

Up-gradation of Khoa Production and Preservation Technologies

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ABSTRACT

India is the largest milk producing nation in the world. Milk is perishable in nature, thus it can not be stored for a very long period. In order to preserve it, more than half of milk produced in India is converted into a variety of traditional value added milk products which played a significant role in the Indian economy. Khoa is a heat desiccated value added indigenous milk product. Due to its large scale consumption about six lakh tones of khoa is being manufactured annually, which is equivalent to seven percent of India's total milk production. In this article, the brief overviews on traditional method of khoa making, technological up-gradation in khoa making process, energy requirements, shelf life, and storage of khoa are presented.

Key words: Milk; Khoa; Khoa Making Process; Khoa Preservation; Khoa Shelf Life.

1. INTRODUCTION

Milk has been used as an article of food since ancient times in India. It plays an important role in the diet. In India, the share of milk and its products is the largest after cereals, and it accounts for 16% of the total food expenditure [1-3]. According to United Nation's Food and Agriculture Organization (FAO, 1999), India has become the single largest milk producing nation in the world, surpassing USA. India has shown impressive growth in the milk production, achieving an annual production of 112.5 million tones in the year 2009-10 which is 15% of the total milk production in the world. India is among the world's largest and fastest growing market for milk and milk products. The average annual growth rate of milk production has been 4% during the past decades. As per the recent report of ministry of animal husbandry, dairying, and fisheries the milk production is projected to rise to 134 million tones by 2015 [4-8].

The lack of cooling facilities to keep the liquid milk fresh led to the diversion of milk for preparation of indigenous milk products with comparatively longer shelf life. An estimated 50% to 55% of milk produced in India is converted into a variety of traditional value added milk products such as heat desiccated products, cultured products, fat rich products, acid-heat coagulated products, and milk based puddings. Over the years, these value added milk products are manufactured by traditional milk based sweetmeat makers who form the core of this cottage industry. This industry has played a significant role in the Indian economy.

According to Prevention of Food Adulteration Act, as amended up to March, 2006, khoa is the product obtained from cow or buffalo (goat or sheep) milk, or a combination thereof by rapid drying containing milk fat content not less than 30 percent on dry weight basis of the final product [9, 10]. Khoa is a heat coagulated, partially dehydrated milk product. It is obtained by heat desiccation of whole milk to 65%

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to 70% milk solids without the addition of any foreign ingredients, mostly in private and unorganized sectors of India. It is also known as khoya, khawa, khava, kava, palghoa, or mawa. Due to its large scale consumption nearly six lakh tones of khoa is manufactured annually, which is equivalent to 7% of India's total milk production [11-13].

Khoa is a rich source of energy, about 458 Kcal per 100 g of the product. The food and nutritive value of khoa is very high. It contains large quantities of muscle building proteins, bone forming minerals, and energy giving fat and lactose. It is also expected to retain most of the fat soluble vitamins A and D, and also fairly large quantities of water soluble B vitamins contained in the original milk. Depending on the end use and the quality of milk used, mainly three commercial types of khoa are identified, namely, Pindi, Dhap, and Danedar which differs in composition, texture and quality. All of these varieties are in demand and are required for making value added khoa based products like Burfi, Pedas, Gulabjamun, pantua, Kalakand, milk cake, Kunda, etc. These products may be potential source for export. Khoa is also used for stuffing vegetables in many food items.

Khoa has considerable economic and dietary importance to Indian population. It forms an important base for preparation of milk sweets which are an integral part of Indian food heritage. The khoa and khoa based sweets have high commercial significance because of their popularity throughout the country and longer shelf life. In India, milk sweets have been an indispensable part of the socio-cultural life. They reflect the wealth and status of people, while forming an important part of their cuisine. These are offered on special religious occasions, social events, and festivals. The market for Indian milk based sweets is expanding overseas also. The total Indian sweet market is around Rs. 520 billion in terms of annual sales [14-16]. Nowadays efforts are being made to develop a standard manufacturing package which will increase

its productivity besides quality improvement in terms of hygiene, standardization of process, and storability.

Khoa is an important Indian indigenous dairy milk product. Thus very few numbers of research papers are available in the open literature from any foreign country. In India the research conducted on this product are primarily concerned with its production methods, energy requirements during its manufacture, shelf life and its storage, chemical composition, microbiological quality, physico-chemical, and biochemical changes. In this communication a brief critical review of the published data on technological up-gradation in khoa making process, energy requirements, shelf life, and storage of khoa is presented.

