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Process Development for the Mechanized Production of Khoa

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ABSTRACT: India has emerged as the world's largest producer of milk and milk based products. Khoa based products have been traditionally produced in the Indian sub-continent since ancient times. The Traditional Indian Dairy Product (TIDP), khoa, is mostly used as a base for various Indian sweets like *peda, burfi, kalakand, gulab jamuns,* etc. The mechanized production of traditional dairy products opens up the scope of export, providing an outstanding opportunity for the organized dairy sector in India. The present study emphasised on optimization of processing parameters and process standardization for mechanized production of khoa and its effect on sensory score and textural attributes of khoa.

A steam jacketed kettle with spring loaded Teflon edged scraper blades assembly was used for mechanized production of khoa. A standardized mixed milk was evaporated using batch type vacuum pan. A batch size of 10 kg of concentrated milk was kept constant during the study. The performance of the mechanized manufacture of khoa was evaluated at different steam pressures (P_1 = 98.06 kPa, P_2 = 147.1 kPa, P_3 = 171.61 kPa), scarper speed (R_1 = 0.67 rps), and different level of milk concentration (in % TS) (C_1 = 35 % TS, C_2=40 % TS, C_3 = 45 % TS) for first stage. During the second stage, operating variables were evaluated at different steam pressures (S_1= 49.03 kPa and S_2 = 78.45 kPa) and scrapers speed (R_2 = 0.33 rps). The sensory quality of khoa manufactured in a mechanized system was found superior (97.22 out of 100) when produced with combined operating parameters C_3, P_2, R_1 and S_1, R_2 during pre-pat formation and post-pat formation stages respectively which were optimized for manufacture of khoa. The sensory quality of khoa produced by optimized processing parameters was at par with the control product prepared traditionally and the market sample. Khoa produced by mechanized method can overcome the demerits of traditional methods of manufacturing like insufficient use of energy, poor hygiene and sanitation, non-uniform product quality, etc.

Keywords: Mechanization of traditional Indian Dairy Products, Mechanised production of Khoa, Process mechanization of TIDPs.

INTRODUCTION

The dairy industry in India stands as a cornerstone of the nation's agricultural and economic landscape, playing a pivotal role in both rural livelihoods and urban sustenance. Renowned for its vast dairy potential, India is the world's largest milk producer in the world contributing 24.64% of global milk production in the year 2021-22. The milk production of India has registered a 58% increase with a CAGR (compound annual growth rate) of 5.85% over the last nine years. India's export of dairy products was 67,572.99 MT to the world for the worth $284.65 Mn during the year 2022-23 (Invest India, 2023). The market for Indian dairy industry is expected to reach a value of INR 25,491 Billion by 2025, exhibiting a CAGR of around 16% during 2020-2025 (IMARC, 2020). At present, nearly 81.1% of the Indian dairy and milk processing market was part of the unorganized sector, which produces milk unhygienic environments (Business wire, 2019).

Khoa is a heat-desiccated milk product having 65 to 70 % total solids. About 5.5 % of milk produced in India is utilized for the manufacture of *khoa* (Chatterjee and Acharya 1987). *Khoa* occupies a pivotal position amongst traditional Indian dairy products as it forms the base material for the production of a various sweetmeats such as *peda, kalakand, burfi, gulabjamun,* etc. In India, about 600000 tons of *khoa* are being produced annually (Aneja and Puri 1997; Kumar *et al*., 2010) valued at ₹ 18,000 million (Varadrajan, 1997). Due to the perishable nature of the *khoa,* it needs to be stored under commercial refrigeration temperature to prevent spoilage, which incorporates the high storage cost of cooling. According to Tambekar and Bhutada (2004), the small scale scattered production, poor quality of milk and unhygienic practices followed during production, handling and storage of *khoa* results in poor shelf life. The microbiological quality of khoa is very poor when it was produced by the small scale producers and cottage industry. Keeping in view the public health significance many researchers studied and

anlaysed the microbiological quality of khoa across various part of the country (Yedatkar *et al*., 2023). To overcome these disadvantages, attempts have been made to automate the process to develop batch, semi-continuous, and continuous equipment for manufacturing Traditional Dairy products on a large commercial scale (Velpula *et al*., 2018). Looking at the demand and profitability, many organized dairy plants have entered in the business of traditional dairy products adopting improved technology and mechanized manufacture of khoa. The principle objective of the present work is to optimise the processing parameters for standardization of the method for mechanised production of khoa.

