Chapter 14
Modernization of Manufacturing Process for Traditional Indian Dairy Products

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14.1 Introduction

A wide variety of traditional dairy delicacies, drawn from different regions of the country, are produced in India using processes such as heat and/or acid coagulation, desiccation and fermentation. These products play a significant role in the economic, social, religious and nutritional functions of the Indian masses. The total milk production in India for 2013–2014 was 137.7 million tonnes (DAHDF 2015). It is estimated that about 50–55 % of milk produced is converted by the traditional sector into variety of Indian milk products (Patil 2005). The increased availability

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of milk during the flush season coupled with the need to preserve it for long-distance transportation and marketing makes conversion of milk into traditional products particularly an attractive commercial proposition and great employment opportunities in the countryside. These traditional dairy products are classified based on the principles involved in their manufacture and could be an intermediate base for subsequent conversion into a wide varieties of delicacies or could be consumed as such in the form of the finished products (Table 14.1). The traditional methods of manufacture of these products have evolved over a long period and quality often depends on the skills of homemakers or local confectioners (*Halwais*). They generally use the batch methods for product preparation which results in higher processing cost and reduced energy efficiency. Due to production in small quantities, the local confectioners are limited to localized marketing. The chemical composition and organoleptic properties of traditional milk products also vary significantly depending on the skills of the workforce involved in its manufacture. With globalization of dairy trade and focus of the local industry on quality and consumer satisfaction, many large industries have taken to mechanized manufacture of these products on large scale. However, mechanization of the manufacturing process of these traditional dairy products is a very challenging task as the traditional processes involved in their manufacture are tailored to facilitate development of unique flavour and texture attributes in the product. Simulating these quality attributes in a product delivered by the mechanized process requires unique design considerations and manipulation of technological parameters and residence times. Systematic efforts have been made through novel approaches to either develop new mechanized equipment or adapt existing equipments for developing a continuous line for the manufacture of many traditional Indian milk products (Sharma et al. 2003).

14.2 The Products

14.2.1 Khoa

Khoa refers to an intermediate milk product traditionally obtained by desiccating milk over gentle heat until a thick viscous concentrate is formed. It serves as a base material for some of the most popular varieties of sweetmeats such as burfi, peda, gulab jamun, milk cake and kalakand. The Prevention of Food Adulteration Act (PFA) recommends that a good quality khoa must confirm to not less than 30 % milk fat on dry weight basis. To meet this regulatory norm, the minimum level of fat desired in buffalo milk should be 5.5 % while in cow milk it should be 4 % (Pal and Raju 2007). Generally, buffalo milk is preferred for the manufacture of khoa as it has larger proportion of butyric acid-containing triglycerides, and there is more release of free fat responsible for smooth and mellow texture which are desirable attributes in khoa (Sindhu 1996). Khoa made from cow milk lacks these characteristics and has moist surface, salty taste and sticky and sandy texture which are considered undesirable for the preparation of sweetmeats.

Table 14.1 Overview of classification of major Indian dairy products

Process	Product	Product type	Similar western product	Description
Heat desiccation	*Khoa*	Intermediate	Evaporated milk	*Khoa* has a dough like consistency and is prepared by continuous boiling of milk until desired concentration of solids (65–72 % TS) and texture are attained. It is used as a base material for a variety of popular sweetmeats, such as *burfi*, *peda*, and *gulab jamun*
Heat acid coagulation	*Chhana*	Intermediate	Lactic coagulated cheese	*Channa* is obtained by heating milk followed by cooling and acidifying it with suitable organic acid. It is the base material for the preparation of *rasogulla*, *sandesh*, *rasomalai,* etc. *Channa* with 50–60 % moisture content is preferred for sweetmeat preparation
	Paneer	Intermediate and Final	Soft cheese	*Paneer* refers to an indigenous variety of acid coagulated soft cheese. It forms base for a variety of culinary dishes, stuffing material for various vegetable dishes, snacks and sweetmeats
Fermentation	*Shrikhand*	Final	Sweetened quarg	Traditional fermented and sweetened milk product of Indian origin. It is prepared from solids (*Chakka*) recovered by draining the whey from lactic fermented curd. Sugar, cream and other ingredients like fruit pulp, flavour and colour are blended with C*hakka* to get semi-solid consistency
Heat clarification	*Ghee*	Final	Butter oil	*Ghee* is heat clarified butter fat for table use or as a frying medium. Apart from dietary usage, ghee is also used for performing religious rites

