible combination. The Design Expert Package was used to evaluate the results. The RSM recommended the best solution based on criteria and their constraints. Table 6 shows the suggested solution for Mathura Peda based on RSM analysis.

Table 7: Comparison of predicted v/s actual values of responses used for process optimization of manufacture of Mathura Peda

Response	P Value	Predicted Value*	Actual Value@	Cal. T-Value#	Level of Significance
Flavour (Score out of 45)	0.266	43.26	43.23	0.662	NS
B & T (Score out of 35)	0.399	32.55	32.57	0.267	NS
C & A (Score out of 20)	0.366	18.16	18.58	0.358	NS
OA (Score out of 100)	0.306	94.42	94.36	0.532	NS

***** Predicted values of Design Expert 8.0.3 package
@ Actual values are average of seven trials for optimized product
# t-values found non-significant at 5 per cent level of significance
NS = Non-Significant
Tabulated t-value = 2.447 (cal. t-value less than tabulated value)

The final product was manufactured employing this suggested formulation and the actual results were obtained from the manufacture of Mathura Peda. The predicted values of the criteria/responses selected for process optimization under study were compared with the actual values of the selected responses. The results obtained confirm that the selected combination is the best one in terms of the sensory responses delineated at the beginning of the study. The results are also validated statistically by 't' test. The calculated 't-value' for all the parameters is reported in Table 7. The values for 't' test being less than the table values, it is inferred that there is non-significant (p>0.05) difference between the predicted and actual values of responses as shown in Table 7.

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