**Design and Development of Controlled Cooling System for Dairy and Food Products: Present Need**

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| Er. Arpita Rathva, Dr. Sunil Patel, Er. Ravi Prajapati, Dr. I.A.Chauhan |
| Assistant Professor, Department of Dairy Engineering, S. M. C. College of Dairy Science, Kamdhenu University, Anand (Gujarat) – 388 110  \*Corresponding Author, E mail:arpitarathva1592@gmail.com |
| Professor, Department of Dairy Engineering, S. M. C. College of Dairy Science, Kamdhenu University, Anand (Gujarat)- 388 110 |
| Assistant Professor, Department of Dairy Engineering, G.N Patel College of Dairy Science, Kamdhenu University, Sardarkrushinager (Gujarat)- 388 110 |
| Assistant Professor, Department of Dairy Engineering, S. M. C. College of Dairy Science, Kamdhenu University, Anand (Gujarat) – 388 110 |

**Abstract**

*This paper presents present need for design and development of controlled cooling system for dairy products. Rheology of many dairy products are controlled by controlled cooling. Textural properties of most of dairy products are very important from consumers view point. Controlled cooling of ghee is very important to have different textural properties of ghee suitable for specific applications like, for ghari, beeryani, ladoo, application on chapati etc. But, in most of the dairies ghee is being cooled by default in the ghee kettle in all the season, which gives variation in the textural properties. Similarly, khoa which is the base for many khoa based sweets needs to develop controlled cooling system to have better textural properties. There are different verities of khoa i.e. dhap, pindi, & danedar, different verities of khoa has different textural properties and specific verities of khoa are used for making specific verities of khoa based sweets with better rheological properties, but still we need to develop controlled cooling system for khoa. Similarly, many other dairy products need controlled cooling system to offer better rheological and textural properties desired by consumer.*

***Keywords* – *Cooling system, Rheology, khoa, ghee, paneer,* \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

**I.Introduction**

Milk production in India progressively continues to increase every fiscal, making the country highest milk producer in world rankings since 2000 having milk production 221.1 Million tones with 444 per capita availability (gms/day) [1]. The lack of cooling facilities required to keep the milk fresh led to the diversion of milk for preparation of products with comparatively longer shelf life [2]. About 50-55 per cent of milk produced in India is converted into various milk products [3] but need to be mechanize production of Traditional Indian Dairy Products (TIDP) and there is urgent need to develop controlled cooling system for better rheological properties. According to ancient literature, physical and mental happiness of individual is based on the food consumed [4]. The consumption of TIDP is likely to grow and annual growth rate of more than 20 per cent [5,6]. Dairy and food items possess not just a well-established domestic market but also showcase significant export prospects owing to the considerable presence of the Indian diaspora across various global regions [7]. Mechanized production of many TIDP is today’s need and controlled cooling of such products results in to better rheological properties desired by consumer.

**II.Mechanization in Dairy and Food Processing**

Non-availability, poor availability or seasonal availability of raw materials too has influenced people to choose processed food products. Processing enables the increase in shelf life and also transportation of delicate perishable foods across longer distances. During processing, it should be taken care that value addition of processed foods such as TIDP, chips, juice, pudding, or any other product is minimally affected with making the foods safe to eat by deactivating spoilage and pathogenic microorganisms. Changing lifestyle, increased work pressure and nuclear families are leading to exponential increase in the demand of ready to cook/eat/drink processed food in developing countries like India increase the need of mechanization [8]. Advanced automation control system consisting of fieldbus technology, distributed control system and food safety inspection features are available for many of the food products. However, the manufacture of TIDP is mainly confined to the cottage scale in the unorganized sector and thus inherently suffer from several disadvantages i.e. insufficient use of energy, poor hygiene, non-uniformity in the final product, etc. In order to overcome these disadvantages, several attempts have been made for mechanization of the process to develop batch, semi-continuous and continuous equipment for manufacture of these products on large and commercial scale [9]. Still lot of work is needed in the area of developing controlled cooling system and innovative packaging system.