(a) *Traditional Method*: Buffalo milk (4–6 L) is boiled over direct fire in a shallow pan (mild steel) with vigorous stirring and scrapping. Within 5–10 min, a semi-solid mass having dough consistency is formed (Punjrath 1991).
(b) *Improved Methods*: *Khoa* manufactured by traditional method suffers from poor and inconsistent quality of the product. Attempts have been made to mechanize the production process of *khoa* using both the batch and continuous type plants (Aneja et al. 2002). These advances for commercial production of *Khoa* have been summarized in Table 14.2. Rajorhia et al. (1991) made a comparative study of quality of *khoa* prepared from different mechanical systems such as inclined scraped surface heat exchanger (ISSHE), conical vat, convap–contherm and roller dryer. Quality score was highest for ISSHE followed by roller dryer, conical vat and convap–contherm process.

Khoa has a great market demand but due to its short shelf life (5 days at 30 °C) it cannot be marketed over long distances. In the absence of proper packaging, the loss of moisture from the product adversely influences the texture and enhances the rate of chemical deterioration such as oxidation and browning. With the use of four-ply laminated pouches and tin containers, the shelf life of *khoa* can be increased up to 13 days at 30 °C and 75 days under refrigerated storage. Sterilization of packaging such as Polypack™ (Pitram Pura, Delhi, India) with gamma radiation using CO^{60} prior to product filling proved to be beneficial. Addition of 0.3 % potassium sorbate at the last stage of *khoa*-making increased the shelf life of *khoa* by another 10 days. Vacuum packaging of *khoa* could enhance the shelf life up to 120 days under refrigerated storage (Rajorhia et al. 1984).

14.2.2 *Chhana*

Chhana is a heat acid coagulated product having marble white colour, spongy texture with mild acidic flavour. It is used as a base material for manufacturing a large variety of sweets such as *Rasogolla*, *Sandesh*, *Rasomalai*, *chum chum* and *chhana murki*. Cow milk is preferred for manufacturing *chhana* as the product obtained is soft with smooth texture and velvety body which are highly desirable attributes for making *chhana*-based sweetmeats particularly *rasogolla*. Buffalo milk *channa* is generally hard and greasy because of inherent differences in qualitative and quantitative aspects of buffalo milk. However, technological interventions have been successfully employed to overcome these defects.

1. *Traditional Method*: Traditionally, cow milk is taken in a pan (2–40 L/batch) and is coagulated at high temperature (70 °C) using sour whey, but some organic acids such as citric acid, lactic acid and calcium lactate may also be used (Mathur 1991; Das 2000). Whey is then drained by straining through a muslin cloth. But in this method the yield is low due to draining of whey protein along with whey.

Table 14.2 Developments in mechanization of process for *khoa*-making in chronological order