2. KHOA PRODUCTION METHODS AND PROCESSES

2.1. Traditional Khoa Making Method and Its Drawbacks

Khoa production is the easiest way of preserving rurally produced milk. For khoa production, generally traditional method (i.e., open pan evaporation process) is followed in which milk is heated in an open pan over non smoky fire and continuously it is stirred and scraped with the help of a scraper to avoid the scorching of milk solids sticking to the pan. The milk is heated till it attains a semi-solid consistency of dough. Thereafter, the product is removed from the fire and rolled up into solid mass known as khoa-pat.

The traditional method of khoa making requires large quantity of energy and in the present era, energy saving is needed to pay more attention. In rural India, generally, wood, cattle dung, coal, kerosene, etc., are used in open chulah as fuel for khoa making which is hardly 8-10% thermally efficient. Khoa making involves intensive heating during the desiccation process with an aim of evaporating the large quantity

of water present in the milk. The traditional method of khoa making has a number of drawbacks. Some of the major drawbacks are: (i) limited capacity due to batch operation, non-uniform product quality and thus not suitable for large volume production, (ii) inefficient use of energy and low heat transfer coefficient results in bulky equipment, (iii) requires more manual labor due to lengthy process, and (iv) sometimes burning of the product occurs which lowers its quality.

2.2. Advancement on Mechanization of Khoa Making Method and Process

In order to overcome drawbacks of traditional methods of khoa making various researchers attempted mechanization of the khoa making process. Earlier, a brief account of such works has been given in the literature [10, 15, 17-19]. In the following paragraphs the technological progress made towards mechanization and automation advancement in khoa production process is mentioned.

The first prototype machine was fabricated of mild steel for continuous manufacture of khoa on a semi-large scale with a rated capacity of 50 liters of milk per hour [20]. Several improvements in the design and operation of this continuous khoa making machine were carried out [21]. To overcome the metallic contamination problem this machine was fabricated in stainless steel [22]. An improved khoa pan for rural application was developed [23] which was used in determining the flow characteristics of khoa at different temperatures [24]. Subsequently, an adoptive model of this mechanized khoa pan was made [25].

Steam jacketed drum fitted with semi-mechanized scraper based on the principle of scraped surface heat exchanger was employed for khoa making [26]. A batch type prototype mechanized conical process vat with a sanitary type scraping mechanism having spring loaded blades for khoa production was developed [27]. A prototype of khoa making machine consisting of a horizontal cylinder of mild steel having a steam jacket on the lower half side was developed

[28]. Inspired by the performance of this prototype machine, another batch type machine of stainless steel with power drive was developed [29]. Subsequently, this unit was developed into a continuous khoa manufacturing machine by providing three jacketed cylinders placed in a cascade arrangement [30].

The khoa powder was manufactured by employing reverse osmosis (RO) technique in which the steam jacketed kettle was replaced by SSHE (scraped surface heat exchanger) [31]. The product obtained by this machine was having burnt flavor. A khoa making process was developed in which the pre-concentrated milk obtained by RO was heated in an open stainless steel steam jacketed kettle [32].

The use of horizontal thin film SSHE was reported for continuous khoa production [33]. A correlation was developed for power requirement to drive the rotor for a straight sided thin film SSHE by taking water as a working fluid [34]. Thin film SSHE application was extended for concentration of milk to high solids and its suitability for continuous khoa production was confirmed [35]. The performance of thin film SSHE was evaluated at different rotor speeds and steam temperatures for continuous manufacture of khoa [36]. An inclined scraped surface heat exchanger (ISSHE) was developed to manufacture khoa continuously [37]. The effects of various parameters on evaporation of water, concentration of milk, and dehydration of cream in straight sided horizontal thin film SSHE was reported [38]. A thin film SSHE system of mild steel for continuous manufacturing of khoa by arranging two SSHE in a cascade fashion was developed [39]. Later on, the quality of khoa obtained from this machine was attempted to improve by adding a third stage with modified rotor blade assembly [40]. A continuous khoa making unit of mild steel was developed by arranging three identical SSHE one over another to control the product flow under gravity [41]. The utilization of solar energy in dehydration of milk for the manufacture of khoa was attempted, and reported

that solar method of dehydration results in less evaporation of water from milk [42]. A 3-stage SSHE for manufacture of khoa was developed [43] and the quality of khoa manufactured from SSHE was claimed

to be comparable with the market samples. The research development carried out by various researchers discussed in this section has also been reported in Table 1.