**III.Importance of Cooling**

Manufacturing procedures that utilize heat for ingredient processing frequently necessitate specialized cooling systems to enhance the final product's quality concerning its texture and rheological properties. A cooling phase might be necessary before proceeding with other stages of production when dealing with processes that include cooking, roasting, or melting of components. Certain components necessitate elevated temperatures for manipulation or shaping and subsequently demand specialized cooling to solidify or revert to the intended viscous condition or texture. A variety of cooling methods can be used, including forced air, chilling, ambient mixing and these methods can use belts, drums, cabinets and other enclosures to maintain cooling performance. Many food products are sensitive to a freezing rate in that it can affect yield, quality, nutritional value, and sensory properties. Holding milk at temperatures below 4°C and above freezing maintains its excellent quality until it is processed or manufactured in to products. Cooling of different product by control rate is integral part of mechanization. Some TIDP must require control cooling to get desired texture e.g. *thabdi*, to get the soft and desired size of grains. Similarly, in ghee fat crystallization is important property in final product, so that control cooling rate of heated ghee is important for achieving desired grainy texture. Mechanized cooling of *khoa* will reduced the cooling time and also increase the capacity of plant with hygienic production that will help in fulfilling the market demand.

Traditional cooling methods use either air or water to remove heat from food via a combination of conduction and convection heat transfer. These methods have been around for decades, but they have several limitations. It can take longer time to cool food products using forced air circulation or jets of water, during which the bacteria can continue to multiply, and the cooling medium (air or water) may itself become contaminated with harmful microorganisms unless strict precautions are taken. Conventional cooling also produces an uneven temperature distribution, with food products at the surface being cooled more quickly than those at the center. Therefore, there is an urgent need to design and develop controlled cooling system for commercial applications to manufacture dairy products with better rheological quality.

**IV.Different Cooling Methods and their Effect on Dairy Product Quality**

As per Food Safety and Standards Authority of India (2011) *khoya* by whatever variety of names it is sold such as *pindi, danedar, dhap, mawa* or *kava* means the product obtained from cow or buffalo or goat or sheepmilk or milk solids or a combination thereof by rapid drying. The milk fat content shall not be less than 30 per cent on dry weight basis of finished product. It may contain citric acid not more than 0.1 per cent by weight. It shall be free from added starch, sugar and coloring matter. Each year, approximately 600,000 tons of khoa is produced, accounting for around 7% of India's total milk output [10,2]. *khoa* is a rich source of energy and provides about 1914.4kJ per 100g of the product.

Traditionally, open pan evaporation process is followed for preparation of *khoa* and requires large amount of energy. In rural India, use of open *chulah* as fuel for *khoa* making which is hardly 8-10 per cent thermally efficient. Hot *khoa* placed in large expanded trays is allowed to cool in open atmosphere. Tray cooling or air cooling is widely used because it is simple, economical and batch type operation which is feasible in small scale industries. The conventional approach to producing khoa suffers from several disadvantages. Among the significant issues are: (i) constrained output due to batch processing, leading to inconsistent product quality that is unsuitable for high-volume manufacturing; (ii) ineffective energy usage and a low heat transfer coefficient, causing inefficiency; (iii) increased need for manual labor due to the time-consuming procedure; and (iv) occasional instances of product scorching and discoloration, which degrade its quality [11].

Vacuum cooling is an alternative method for the rapid removal of heat from the product to cool it at the required storage temperature. In vacuum cooling, some factors affect the final product temperature such as initial product temperature and moisture content, cooling period in the cabinet, applied vacuum, etc. Moreover, production of vacuum requires higher energy and thus incorporates high cost to production. The study shows that the conventional cooling is much slower than the vacuum cooling. Moreover, the microbial growth rate of the vacuum cooling is extremely low compared with the conventional cooling. The mass loss ratio for the conventional cooling and vacuum cooling was about 5 and 9 per cent respectively.

A number of equipment have been developed for mechanized production of khoa such as inclined scraped surface heat exchanger (SSHE) [12], two stage scraped surface heat exchanger [13], three stage scraped surface heat exchanger [14,15], in-line system [16,17], etc. Developed first prototype machine of mild steel for continuous manufacture of *khoa* on a semi-large scale under hygienic conditions with capacity of 50 liters of milk/h [18]. From the literature, it was revealed that very few of investigators worked on development of *khoa* cooling at industrial scale.