Sl. No	Work done/ reported by	Description	Type of operation
1.	Banerjee et al. (1968)	The pilot plant has a scraped surface heat exchanger (SSHE) and two open semi-jacketed pans with reciprocating spring loaded scraper (Fig. 14.3). Milk with 12–13 % total solids (TS) is pumped into SSHE for concentration to 30–35 % TS. The first stage of the open semi-jacketed pan further concentrates the milk to 50–55 % TS. The final concentration to 70–75 % TS is achieved in the second pan. The equipment has a capacity of 50 L of milk per hour	Semi-continuous
2.	More (1985)	SSHE consists of a semi-jacketed drum with vapour exhaust. The scraper assembly comprises of central shaft and spring loaded blades with rubber boots (Fig. 14.4)	Semi-continuous
3.	Agrawala et al. (1987)	Conical process vat consists of stainless steel conical vat with cone angle of 60° with steam jacket partitioned into four segments for efficient use of thermal energy and less heat loss (Fig. 14.5). The mechanism consists of 3-equidistant arms supported at two points in the shaft and each arm having three independent spring loaded blades for scraping. A positive displacement screw pump is connected at the outlet of the vat for recirculation and spreading of the product over heat transfer surface	Batch
4.	Christie and Shah (1990)	It consists of a single stage SSHE, with silts on the top with hopper to collect foam during *khoa* manufacturing (Fig. 14.6). The steam jacket is provided at the lower part of the SSHE. Spring loaded scraper blades help in uniform milk heating and spreading. The equipment has a capacity of 50 L of milk per hour	Batch
5.	Punjrath et al. (1990)	Inclined scraped surface heat exchanger (ISSHE): In this machine, concentrated milk of 42–45 % total solids is used as feed. The inclination of ISSHE permits formation of a pool of boiling milk critical to formation of *Khoa* (Fig. 14.7). By varying the total solids, temperature and flow rate of feed, scraper speed and angle of inclination, product characteristics can be varied to meet the functional requirements	Continuous
6.	Patel (1991)	Double jacketed kettles. Heating is done through steam	Batch
7.	Verma and Dodeja (2000)	Two SSHEs are arranged in a cascade fashion (Fig. 14.8). Milk is concentrated into first SSHE to about 40–45 % TS and finally to *Khoa* in the second SSHE	Continuous
8.	Rajorhia (1995)	Roller drier can be used for preparing *khoa* by adjusting process variables such as steam pressure, roller speed, concentration and flow rate of milk and by changing the distance between the rollers and scrapper blades. Vacuum concentrated milk with 50 % total solids preheated to 74 °C for 10 min was found suitable for *khoa*-making on roller driers at 25–30 psi. A kneader is placed at the outlet of roller drier to make homogenous mass of *khoa*	Continuous
9.	Alfa laval Convap–contherm process (Aneja et al. 2002)	Concentrated milk from SSHE is pumped through a holding tube to impart desirable texture and flavour	Continuous

2. *Improved Methods*:

   (a) *Ultrafiltration Process*: Application of Ultrafiltration (UF) process for *Chhana* manufacture resulted in 18–19 % extra yield due to higher recovery of whey proteins. In this process, heat-treated (92 °C for 5 min) skim milk is subjected to ultrafiltration followed by diafiltration (23 % TS) and the resultant retentate is mixed with plastic cream. The mixture is heated to 90 °C for 5 min and coagulated with lactic acid to develop soft coagulum. The granular mass is pressed to remove free moisture, yielding *Chhana* (Sharma and Reuter 1991).

   (b) *Continuous Method*: It involves following steps (Singh 1994):

   - Indirect heating of milk in a tubular heat exchanger to 95 °C
   - Cooling to 70 °C
   - Continuous coagulation with hot citric acid (70 °C) in a vertical tube
   - Holding milk–acid mixture to permit complete coagulation
   - Separation of whey in a continuous flow employing double wall basket centrifuge
   - Chilling to 4 °C by directly spraying chilled water on the layer of *Chhana*

   (c) *Casein Process*: Continuous casein making equipment can be adopted for large-scale production of *chhana* (Rajorhia 1995). Certain modifications of equipment required are:

   - Intake of milk at 70 °C instead of 35 °C
   - Strength of coagulant and milk to obtain a pH of 5.1
   - Adequate residence time to effect co-precipitation of casein and whey proteins together with fat
   - Mechanical removal of whey using a basket centrifuge or provision of additional vibrating screen as *chhana* drains too slowly
   - Washing of coagulum once with potable water followed by pressing to retain about 60 % moisture in the finished product
   - Arrangement for bulk packaging to synchronize with product delivery

14.2.3 Paneer

Paneer represents one of the semisoft varieties of the Queso-blanco type of cheese having a high moisture content of 50–60 % (Pal 2002). It is obtained by heat and acid coagulation of milk. It is consumed either in raw form or used in preparation of several varieties of culinary dishes and snacks. Good quality *paneer* has a characteristic white colour, sweetish, mildly acidic, nutty flavour, spongy body and close knit texture. Buffalo milk is considered more desirable for *paneer* manufacture as the product obtained has all these attributes. Buffalo milk also offers higher *paneer* yield due to higher total solids in it. Higher concentration of casein in the micelle state with bigger size, harder milk fat due to larger proportion of high melting triglycerides in it and higher content of total and colloidal calcium are responsible for producing desired quality of *paneer*. On the contrary, cow milk paneer has very compact and fragile body and its pieces may get disintegrated and loose their identity during cooking. The yield of *paneer* made from cow milk is also low as compared with buffalo milk (Pal and Raju 2007).