Table 1: Various Equipments Developed for Khoa Making

Researchers	Method	Remarks
[20]	Steam Jacketed Kettle	Developed first prototype of continuous khoa making machine
[21]	Steam Jacketed Kettle	Standardized and suggested several improvements in design and operation of continuous khoa making machine
[22]	Steam Jacketed Kettle	Fabricated continuous khoa making machine in stainless steel to overcome contamination problem.
[23]	Steam Jacketed Kettle	Improved khoa pan was developed for rural applications
[25]	Steam Jacketed Kettles	Incorporated more safety features.
[27]	Mechanized conical vat	Mechanized conical process vat was developed.
[26]	Steam jacketed drum	Steam jacketed drum based on the principle of scraped surface heat exchanger was developed.
[28]	Steam jacketed drum	A mild steel prototype of khoa making machine with horizontal cylinder was developed.
[29]	Steam jacketed drum	Batch type stainless steel machine with power drive was developed
[30]	Steam jacketed drum	Continuous khoa making machine with three steam jacketed cylinder was developed.

Due to high thermal losses and non-uniform quality of the product the scraped surface heat exchanger systems and conical vat machines met with limited success. It was claimed by every researcher that their equipment/process has manufactured khoa successfully. But among them the inclined scraped surface heat exchanger equipments are observed to have potential for industrial use.

3. RECENT STUDIES ON MILK HEATING PROCESS FOR KHOA MAKING

The convective heat transfer coefficients are required for the proper design of an evaporator for khoa production as well as in the theoretical modeling of simultaneous heat and mass transfer process. The

natural (sensible heating) and boiling convection heat transfer are the major heat transfer mechanisms which occur during milk heating process. The sensible heating or natural convection boiling exist up to a temperature of $\approx 90^\circ\text{C}$ and the pool or nucleate boiling exist for temperature $>90^\circ\text{C}$ to 95°C [44, 45].

The convective and evaporative heat transfer coefficients during sensible heating of milk in an aluminum pot for khoa making under open condition (i.e., traditional khoa production method) were reported to decrease from $5.25\text{ W/m}^2\text{ }^\circ\text{C}$ to $3.09\text{ W/m}^2\text{ }^\circ\text{C}$ and from $63.83\text{ W/m}^2\text{ }^\circ\text{C}$ to $27.8\text{ W/m}^2\text{ }^\circ\text{C}$ respectively with the increase in heat inputs from 240 watts to 420 watts, whereas for a stainless steel pot it

were found to decrease from 4.70 W/m²°C to 2.68 W/m²°C and from 57.24 W/m²°C to 24.97 W/m²°C [44-46]. The variation in convective and evaporative heat transfer coefficients with respect to rate of inputs is illustrated in Figure 1(a) and (b).

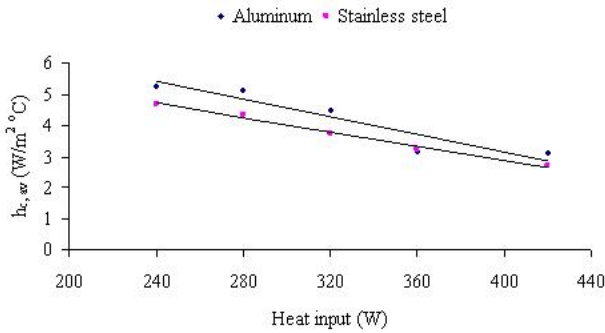


Fig.1(a). Variation in Sensible Heating h_c Versus Heat Input [44, 45]

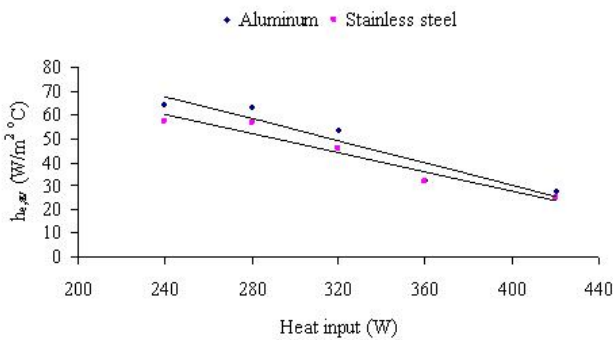


Fig.1(b). Variation in Sensible Heating h_c Versus Heat Input [46, 46]

The convective heat transfer coefficients for pool boiling of milk under open condition during khoa making in an aluminum pot was observed to increase from 334.48 W/m²°C to 837.78 W/m²°C with the increase in heat inputs from 240 watts to 360 watts, whereas for the stainless steel pot it was reported to increase from 283.02 W/m²°C to 783.97 W/m²°C. [47, 48]. The value of nucleate boiling heat flux during pool boiling of milk for khoa making in aluminum and stainless steel pot under open condition were observed to increase exponentially. The fluid-surface constant for Rohsenow pool boiling correlation during khoa making in aluminum and stainless steel pots were

reported as 7.8815×10^{-3} and 9.4772×10^{-3} respectively [49].