MATERIAL AND METHODS

A. Sample Preparation and Analysis of Milk

Raw fresh mix milk was standardized to 6% fat and 9% SNF and collected in clean and dry aluminum cans maintaining refrigeration temperature. Fat content, protein content, lactose content, titratable acidity and total solids in all the milk samples were determined by the procedure as described in the BIS Handbook (BIS: Part XI, 1981). The procedure outlined in BIS Handbook (BIS: Part XI, 1981) was followed for the determination of ash content in all the milk samples.

B. Experimental Set-up for Mechanized Production of Khoa

Scraped Surface Heat Exchangers (SSHEs) are widely used in the food industries for better heat transfer, crystallization, freezing and other continuous processes. SSHEs are ideally suited for heat-desiccated milk products such as *Khoa, Burfi, Peda, Halwasan, Halwa* etc. which are viscous, sticky and that contain particulate matter. Batch type SSHEs with conical or hemispherical bottom kettle concept to facilitate control over critical manufacturing stages.

C. Steam Jacketed Hemi Spherical Kettle

The steam jacketed hemispherical kettle was designed based on the principle of SSHE. The steam jacketed hemispherical kettle, made from AISI 304 stainless steel, having a volumetric capacity of 50 litre, was provided with all accessories and mountings like steam pressure gauge, air release valve, safety valve, steam regulating valve, steam trap, worm and worm wheel mechanism for unloading of hot processed product and lid for covering the kettle. The unit was equipped with a specially designed scraper assembly to avoid product burning and give the desired texture with a higher heat transfer rate. The Scraper assembly was attached with a Variable Frequency Drive (VFD) to vary the scraper speed in the range of 1 to 50 rpm to get the desired rheological attributes of the product. The steam generated from the IBR boiler was supplied to the installed jacketed kettle. Electricity connection for the operation of scraper assemblies was made through a three-phase energy meter and a direct-on-line starter. Trials were conducted and the quality of the product was evaluated to optimize and select the range of operating conditions for the performance evaluation of the steam jacketed kettle for manufacture of *khoa.* The photographs of the mechanized system are shown in different plates as under.

Plate 1. Steam jacketed kettle.

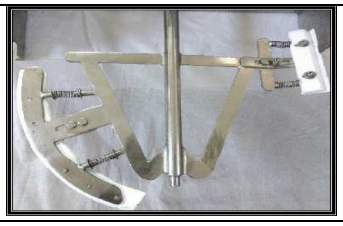

Plate 2. Scraper assembly.

Plate 3. Scraper assembly inside the steam jacketed kettle.

Plate 4. Power analyzer and VFD.

D. Manufacture of khoa through a mechanized production System

The basic need for mechanized *khoa* production is to optimize the operating variable associated with *khoa* production. Optimization of process variables is needed for different stages to have better control over the product's desired colour, flavour, body and texture of the mechanized system. The *khoa* was prepared by various operating variables at different levels like the concentration of mixed milk (35%, 40%, and 45% TS), steam pressure (98.06, 147.1, and 171.61 kPa), scraper speed (0.67 rps), steam pressure after pat formation (49.03 and 78.45 kPa) and scraper speed (0.33 rps) after pat formation. Optimization of different variables during product manufacture stages were evaluated by the BIS scorecard for sensory attributes. Results of the sensory attributes of *khoa* prepared from such operating variables were analyzed by statistical tool using

completely randomized design (CRD) and factorial completely randomized design (FCRD).

E. Chemical Analysis of Khoa

A representative sample from the whole cross section of each sample of *khoa* was taken as described in Indian Standard: 2785-1964. The proximate analysis of chemical composition for *khoa* such as moisture content, protein, fat and ash was determined according to AOAC (1990) standard method. Carbohydrate content was determined by difference.

F. Analysis of Khoa for Rheological Properties

Samples of each experimental product were subjected to uniaxial compression to 80 percent of the initial sample height, using a Food Texture Analyzer of Lloyd Instruments LRX Plus material testing machine, England; fitted with a 0-500kg load cell. The force-distance curve was obtained for a two-bite deformation cycle employing a cross-head speed of 50 mm/min, Trigger 10 Kgf and 80 % Compression of the samples to determine various textural attributes of products held for 1 h at 23±10°C and 55 % RH (Relative Humidity).

G. Microbiological Analysis of Khoa

The khoa produced through optimized parameters was analyzed for the Aerobic Plate Count (APC), Coliform count and Yeast and Mold count.