1. *Traditional Method*: Buffalo milk is standardized to 5.5 % fat and heated to around 90 °C. After coagulation with citric acid at 70–85 °C, a coagulum of casein–whey protein complex with entrapped fat is formed. Free whey is drained and coagulated mass is pressed in cloth-lined hoops. The coagulum knits together into a compact spongy mass under pressure. After removing from the hoops, blocks are placed in chilled water for firming. Blocks are cut into smaller pieces and are loosely placed in polythene bags for retail sale (Mathur 1991).

2. *Improved Methods*:

   (a) *Ultrafiltration Process*: Ultrafiltration (UF) when employed for *paneer* manufacture offers advantages of mechanization, uniform quality, improved shelf life, increased yield and a nutritionally better product. The process involves standardization and heating of milk followed by UF whereby lactose, water and some minerals are removed (Sachdeva et al. 1993). UF of milk and the removal of permeate are synonymous to removal of whey by coagulation in conventional method. The concentrated mass, which has about 40 % total solids, is cold acidified to get the desired pH. Texturization is achieved in a continuous process by using microwave tunnels. Such tunnels comprise of a series of magnetrons under which the product moves continuously on the conveyor belts. The resulting product has typical characteristics of normal *paneer* (Pal 2005).

   (b) *Nanofiltration Technique*: *Paneer* prepared from normal cow milk has hard, compact and dry characteristics. Nanofiltration of cow's milk helped to minimize these defects and produced better quality *paneer*, but imparted excessive brittleness. *Paneer* prepared from nanofiltered milk has higher moisture retention resulting in higher yield (Pal et al. 2002).

   (c) *Centrifugal Method*: After coagulation of milk (at 70 °C) using citric acid, primary whey is drained using gravity separation through muslin cloth. The coagulum is subjected to centrifugal pressing by double wall basket centrifuge at 30–60 °C to remove the residual whey. The pressed coagulum is chilled inside the basket centrifuge by chilled water at 4 °C for better body and textural characteristics. Pressing and chilling of coagulum by centrifugal method considerably reduces time for production of *paneer* (Agarwal 1996; Das 2000).

   (d) *Continuous Method*: Impact type device can compress blocks of coagulum to form *paneer* which could be taken out at regular intervals. For the pressing, coagulum is kept in cages made from a special type of screen and the cages are subjected to impact forces (Das and Das 2009).

(e) *Processed Paneer*: Processed *paneer* production is an attempt primarily aimed at evolving a product, which in its physico-chemical, sensory and functional characteristics has as close a resemblance as possible with the processed cheese. It has a lower cost relative to the western processed natural cheeses and can offer a variety in flavour, consistency and functionality. For manufacturing processed paneer, NaCl 0.5 %, emulsifying salt and flavour is mixed with shredded or comminuted paneer at 80 °C for 5 min. The mix is filled into moulds and cooled. Depending upon the type and intensity of the flavour desired, various dairy and non-dairy additives can be added (Pal 2002).

14.2.4 Shrikhand

1. *Shrikhand* is a very popular traditional fermented and sweetened milk product of India. It is prepared by lactic acid coagulation of milk and expulsion of whey from the curd followed by blending with cream, sugar, flavour and spices. *Shrikhand* has a typical semi-solid consistency showing characteristics firmness and pliability contributing to its suitability for consumption with "*Puree*" or "*Chapati*". The consistency is influenced to a great extent by the moisture, fat and sugar levels. Its colour varies from yellowish white to marble white depending on the type of milk used. *Shrikhand* has been traditionally prepared by homemakers or on small scale by the confectioners (*Halwais*). According to Prevention of Food Adulteration Act (PFA) of India, *shrikhand* shall contain not less than 8.5 % milk fat (on dry basis), not less than 9.0 % protein (on dry basis), and should not contain more than 72.5 % sugar (on dry basis). Same PFA standards imply to fruit *shrikhand* as for plain *shrikhand* except that the fat content in it shall not be less than 7.0 %. Buffalo milk is the preferred raw material for *shrikhand* as it has a high fat, SNF and Ca++ content. Fermentation of milk is accomplished by back-slopping, which contains mixed type of lactic acid bacteria. Higher fat content in milk is preferred as it produces a balanced delicate and pleasant flavour as well as desirable body and texture. *Chakka* (Quarg-like product) which serves as the base material is obtained by removal of whey from dahi (Yoghurt-like product). The quality of shrikhand depends significantly on the physical and chemical properties of *chakka*. Yield of *chakka* depends upon the heat treatment and total solids content of skim milk and starter culture (Aneja et al. 2002). The heating of milk to 85–90 °C for 16 s reportedly resulted in 24 % and 25 % yield of *chakka*, respectively. *Chakka* made from whole milk gives smooth body but leads to higher fat loss in whey, whereas skim milk *chakka* tends to be rough and dry.
2. *Traditional Method*: In the traditional method, buffalo or mixed cow milk is boiled and after cooling to room temperature (30–35 °C), it is inoculated with lactic culture and incubated for 6–8 h. When the curd is firmly set (acidity 0.9–1.0 %), it is placed in a muslin cloth bag and hung on a peg for drainage of whey for 6–8 h. The intermediate product (*chakka*) is used for the preparation of