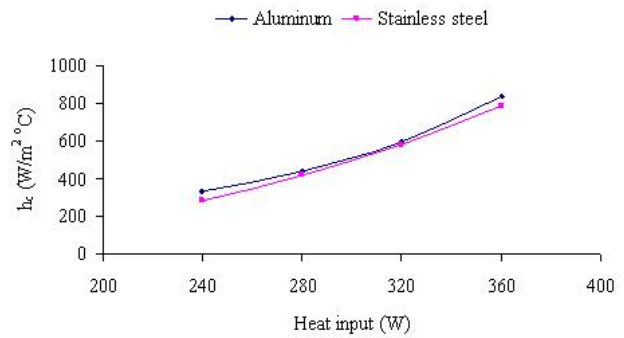


Fig.2 Variation in Pool Boiling h_c Versus Heat Input [47, 48]

The convective heat transfer coefficients for pool boiling of milk under closed condition during khoa making in an aluminum pot were observed to increase from 186.32 W/m²°C to 567.56 W/m²°C with the increase in heat inputs from 240 watts to 360 watts, whereas for the stainless steel pot it was reported to increase from 160.51 W/m²°C to 374.52 W/m²°C. The heat flux values during pool boiling of milk under closed condition in an aluminum pot were 28.12% higher than in the case of a stainless steel pot [50, 51]. These results have also been illustrated in Figure 3.

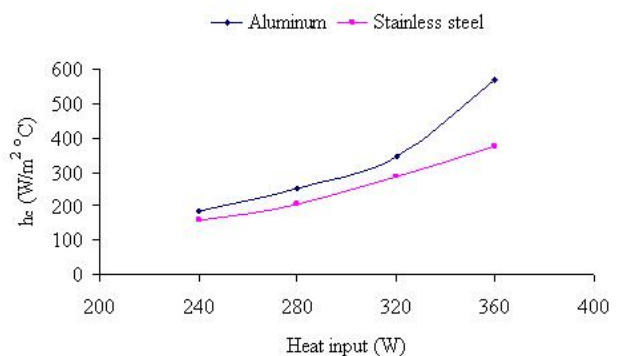


Fig. 3. Variation in Pool Boiling h_c Versus Heat Input Under Closed Condition [50, 51]

4. ENERGY REQUIREMENTS STUDIES ON KHOA PRODUCTION

Generally, energy costs contribute about 30% to 35% of overall manufacturing cost. The steam consumption for khoa making in an open kettle was reported as 1.17 kg per kg of milk and 6.802 kg per kg of khoa [52]. The steam consumption was observed as 1.2 to 1.35 kg per kg of khoa produced at a steam pressure of 0.5 to 1.5 kg/cm² [53]. The heat loss during khoa making was estimated about 35.5%. Energy requirement for khoa making in a stainless steel steam jacketed vat was estimated [54].

The average total thermal energy loss during the khoa making process was reported to be 32.03%. The labor and utility costs for mechanized khoa making system employing ISSHE substantially was found low than the conventional methods [55]. It was reported that RO and vacuum evaporators system consumes less than half of the energy required in normal evaporation process, thus can be utilized on an industrial scale for khoa production [56]. A general comparison for energy requirement in various equipments/process for khoa making is given in Table 2.

Table 2: Comparison Between Various Equipments and Processes

Characteristics	Steam jacketed kettle	Scraped surface heat exchanger	Reverse osmosis
Energy/steam consumption	1.2-1.35 kg / kg of khoa produced [54]	Low than the conventional methods [55]	Half of the normal evaporation process [56]

The energy required for manufacture of khoa in aluminum and stainless steel pots by following the traditional method was estimated under open condition [57]. The aluminum pan was reported to save 6.97% amount of energy for each gram of water evaporated in comparison to a stainless steel pan. An aluminum pot would save 17.24% amount of energy for each

gram of water evaporated in comparison to a stainless steel pot during heating of milk under closed condition [58]. It was also concluded that the actual energy consumption during khoa making in open and closed conditions decreases at high rate of heat inputs, thus energy losses increase. So, it was advised to make khoa at low heat inputs.