Developed mechanized system for continuous cooling of *khoa* using jacketed enclosed screw conveyor. Using well water as a cooling media in jacket around conveyor, highest cooling efficiency of 74.51 per cent was achieved [19]. Cooling of *khoa* in third stage of three stage thin film scraped surface heat exchanger. Maximum interaction for cooling efficiency was found 80.55 per cent.[20]

Assessment of the thermal efficiency of an ongoing khoa cooling process with a 60 kg/h capacity. The khoa, made from buffalo milk with 5% fat and 9% SNF, was initially heated to 80°C using a steam jacketed kettle and subsequently cooled down to room temperature (30°C) within the newly designed system. Thermal performance was evaluated based on screw speed (3, 6, 9 rpm) and 0°, 5°,10° inclination angle of cooling barrel. Optimum operating parameters for mechanized cooling system were 9 rpm screw speed and angles of inclination,100 [21]. The effectiveness of a screw conveyor's operation was influenced by factors including the conveyor's shape and dimensions, the characteristics of the metal employed, and the operational variables like the clearance between the screw and the casing, the configuration of the blades, the angle at which materials were conveyed, and the rotational speed of the screw [22,23]. The highest combined heat transfer rate and cooling effectiveness were recorded as 338.68 W/m2oC and 84.3%, respectively. This setup has the potential to be incorporated with ongoing khoa manufacturing machinery to swiftly cool khoa to the surrounding temperature. A commercial dairy plant, Sabar Dairy, Himatnagar, Gujarat produces *khoa* using vacuum cooling for its continuous production. The designed vacuum khoa cooling system works on 600 psi to cool *khoa* up to 300C.Continuous cooling system integrated with khoa making machine reduces the manufacturing time and also contributes in hygienic processing.

Burfi, one of the most popular *khoa* based sweets all over India is prepared by heating a mixture of concentrated milk solids (*khoa*) and sugar to a near homogenous consistency followed by cooling and cutting into small cuboids [24]. The mechanized cooling system with integrating SSHE and conical process vat. Reduction in temperature of burfi from 800C to 400C was achieved using rotor speed of 8 rpm and water flow rate in cooling system of 1200 L/h for continuous cooling system and resulted in product with maximum sensory textural score. *Burfi* cooling in integrated system was significantly acceptable in comparison to burfi cool in tray at atmospheric conditions [25]. *Peda* generally referred to as a blob of any doughy substance, is another traditional Indian product. Various varieties of *peda* are available in the market which can be classified or grouped depending upon their taste, characteristics, technology of processing or the area specific availability [26]. *Peda* is generally cooled at atmospheric conditions that lead to unhygienic conditions. Rapid cooling and low temperature leads to brittle body and textural defect in *peda*. Standardized a method for manufacturing of *peda* from *khoa*. *Khoa* with 72 per cent TS is heated up to 60⁰C and then sugar is added at the rate of 30 per cent of *khoa*. At the same time flavors and nuts are added and the mixture is mixed thoroughly in planetary mixture and the *peda* mass is cooled and molded in different shapes by using different technologies like piston press technology (die and punch technology), roll press technology, pelletizing technology [27]. Temperature of khoa base taken for ball formation by manual method or by rheon forming machine affect the design and shape of the final product. In *peda* making process, prolonged *khoa* cooling time leads to uneven colour and browning defects in final product quality [28]. Product requires sharp cutting edge at low vibration like in case of chocolate, kajukatri, etc. and hence temperature control is important for decrease in wastage of product [29].

Fudge is a soft crumbly or chewy sweet made from sugar, butter and milk or cream. The main ingredient in fudge is sugar, howeverrapid cooling and agitation and presence of seed crystals, a chain reaction involving sucrose molecule starts and cyclizes them, resulting in gritty texture. The best quality of *halwasan* should have a typical grainy, sticky, chewy and cohesive body and texture, as well as golden yellow to brown colour and free from unhygienic off flavour. Optimum temperature, steam pressure and scrapper speed is important for desired quality product. Grainy and sticky body is desirable in final product but if rapid cooling with refrigeration temperature give hard and brittle body [30].

*Kheer* is popular in northwest central and eastern parts of India and is popular as *Payasam* in its southern states.In-package cooking and sterilization of *payasam* in retort pouches enhanced its shelf life up to 4 months at 370 C. Concentrated milk, rice (washed and soaked at 300C for 30 min) and sugar were filled in the retort pouches (bursting strength of 4 psi for 30 s) which were placed in a rotary retorting system rotating at 2 rpm and sterilized at 1210 C for about 25 min. Control cooking and cooling is must require in processing to get desired softness in rice and distribution of rice in final product.Cooling some foods after cooking increases their resistant starch. Some starches lose their original structure due to heating or cooking. If these starches are later cooled after cooked, a new structure is formed. Cooling potatoes overnight after cooking tripled their resistant starch content [31]. Cooling rice after cooking may promote health by increasing the amount of resistant starch it contains. The rice that was cooked then cooled had 2.5 times as much resistant starch as the freshly cooked rice [32].