shrikhand. The c*hakka* thus obtained is mixed with sugar, kneaded well and rubbed through a muslin cloth to give a smooth product. Colours, flavours and fruits are added to provide variety (Sharma 1998; Punjrath 1991).

3. *Improved Methods*:

   (a) *Industrial Process*: In this process, skim milk curd is centrifuged in a continuous quarg separator to produce *chakka*. It is mixed with cream, sugar and flavourings in a scraped surface heat exchanger for manufacture and pasteurization of *shrikhand*. The product is filled in preformed cups under semi-aseptic environment before retail trade. The process line developed by National Dairy Development Board (NDDB) for *shrikhand* production is shown in Fig. 14.1.

   (b) *Ultrafiltration Technique*: Skim milk is heated in a double jacketed vat with slow agitation. It is cooled to 21–22 °C and inoculated with mixed starter culture (i.e. *Streptococcus lactic*, *S. cremoris* and *S. diacetylactis*) at the rate of 0.1–0.15 %. Incubation time varies from 16 to 18 h at 21–22 °C so as to get curd pH of 4.6–4.5 and a pleasant diacetyl aroma. Rapid fermentation may alternatively be done with the help of yoghurt culture (*Streptococcus thermophilus* and *Lactobacillus bulgaricus*) requiring 4 h of incubation. After ultrafiltration, the retentate is pressed to get c*hakka*. *Chakka*, cream (70 % fat) and sugar are mixed in a planetary mixer (30–35 rpm) for half an hour to get a product with smooth texture, plastic body and a sweet-acidic flavour (Sharma and Reuter 1992; Sharma 1998). Addition of colour and flavour is optional. The process flow of *shrikhand* manufacture using ultrafiltration (UF) is shown in Fig. 14.2. The yield is 23.16 % higher in UF process as compared to traditional process because of better recovery of whey proteins.

   (c) *Reverse Osmosis* (*RO*) *Process*: This process involves heating of milk (90 °C for 5 min), application of RO, cooling to 22 °C, inoculation with 20 % mixed lactic culture, incubation for 18 h and then removal of whey by filtration to get c*hakka* (Sachdeva et al. 1994). Increased yield, higher solid recovery, reduced processing time, access to mechanization and alleviation of whey disposal problem are the major advantages of the process.