Table 3: Comparison between aluminum and stainless steel pots under open and closed conditions for milk heating [57, 58]

Characteristics	Aluminum pot (open condition)	Aluminum pot (closed condition)	Remarks
Energy required per gram of water evaporated	Save 6.97%	Save 17.24%	From energy consumption point of view aluminum pot is better

5. SHELF-LIFE AND STORAGE STUDIES ON KHOA

Steaming of khoa for 15 to 20 minutes was reported to prevent its further deterioration [59]. The keeping quality of khoa samples was extended by ultraviolet radiation [60] and by the addition of cane-sugar [61]. Various approaches like different packaging materials [62-69], addition of preservatives and antioxidants [65, 70-77] were reported to increase the shelf life of khoa. The presence of moulds in khoa causes its fast deterioration by producing discoloration defects as well as disagreeable flavors [78-80]. Efficacy of solar radiation on germicidal influence on khoa during storage was studied and was reported that solar radiation has a definite role in significant reduction of yeast and mould counts [81]. Solar energy and microwaves techniques exhibited germicidal and micro biostatic property during its application in khoa storage and were reported as an ideal and promising techniques for preservation of dairy products like khoa [82]. The convective heat transfer coefficients of khoa were investigated in an open sun and greenhouse drying for natural as well as forced convection modes [83] by taking khoa sample of size $0.09 \times 0.06 \times 0.015 \text{ m}^3$. The convective heat transfer coefficient under forced convection greenhouse drying was found higher than the other modes.

6. CONCLUSION

Khoa occupies an important place among indigenous milk products. Khoa has considerable economic, dietary, and commercial significance to the Indian population. It forms an important base for preparation of variety of milk sweets which are an integral part of the Indian food heritage. From the literature, it has been observed that khoa is mainly being produced in unorganized sectors of India by following the conventional milk heating method which has many drawbacks. Thus various researchers

attempted to mechanize the khoa making process. Each researcher claimed that his equipment or process manufacture khoa successfully. But among them inclined scraped surface heat exchanger found industrial use. In this review article, a critical account of continuous khoa making methods, recent efforts on traditional milk heating process for khoa making, and the energy utilization during khoa production has been depicted. The various methods and materials used for packaging and storage of khoa to increase its shelf life have also been delineated.

REFERENCES

- [1]. Aneja, R.P., Mathur, B.N., Chandan, R.C., Banerjee, A.K., 2002, Technology of Indian milk products, Dairy India Yearbook, Priyadarshini Vihar, New Delhi, pp. 99-109.
- [2]. Gupta, P.R., 2007, Dairy India published by Dairy India Yearbook, New Delhi.
- [3]. Kanawjia, S.K., 2008, Value addition to buffalo milk, present scenario and future prospects, Dairy Year Book, Sadhna Publications, India, pp. 57.
- [4]. Bhasin, N.R., 2007, From the President's desk, Indian Dairyman, 59 (80), pp. 3-4.
- [5]. Bhasin, N.R., 2010, From the President's desk, Indian Dairyman, 62 (9), pp.10-11.
- [6]. Bhasin, N.R., 2011, From the President's desk. Indian Dairyman, 63(10), pp. 6-7.
- [7]. Mishra, A., Shukla, D.C., 2010, Somatotropin to augment milk production, Indian Dairyman, 62 (7), pp. 56-61.
- [8]. Annual Report, 2010-2011, Department of Animal Husbandry, Dairying and Fisheries, Ministry of Agriculture, Government of India, New Delhi, pp. 10.
- [9]. Reddy, P.N., 2007, Regulations for milk and milk products in Dairy India, Published by P.R. Gupta (6th ed), Thomson Press (India) Limited, New Delhi, pp. 455-463.
- [10]. Kumar, M., Prakash, O., Kasana, K.S., Dabur, R.S., 2010, Technological advancement in khoa making, Indian Dairyman, 62, pp. 64-70.
- [11]. Banerjee, A.K., 1997, Process for commercial production, in 'Dairy India' P. R. Gupta (ed), Baba Barkha Nath Printers, New Delhi, pp. 387.