RESULTS AND DISCUSSION

A. Importance of Stages of Processing During Mechanized Manufacture of Khoa

Khoa is a milk based product which is very popular for its typical characteristics *viz.,* colour, sweet flavour and its smooth body and texture. Based on the scientific study during preliminary trials, we had bifurcated the entire process of Mechanized production of *khoa* in different stages to control the process variable for each stage as specified in Table 2.

B. Effect of Various Operating Parameters on Sensory Attributes of Khoa

Effects of different operating parameters on sensory attributes of the final product manufactured by mechanized system were evaluated considering flavour score, colour and appearance, body and texture, and total score. The product was evaluated using BIS score card (100 point). Table 4 represents the effect of total solids of milk (%TS) and steam pressure at different stages on sensory attributes of *khoa.*

Table 1: Chemical composition of the standardized mixed milk.

Parameters	Average Value	Parameters	Average Value
Fat, %	6.10 ± 0.1	Protein, %	4.36 ± 0.10
SNF, %	9.28 ± 0.11	Ash, %	0.67 ± 0.02
Lactose, %	4.93 ± 0.10	Acidity, % LA	0.16 ± 0.01

Table 2: Processing stages during mechanized production of *khoa.*

Sr. No.	Stages	Defining process stages
1.	I	Boiling and Pre-pat formation
2.	II	Working and Cooling

Table 3: Operating variables for mechanized production of *khoa.*

Total solids of Milk C (% TS)	Steam pressure P (kPa)	Pressure after pat formation S (kPa)	Batch Size (kg)	Scraper speed before Pat formation R_1(rps)	Scraper speed after Pat formation R_2 (rps)
C_1 (35%TS) C_2 (40%TS) C_3 (45%TS)	P_1 (98.060) P_2 (147.10) P_3 (171.61)	S_1(49.03) S_2(78.45)	10	0.67	0.33

Table 4: Effect of various operating parameters on sensory attributes of *khoa.*

% Concentration	Pressure P (kPa)	Pressure After Pat formation S (kPa)	Sensory Score			
			Flavour (45)	Body & Texture (35)	Colour & Appearance (15)	Total* (100)
C_1 35% TS	98.06	S_1(49.03)	38.83±0.33	29.11±0.19	11.00±0.30	83.94±0.33
		S_2(78.45)	39.89±0.50	29.83±0.50	10.94±034	85.67±0.57
	147.10	S_1(49.03)	40.67±033	30.83±0.16	11.67±0.33	88.17±0.10
		S_2(78.45)	40.50±033	30.61±0.25	11.39±0.35	87.50±0.77
	171.61	S_1(49.03)	40.61±0.25	30.00±0.33	11.94±0.25	87.56±0.03
		S_2(78.45)	40.94±0.10	30.83±0.50	11.61±0.19	88.39±0.39
C_2 40% TS	98.06	S_1(49.03)	40.17±0.33	30.44±0.25	12.50±0.33	88.11±0.44
		S_2(78.45)	40.67±0.50	31.00±0.16	12.78±0.25	89.44±0.25
	147.10	S_1(49.03)	41.78±0.10	31.50±0.33	12.83±0.33	91.11±0.69
		S_2(78.45)	41.33±0.33	31.83±0.16	13.33±0.16	91.50±0.10
	171.61	S_1(0.5)	40.50±0.33	32.22±0.42	13.56±0.35	91.28±0.59
		S_2(78.45)	41.67±0.33	32.67±0.33	13.33±0.17	92.67±0.35
C_3 45% TS	98.06	S_1(49.03)	40.67±0.17	30.83±0.33	13.44±0.25	89.94±0.17
		S_2(78.45)	41.83±0.33	31.39±0.25	13.83±0.33	92.06±0.42
	147.10	S_1(49.03)	44.05±0.34	33.83±0.33	14.33±0.17	97.22±0.72
		S_2(78.45)	42.67±0.33	33.28±0.25	13.83±0.17	94.78±0.25
	171.61	S_1(49.03)	41.00±0.33	32.05±0.51	13.67±0.33	91.72±0.69
		S_2(78.45)	41.67±0.50	32.56±0.01	13.17±0.16	92.39±0.48
Control			44.33±0.17	34.11±0.16	14.33±0.17	97.78±0.51

* Total score includes score of 5.0 for package

Table 5: Effect of various operating parameters on flavour score of *khoa* produced by mechanized system.