Paneer stands as the widely embraced classic dairy product formed by curdling milk with heat and acid. It boasts abundant premium fat, protein, essential vitamins, and minerals such as calcium and phosphorus. Paneer exhibits a pale white color and has a porous structure with a dense consistency. It offers a taste that combines mild sweetness with a hint of acidity and nuttiness. Roughly 4-5% of India's total milk output is transformed into paneer [33]. Reference [34] have reviewed about different ways to prepare paneer, diverse manufacturing conditions for paneer production, various types of paneer variations, and the automation of the paneer manufacturing process. Data available on yield of paneer, textural analysis, continuous paneer making machine, storage conditions and packaging material to extend the shelf life etc., however, lack in systematic study on how cooling parameters affecting the final product quality and continuous methods for cooling and chilling after pressing. Although in industry use of spiral chiller and tunnel chiller for continuous production is mostly observed. After pressing of paneer it will be dipped into chilled water for less than 40C for 30 min for achieving the block temperature near to 150C-200C followed by slicing, vacuum packaging, sealing and sterilization (900C for 30 min) followed by blast cooling (-200C) for achieving the block temperature 20-250C and transfer to storage room (-50C) these paneer have shelf life of 45 days at 40C. In diced paneer after dicing at 150C-200C transfer into hardening tunnel (-220C) to achieve the product temperature of -20C then storage is done at -240C having shelf-life of 6 months at -180C. So different temperature maintains at chilling and storage temperature effect on the product shelf life and rate of cooling also affect the product texture. If the temperature is slowly increased, temperature after dicing leads to brittleness in final quality of the paneer.

Chhana is typically made by heating milk to approximately 90-95°C, then cooling it down and causing coagulation at around 80-85°C using a solution containing 1-2% citric acid or sour whey [35]. Kneading involves combining and folding chhana, resulting in alterations to its rheological and textural characteristics, as well as influencing the texture of the resulting rasogolla. Rheological properties of cheddar cheese during heating and cooling were characterized using a dynamic test and found significant differences in G’and G” during heating and cooling which was affected by the amount of fat and the ratio of protein and water present in the cheese.

The viscoelastic properties of Cheddar cheeses increased due to cooling as evidenced by increase in G’and G”values [36]. Cooling rates of green cheddar cheese under immersion in brine and air cooling and determine microbial metabolism and chemical changes during curing like proteolysis, and lipolysis organoleptic changes during curing. The air-cooled cheeses were more severely criticized for high acid, fruity, and other flavor defects than the brine-cooled cheeses and hence, the brine cooled cheeses were having higher scores. Rapid cooling of cheese definitely proved to be better in producing uniform flavor, body and texture and color [37]

In *dahi* immediate cooling is important after achieving the desired acidity to get desired body and firmness in the curd. In conventional methods, before the desired acidity reached, the curd is transferred to less than 50C that leads to slow cooling and find a to grainy texture defect in final product. Transfer of curd in to blast room (-200C) for 1-1.5 h and then transfer to storage temperature less than 50C overcome the textural defect. There is no such technical data available how cooling behavior effect on texture and final quality of the *dahi.* Sugar settling is the major problem in *shrikhand* during storage and one of the reason for these defect is rapid cooling. Some food products such as *shrikhand* and *sausages* has high fouling potential but needs delicate handling to preserve product integrity. Stainless steel scraping mechanism that is hydraulically moved back and forth create turbulence within the material. These actions help to increase heat transfer rates. Also, the separate hydraulic action means that the speed of the scrapers can be highly controllable. It can be optimized for the product being processed, so materials that are susceptible to shear stress or pressure damage can be handled gently.