- [12]. Rajarajan, G., Kumar, C.N., Elango, A., 2007, Distribution pattern of moulds in air and khoa samples collected from different sections of khoa plants, *Indian Journal of Dairy Science*, 60(2), pp. 133-135.
- [13]. Kulkarni, R.V., Hembade, A.S., 2009, Occupational pattern of khoa producers in Beed district of Maharashtra State, *International Research Journal*, 1(7), pp. 14-15.
- [14]. Solanki, P., Dabur, R.S., Masoodi, F.A., 2002, Storage study of microwave treated burfi, *Indian Food Packer*, pp. 153-157.
- [15]. Pal, D., 2008, New innovations in the processing of traditional Indian dairy products, *Indian Dairyman*, 60(3), pp. 127-131.
- [16]. Kamble, K., Kahate, P.A., Chavan, S.D., Thakure, V.M., 2010, Effects of pine-apple pulp on sensory and chemical properties of burfi, *Veterinary World*, 3(7), pp. 329-331.
- [17]. Rajorhia, G.S., Srinivasan, M.R., 1979, Technology of khoa- a review, *Indian J. Dairy Sci.*, 32(3), pp. 209-216.
- [18]. Bandyopadhyay, P., 2006, Technological advancement on traditional Indian desiccated and heat coagulated dairy products, *Indian Dairyman*, 58(11), pp. 59-65.
- [19]. Gupta, S.K., Agrawala, S.P., Patel, A.A., Sawhney, A.K., 1987, Development of equipments for indigenous dairy products, *Indian Dairyman*, 39(9), pp. 419-425.
- [20]. Banerjee, A.K., Verma, I.S., Bagchi, B., 1968, Pilot plant for continuous manufacture of khoa, *Indian Dairyman*, 20, pp. 81-86.
- [21]. De, S., Singh, B.P., 1970, Continuous production of khoa, *Indian Dairyman*, 2(12), pp. 294-298.
- [22]. Rajorhia, G.S., Srinivasan, M.R., 1975, Annual Report, National Dairy Research Institute, Karnal, pp. 203.
- [23]. Sawhney, I.K., Sarma, S.C., Kumar, B., Rajorhia, G.S., 1980, Development of village level khoa-pan, *Journal of Institution Engineers, India*, 61, pp. 613-618.
- [24]. Sawhney, I.K., Kumar, B., Singh, Y., 1984, Flow characteristics of khoa at different stages of processing, *Journal of Food Science and Technology*, 21, pp. 381-385.
- [25]. Sawhney, I.K., Kumar, B., 1986, Adoption and popularization of mechanized khoa pan, Annual Report, National Dairy Research Institute, Karnal, pp. 57.
- [26]. More, G.R., 1987, Development of semi-mechanized khoa making equipment, *Indian J.Dairy Sci.*, 40(2), pp. 246-248.
- [27]. Agrawala, S.P., Sawhney, I.K., Kumar, B., 1987, Development of conical process vat for viscous milk products, Annual Report, National Dairy Research Institute, Karnal, pp. 67.
- [28]. Christie, I.S., Shah, C.M., 1988, Feasibility studies on prototype of khoa making machine, *Beverage and Food World*, 3, pp.15-16.
- [29]. Christie, I.S., Shah, C.M., 1990, Development of khoa making machine, *Indian Dairyman*, 42, pp. 249-251.
- [30]. Christie, I.S., Shah, C.M., 1992, Development of a three stage continuous khoa making machine, *Indian Dairyman*, 44, pp. 1-4.
- [31]. Rizvi, S.S.H., Mann, R.S., Ali, S.I., 1987, A case study of appropriate technology transfer: development of an automated, continuous khoa powder manufacturing process, *Indian Dairyman*, 39(2), pp. 63-67.
- [32]. Pal, D., Cheryan, M., 1987, Application of reverse osmosis in the manufacture of khoa process optimization and product quality, *Journal of Food Science and Technology*, 24, pp. 233-238.
- [33]. Abichandani, H., Sarma, S.C., 1985, Heat transfer correlations for mechanically formed thin film heat exchangers, Annual Report, National Dairy Research Institute, Karnal, pp. 60.
- [34]. Abichandani, H., Sarma, S.C., 1988, Heat transfer and power requirements in horizontal thin film scraped surface heat exchanger, *Chemical Engg. Sci. (U.K)*, 10(2), pp. 71-80.
- [35]. Dodeja, A.K., Sarma, S.C., Abichandani, H., 1990, Heat transfer during evaporation of milk to high solids in thin film scraped surface heat exchanger, *Journal of Food Processing Engineering*, 12, pp. 211-225.
- [36]. Dodeja, A.K., Abichandani, H., Sarma, S.C., Pal, D., Verma, R.D., 1990, Performance of thin film scraped surface heat exchanger for continuous manufacture of khoa, *Indian J.Dairy Sci.*, 43(4), pp. 625-627.
- [37]. Punjraath, J.S., Veeranjanyulu, B., Mathunni, M.I., Samal, S.K., Aneja, R.P., 1990, Inclined scraped surface heat exchanger for continuous khoa making, *Indian J.Dairy Sci.*, 43(2), pp. 225-230.