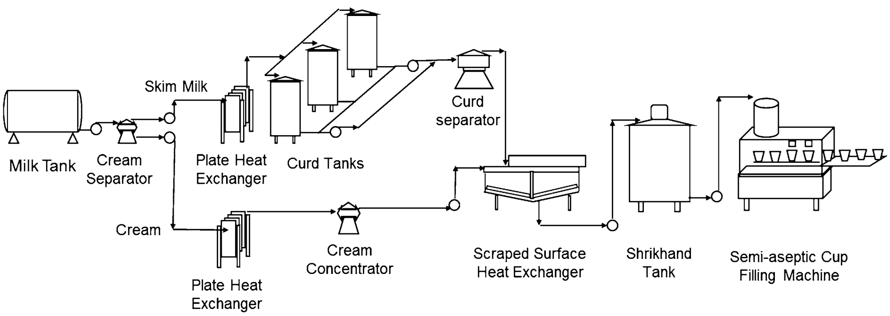

Fig. 14.1 Industrial method for Shrikhand production

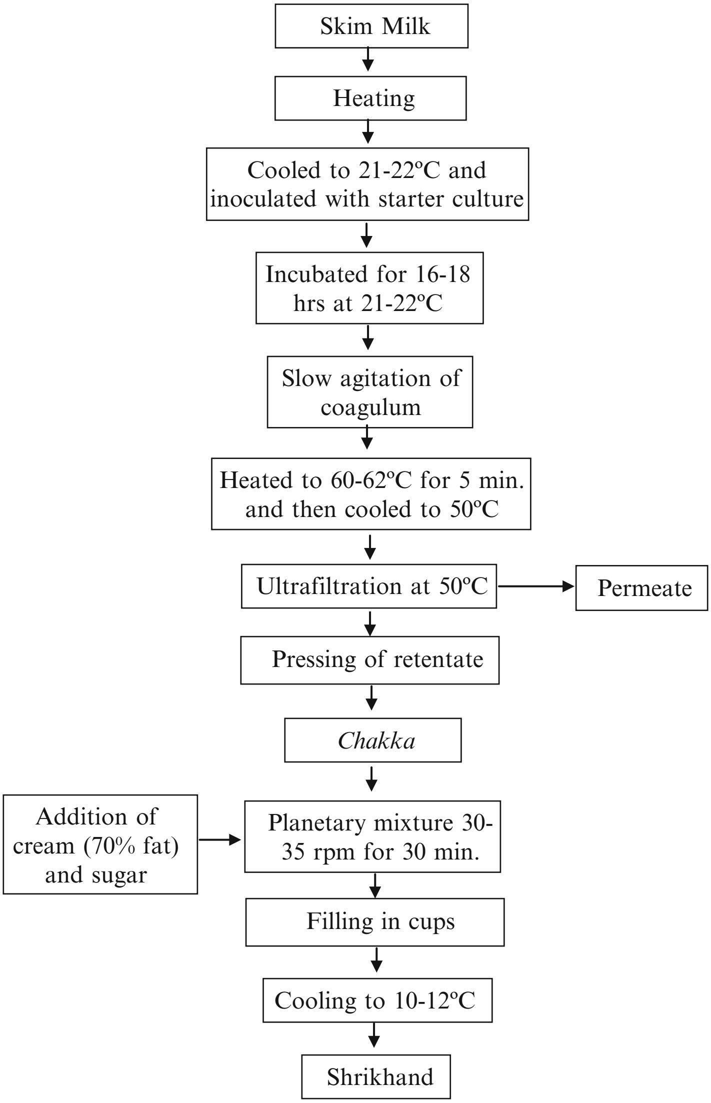

Fig. 14.2 Ultrafiltration process for Shrikhand production

14.2.5 Ghee

Ghee is clarified butter fat prepared from cow or buffalo milk. It has the largest share in trade of traditional Indian milk products. *Ghee* has an important place in Indian diets because of its characteristics flavour and pleasant aroma, besides being a source of fat-soluble vitamins. It is produced by heat desiccation and clarification of *makkhan*, butter or cream at 105–110 °C. *Makkhan* here refers to

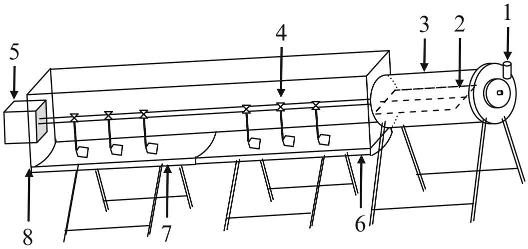

Fig. 14.3 Pilot plant for *Khoa*-making

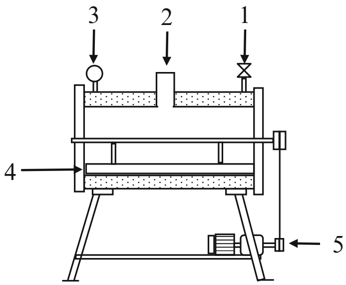

Fig. 14.4 Semi-continuous *Khoa*-making plant

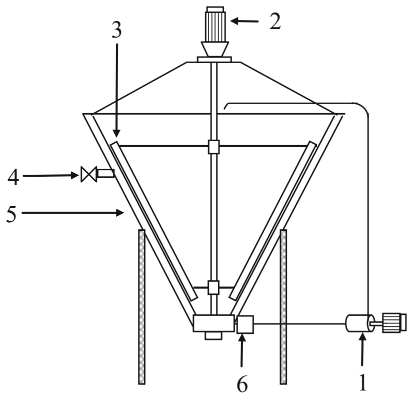

Fig. 14.5 Conical process vat

the country butter normally obtained by churning whole milk curd with crude indigenous devices. Heat-induced changes in milk protein/lactose during the clarification process impart a distinctive, pleasant cooked flavour to ghee (Aneja et al. 2002).