% Concentration (C)	Pressure P (kPa)	Flavour score (out of 45)		Average (P)	Average (C)
		Pressure After Pat formation S (kPa)			
		S_1(49.03)	S_2(78.45)		
35 %TS	098.06	38.83±0.33	39.89±0.50	39.36	40.24
	147.10	40.67±033	40.50±033	40.58	
	171.61	40.61±0.25	40.94±0.10	40.76	
40%TS	098.06	40.17±0.33	40.67±0.50	40.42	41.05
	147.10	41.78±0.10	41.33±0.33	41.55	
	171.61	40.50±0.33	41.67±0.33	41.09	
45%TS	098.06	40.67±0.17	41.83±0.33	41.25	41.98
	147.10	44.05±0.34	42.67±0.33	43.36	
	171.61	41.00±0.33	41.67±0.5	41.34	
Average (S)		40.92	41.26		
Source	S.Em.	CD (0.05)		CV%	
C	0.079	0.23		0.81	
P	0.079	0.23			
S	0.064	0.17			
C × P	0.132	0.38			
P × S	0.11	0.18			
C × P*S	0.19	0.55			

Table 6: Effect of operating parameters on Body & Texture score of *khoa* produced by mechanized system.

% Concentration (C)	Pressure P (kPa)	Body and Texture Score (out of 35)		Average (P)	Average (C)
		Pressure After Pat formation S (kPa)			
		S_1(49.03)	S_2(78.45)		
35 % TS	098.06	29.11±0.19	29.83±0.50	29.27	30.14
	147.10	30.83±0.16	30.61±0.25	30.72	
	171.61	30.00±0.33	30.83±0.50	30.42	
40% TS	098.06	30.44±0.25	31.00±0.16	30.72	31.61
	147.10	31.50±0.33	31.83±0.16	31.67	
	171.61	32.22±0.42	32.67±0.33	32.45	
45%TS	098.06	30.83±0.33	31.39±0.25	31.11	32.32
	147.10	33.83±0.33	33.28±0.25	33.55	
	171.61	32.05±0.51	32.56±0.01	32.31	
Average (S)		31.20	31.56		
Source	S.Em.	CD (0.05)		CV%	
C	0.076	0.22		1.03	
P	0.076	0.22			
S	0.062	0.18			
C × P	0.136	0.39			
P × S	0.11	0.18			

Table 7: Effect of various operating parameters on Colour and Appearance score of *khoa* produced by mechanized system.

% Concentration (C)	Pressure P (kPa)	Colour and appearance score (out of 15)		Average (P)	Average (C)
		Pressure After Pat formation S (kPa)			
		S_1(49.03)	S_2(78.45)		
35 % TS	098.06	11.00±0.3	10.94±034	10.97	11.42
	147.10	11.67±0.33	11.39±0.35	11.53	
	171.61	11.94±0.25	11.61±0.19	11.76	
40% TS	098.06	12.50±0.33	12.78±0.25	12.64	13.06
	147.10	12.83±0.33	13.33±0.16	13.08	
	171.61	13.56±0.35	13.33±0.17	13.45	
45% TS	098.06	13.44±0.25	13.83±0.33	13.64	13.71
	147.10	14.33±0.17	13.83±0.17	14.08	
	171.61	13.67±0.33	13.17±0.16	13.40	
Average (S)		12.77	12.69		
Source	S.Em.	CD (0.05)		CV%	
C	0.066	0.19		2.19	
P	0.066	0.19			
S	0.054	NS			
C × P	0.113	0.33			
P × S	0.093	0.15			

Table 8: Total Sensory Score of *khoa* produced by mechanized system.

% Concentration (C)	Pressure P (kPa)	Total score* (out of 100) Pressure After Pat formation S (kPa)		Average (P)	Average (C)
		S_1(49.03)	S_2(78.45)		
35 % TS	098.06	83.94±0.33	85.67±0.57	84.81	86.88
	147.10	88.17±0.10	87.50±0.77	87.84	
	171.61	87.56±0.03	88.39±0.39	87.98	
40% TS	098.06	88.11±0.44	89.44±0.25	88.76	90.68
	147.10	91.11±0.69	91.50±0.10	91.31	
	171.61	91.28±0.59	92.67±0.35	91.98	
45% TS	098.06	89.94±0.17	92.06±0.42	91.00	93.02
	147.10	97.22±0.72	94.78±0.25	96.00	
	171.61	91.72±0.69	92.39±0.48	92.06	
Average (S)		89.87	90.40		
Source	**S. Em.**	**CD (0.05)**		**CV%**	
C	0.109	0.31		0.52	
P	0.109	0.31			
S	0.090	0.26			
C × P	0.19	0.54			
P × S	0.27	0.77			
C × S	0.155	0.44			

* Total score includes score of 5.0 for package

Table 9: Optimization of operating parameters for mechanized production of *khoa* based on sensory attributes (batch size-10 kg).