- [38]. Abichandani, H., Sarma, S.C., 1991, Evaporation in a horizontal thin film scraped surface heat exchanger, *Journal of Food Processing Engineering (USA)*, 14(3), pp. 173-188.
- [39]. Dodeja, A.K., Abichandani, H., Sarma, S.C., Pal, D., 1992, Continuous khoa making system- design, operation and performance, *Indian J.Dairy Sci.*, 45(12), pp. 671-674.
- [40]. Kumar, A., Agrawala, S.P., Dodeja, A.K., Pal, D., 2009, Effect of modifications in the 3rd stage scraped surface heat exchanger for continuous khoa production, *Indian Journal of Dairy Science*, 62(3), pp. 175-181.
- [41]. Bhadania, A.G., Shah, B.P., Shah, U.S., 2005, Energy requirement of scraped surface heat exchanger during khoa manufacture, *J. of Institution Engineers, India*, 86, pp. 13-17.
- [42]. Dande, K.G., Gaikwad, S.M., Mushtaq, S.A.K., 2011, Utilization of solar energy in dehydration of milk and the manufacturing of khoa, *African journal of food science*, 5(15), pp. 814-816.
- [43]. Dodeja, A.K., Deep, A., 2012, Mechanized manufacture of danedar khoa using three stage SSHE, *Indian journal of dairy science*, 65(4), pp. 274-284.
- [44]. Kumar, M., Kasana, K.S., Kumar, S., Prakash, O., 2011, Experimental study on heat and mass transfer for heating of milk, *Journal of Energy in Southern Africa*, 22(3), pp. 45-53.
- [45]. Kumar, M., Prakash, O., Kasana, K.S., 2012, Experimental investigation on natural convective heating of milk, *Journal of Food Process Engineering*, 35(5), pp. 715-726.
- [46]. Kumar, M., Kumar, S., Kasana, K.S., Prakash, O., 2012, Evaluation of the evaporative heat transfer coefficients during sensible heating of milk, *S-JPSET*, 3(1), pp. 1-6.
- [47]. Kumar, M., Prakash, O., Kasana, K.S., 2011, An Experimental Study on Pool Boiling of Milk, *Heat Transfer- Asian Research*, March, 2011, 40(2), pp. 159-170.
- [48]. Kumar, M., Prakash, O., Kasana, K.S., 2011, Experimental study on pool boiling heat transfer coefficient of milk, *Scientific Journal FACTA UNIVERSITATIS Series Mechanical Engineering*, 9 (1), pp. 61-70.
- [49]. Kumar, M., Kasana, K.S., Kumar, S., Prakash, O., 2011, Experimental Evaluation of Constants for the Rohsenow Pool Boiling Correlation for Khoa, *S-JPSET*, 2011, 2 (1), pp. 21-25.
- [50]. Kumar, M., Kasana, K.S., Kumar, S., Prakash, O., 2010, Evaluation of convective heat transfer coefficient for pool boiling of milk under closed condition, *S-JPSET*, 1(2), pp. 91-99.
- [51]. Kumar, M., Kasana, K.S., Kumar, S., Prakash, O., 2011, Pool Boiling of Milk in a Stainless Steel Pot under Closed Conditions, *International Journal of Current Research*, 3 (8), pp. 94-99.
- [52]. Agrawala, S.P., More, G.R., Kumar, B., Sawhney, I.K., 1987, Energy management in processing of milk and milk products, I.S.A.E, Monograph series no. 1., National conference on energy in production, agriculture and food processing. PAU Ludhiana, India.
- [53]. Verma, R.D., 1988, Energy conservation in dairy processing, *Indian Dairyman*, 40(12), pp. 679-689.
- [54]. Verma, R.D., Lal, G., 1989, Energy analysis in Indian dairy products processing, *Indian J. Dairy Sci.*, 42(3), pp. 608-610.
- [55]. Solanki, D.C., Dutta, S., Bandyopadhyay, P., 2002, Cost effectiveness of various khoa manufacturing methods, *Indian Dairyman*, 54(5), pp. 29-33.
- [56]. Mahalingaiah, L., Venkateshaiah, B.V., Kumar, H.A., Venkatesh, M., Rao, K.J., 2008, Energy conservation in manufacture of traditional products, *Indian Dairyman*, 60(5), pp. 27-31.
- [57]. Kumar, M., Kumar, S., Prakash, O., Kasana, K.S., 2012, Energy requirements in manufacture of khoa-a heat desiccated milk product, An international conference on energy security, global warming and sustainable climate, *SOLARIS*, Varanasi, India, pp. 174-179.
- [58]. Kumar, M., Kasana, K.S., Kumar, S., Prakash, O., 2011, Energy requirements in manufacture of khoa under closed condition, *International Journal of Mechanical Engineering Research and Development*, 1(1), pp. 33-40.
- [59]. Bhat, J.V., Sethna, K., Fernandes, F., 1948, Chemical and microbiological studies on mawa, *Indian J. Dairy Sci.*, 1, pp. 49-58.