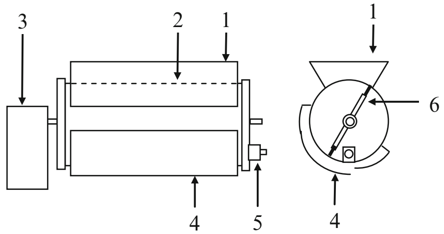

Fig. 14.6 *Khoa* making machine

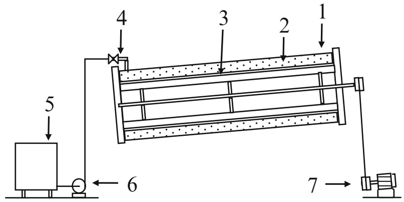

Fig. 14.7 Inclined scraped surface heat exchanger (ISSHE)

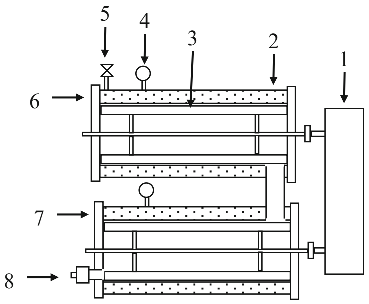

Fig. 14.8 Two-stage scraped surface heat exchanger (SSHE)

1. *Traditional Method*: Traditionally, *ghee* is produced at household level by fermenting the whole milk into curd and churning the curd to recover fat (indigenous butter) followed by heat clarification at 105–145 °C.
2. *Industrial Process*: In the industrial sector, *ghee* is manufactured by batch processes directly from cream or via cream-butter route or by the prestratification (Punjrath 1991; Mathur 1991).

   (a) *Direct Cream*: A steam jacketed kettle of 500–1000 L capacity is generally employed. Heat clarification is done at 105–120 °C until entire moisture is removed. The curd particles become brown and characteristic *ghee* flavour is developed. After cooling and sedimentation, *ghee* is filtered to remove the sediment before packing in tin containers. Centrifugal *ghee* clarifier can also be used for removal of sediments and residues. Direct cream method yields a higher quantity of ghee residue and takes a much longer time. Cream is at times washed to reduce solids not fat (SNF) also known as *ghee* residue and to improve yield of *ghee*.

(b) *Cream-Butter Method*: This process involves churning of cream to obtain butter and heat clarification is done at 105–110 °C. Rest of the process is same as direct cream method.

(c) *Prestratification*: In the prestratification method, butter is melted at 80 °C and held for 30 min. Three layers are formed. The top layer being scum, middle layer of fat and bottom layer of butter milk serum. Removal of bottom aqueous layer helps in reduction of 70–95 % of the moisture, and also brings economy in steam consumption.

(d) *Continuous Ghee Making Machine*: Abhichandani et al. (1995) designed continuous *ghee* making machine by integrating continuous butter melter with scraped surface heat exchanger (SSHE). Butter (80–85 % fat) at 10 °C was fed into the butter melter and ghee was manufactured at 115–118 °C. Steam consumption was 35 kg per 100 kg of ghee which was 50 % lower compared to 68 kg per 100 kg of ghee required in jacketed steam kettle. Further modification was made and a ghee clarifier/bag filter system was used to remove ghee residues (Abhichandani 1997).

3. *Butter Oil Method*: *Ghee* can be manufactured from butter oil by incorporating curd/skim milk powder. The flavour quality of *ghee* and shelf life are comparable to dairy *ghee*. Curdy flavour can be simulated by employing low temperature clarification (105 °C) and by addition of cultured milk or curd powder at the time of heating (Rajorhia 1995). Cooked flavour can be simulated by clarification at 115 °C for 10 min or 120 °C for 5 min or 125 °C without any holding time.

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