% Concentration	Batch (kg)	Pressure (kPa)	Pressure After Pat formation (kPa)	Scraper speed before pat formation (rps)	Scraper speed after pat formation (rps)	Sensory Evaluation score			
						Flavour (45)	Body & Texture (35)	Colour & Appearance (15)	Total score (100)*
45 %TS	10	147.1	49.03	0.67	0.33	44.05 ±0.34	33.83 ±0.33	14.33 ±0.17	97.22 ±0.72

* Total score includes score of 5.0 for package

Based on the statistical analysis of effect of various operating parameters on sensory score of *khoa*, the combination C_3 P_2 S_1 gave the higher total sensory score as compared to other combinations of treatment. Optimized processing variables for mechanized production of *khoa* by open type SSHE are mentioned in Table 9.

Quality of *khoa* produced from optimized parameters (Table 10) was analyzed for it's proximate compositions, physico-chemical properties and microbial quality. The average values of quality attributes are shown in Table 10.

Table 10: Proximate composition, physico-chemical properties, microbial count and sensory scores of *khoa* manufactured by optimized mechanized process

Physico-chemical properties	Average Value	Constituents	Average Value
Moisture	23.94±0.41	Acidity, % LA	0.56±0.06
Fat%	35.50±1.06	FFA,%OA	0.33±0.02
Lactose	22.10±0.78	HMF, µM(mole)/ml	29.0 ±1.70
Total Protein	17.56±0.17	Peroxide Value (meq.O_2/kg)	0.00
Ash	3.70±0.010		
Microbial Count		**Textural Properties**	
APC	3.6 log cfu/gm	Hardness	44.0±1.5
Yeast and Mold	Absent/g	Gumminess	15.0±1.0
Spore formers	Absent/g	Chewiness	55.0±4.5
		Cohesiveness	0.4±0.05

* Total score includes score of 5.0 for package

C. Process Standardization for Manufacture of Khoa in Mechanized System

Process standardization for the manufacture of *khoa* by mechanized system with optimized parameters was necessary to maintain hygienic conditions, labour saving, reduction in processing time and to have large scale production with consistent product quality with improved energy efficiency. Based on the outcome of sensory analysis, standardized process for mechanized steps of manufacture of *khoa* with defined operating variables conditions is illustrated in Fig. 1.

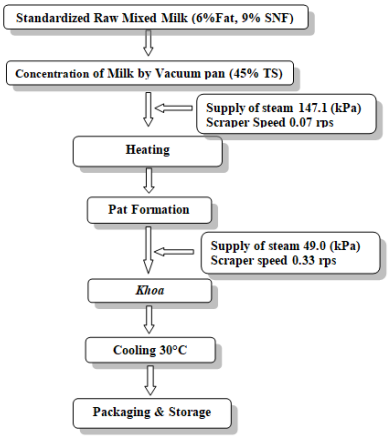

Fig. 1. Standardized Process for the mechanized production of *khoa*.

CONCLUSIONS

During the experimental trials to produce *khoa*, a mechanized system based on steam jacketed kettle with spring loaded Teflon scraper blade assembly was used. The sensory quality of *khoa* manufactured in the mechanized system was superior (97.22 out of 100.0) when starting *khoa* making from 45% TS concentrated milk (C_3), adopting steam pressure of 147.1 kPa (P_2), keeping scraper speed 0.33 rps (R2) and post pat formation steam pressure (S_1) of 49.03 kPa as compared to other possible combinations. The sensory quality of *khoa* prepared under optimized mechanized protocol was at par with that of the control product prepared traditionally. So, it was concluded that the mechanized system could be successfully used for the commercial production of *khoa*.

FUTURE SCOPE

The developed Mechanized system for khoa production contains open type hemispherical SSHE. During the khoa production, lots of vapour was lost upon evaporation from the open pan. As a part of further investigation, the scope and effectiveness of the mechanized system can be further enhanced by incorporating an insulated steam jacket, vapour hood exhaust system to remove water vapour and improved scraper assembly design.

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Conflict of Interest. None.

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