- [60]. Sethna, K., Bhat, J.V., 1949, Irradiation as a method for preserving mawa, *Indian J. Dairy Sci.*, 2, pp. 12-15.
- [61]. De, S., Ray, S.C., 1952, Studies on the indigenous method of khoa making, *Indian J. Dairy Sci.*, 5, pp. 147-165.
- [62]. De, S., Ray, S.C., 1953, Studies on the indigenous method of khoa making, *Indian J. Dairy Sci.*, 6, pp. 47-60.
- [63]. Rudresppa, K.G., De., S., 1971, Studies on preservation of khoa, *Journal food science and Technology*, 8, pp. 50-52.
- [64]. Kumar, A., Rajorhia, G.S., Srinivasan, M.R., 1975, Effect of modern packaging materials on the keeping quality of khoa, *J. Food Sci. Tech.*, 12, pp. 172-177.
- [65]. Rao, O.V., Singh, S., Singh, S., 1977, Effect of packaging materials on the keeping quality of khoa, *J. Food Sci. Tech.*, 14(4), pp. 152-156.
- [66]. Kumar, G., 1978, PhD Thesis, K.U., Kurukshetra.
- [67]. Goyal, G.K., Srinivasan, M.R., 1989, Protective role of packaging materials in refrigerated conditions on the microbiological quality of khoa, *Asian Journal Dairy Res.*, 8(2), pp. 95-99.
- [68]. Sharma, H.K., Singhal, R.S., Kulkarni, P.R., 2001, Effect of packaging under vacuum or under nitrogen on the keeping quality of Danedar khoa, *International Journal of Dairy Technology*, 54(3), pp. 107-110.
- [69]. Acharya, P.P., Agrawal, J., 2010, Effect of packaging materials and modified atmosphere packaging on the shelf life of khoa, *Nepal journal of science and technology*, 11, pp. 87-94.
- [70]. Ghodekar, D.R., 1969, M.Sc. Dissertation, Bombay University, Bombay.
- [71]. Jha, Y.K., Singh, S., Singh, S., 1977, Effect of antioxidants and antimicrobial substances on keeping quality of khoa, *Indian J. Dairy Sci.*, 30, pp. 1-6.
- [72]. Kalra, M.S., Laxminaraya, H., Dudani, 1977, Use of nisin for extended shelf life of processed cheese and khoa, *Journal food Sc.*, 10(3), pp. 92-94.
- [73]. Patel, K.H., Pardesh, B.S., Sharma, R.S., 1985, Effect of sodium and potassium meta-bisulphites on the shelf life of khoa, *Asian J. Dairy Res.*, 4(2), pp. 89-96.
- [74]. Jha, Y.K., Verma, N.S., 1988, Effect of potassium sorbate on shelf life of khoa, *Asian J. Dairy Res.*, 7(4), pp. 195-198.
- [75]. Wadhwa, B.K., Gandhi, D.N., Goyal, G.K., 1993, Enhancement in the shelf life of khoa, *Indian Food Packer*, 47, pp.53-55.
- [76]. Rahman, Z., Salariya, A.M., 2006, Effect of synthetic antioxidants on storage stability of Khoa - a semi-solid concentrated milk product, *Food Chem.*, 96(1), pp. 122-125.
- [77]. Kumar, M., Beniwal, B.S., Rai, D.C., 2010, Effect of antioxidants on shelf life of khoa under refrigerated conditions, *Egyptian Journal of Dairy Science*, 38(2), pp. 211-218.
- [78]. Davies, W.L., 1940, *Indian Indigenous Milk Products*, 2nd edition, Thacker, Spink and Company Pvt. Ltd., Calcutta.
- [79]. Naidu, K.A., Ranganathan, B., 1965, Studies on microbiological deterioration of khoa. *Indian J. Dairy Sci.*, 18, pp. 4-9.
- [80]. Nareshkumar, C., Kumaresan, G., Saravanan, K., 1996, Incidence of moulds in khoa. *Indian J. Dairy Sci.*, 49, pp. 462-464.
- [81]. Chavan, K.D., Kulkarni, M.B., 2006, Solar radiation-an effective approach for khoa preservation, *J. Dairying, Foods & H.S.*, 25(3/4), pp. 182-185.
- [82]. Chavan, K.D., Kulkarni, M.B., 2006, Effect of solar radiation and microwave heating on microbiological quality of khoa, *Indian J. Dairy Sci.*, 59(5), pp. 291-295.
- [83]. Kumar, M., Kasana, K.S., Kumar, S., Prakash, O., 2011, Experimental investigation on convective heat transfer coefficient for khoa drying, *International journal of current research*, 3(8), pp. 88-93.