As per the Food Safety and Standards Authority of India (FSSAI), ghee refers to the pure clarified fat obtained exclusively from milk, curd, desi (cooking) butter, or cream. No artificial coloring or preservatives are included in its production.   
Ghee can be manufactured with a sought-after granular consistency by carefully managing operational conditions. The formation of granules in ghee is due to the crystallization process of the high-melting triglycerides. This involves the stages of nucleation and subsequent crystal growth. The texture of ghee's graininess can be influenced by several factors, including the composition of milk fat's fatty acids, the existence of phospholipids and additional substances, the temperature used during the clarification of ghee, the speed at which it is cooled, the introduction of seed crystals, the duration it is kept under calm conditions prior to packaging, and the temperature maintained during storage within the distribution network. [38, 39]

Ghee samples exhibited the best granulation results when subjected to an incubation temperature of 290°C for a duration of 24 hours. This led to grains with an average size of 0.241 mm and a yield of 42 percent [40]. Industries also practice to use insulated granulation room for control cooling and maintains the temperature 20-240C for 24 h and then transfer it to atmospheric temperature storage, which improves the texture of the final ghee. In processing parameter after ghee boiler cooling can be done by using tubular heat exchanger using well water in jacket to decrease the temperature from 85-900C to 450 C and then transfer to atmospheric temperature also help in reducing the time of processing and energy saving in continuous production.

Rapid cooling of hot ghee after clarification or even subjecting ghee to further heating and cooling after preparation may lead to ‘greasy’ defect in ghee. Heating of ghee to clarification temperature, followed by rapid cooling, yields small grains in ghee; however, if the same ghee is held for crystallization at a temperature about 1oC above the melting point of ghee (29oC for cow ghee) a large number of big grains results. Cold storage of ghee should be avoided, since it leads to a loss of granularity and the development of a waxy consistency in the stored product. Industries also use a plate heat exchanges (PHE) with regeneration of well water for cooling ghee to 450C. Fresh cream is used for making ghee by using cream concentrator and oil polisher for ghee making. Use of tubular heat exchanger for heating the oil phase at 85 to 900C after phase inversion process and vacuum chamber for removing the moisture and hence, temperature of ghee decrease to 450C by well water in PHE after vacuum chamber which is important for final product quality. Rapid cooling leads to greasy and oily consistency so control cooling after processing is important criteria. In continuous butter mix cooling with double jacketed screw conveyor system. The type of crystallization can be influenced by temperature profile of the cream [41].

Aseptic sterilization is employed to ensure the long-term stability of uniform liquid items like milk, cream, ice cream mix, yogurt, salad dressing, liquid eggs, fruit juices, and concentrates. This process safeguards their quality at exceptional levels. This controlled and gentle transition from sterilization to cooling avoids thermal shock or uncontrolled pressure drop. By means of container guides, containers move through a series of shells or towers to pre-heat, cook and cooling of each single container in the system is carried out. Responses consist of a pair of doors – one for entering and the other for exiting. The usual method involves utilizing steam to raise the product's temperature to a specified degree during processing. After sterilization, the food is conveyed to the cooling side of the retort. Evaporative cooling reduces the pressure within the container, causing rapid water evaporation from the item, subsequently cooling it. The product is then taken out through the exit door after undergoing sterilization and cooling processes. The smaller diameter of the vessel and the narrower void between drum and shell generate savings in steam, compressed air and cooling water. In Rotary type benefit from some amount of agitation, including products like canned fruits or vegetables in juice, soups, ready meals, evaporated and flavored milks, infant formula and nutritional drinks, etc. The reel, working in conjunction with the stationary spiral, advances the cans through the vessel. Cans are directly transferred from the seamer to the rotary sterilizer and automatically transferred through cooker and cooler shells in that spray water jets provide additional cooling and these innovative water spray technology results in superior temperature distribution and significant energy also savings of cooling water, rapid and efficient cooling in an automatic continuous operation.

Atmospheric cooling and pressure cooling these are two common methods of cooling. The gradual cooling provided to avoid a sudden shock which may disrupt the packaging and other physico-chemical characteristics of the product [42].

Belt cooling and spiral cooling tunnel needed for the heavier product leads to a greater operational efficiency for all types of product and maintains a uniform cooling. The most commonly used coolants for liquid cooling applications are water, deionized water, glycol, dielectric fluids, liquid nitrogen, refrigerants, etc. A multi method approach for cooling makes uniform appearance, using a cryogenic plate belt or super contact cooler improves efficiency by preventing adhesion and embrittlement of small pieces of food that break free and increase the product loss. Plate belt cooler configured of solid stainless-steel plates, allowing processing of soft and delicate products by eliminating the typical wire-mesh belt. High performance cooling system are designed with multiple cooling zones having independently control airflow and temperature for sensitive products that increase operational efficiency. This can be a good solution for chocolate and bakery applications and some of traditional Indian dairy products. Dual-belt cooler has two conveyor belts that operate side by side in one machine housing. Processing of two different types of products with independent controls for belt speeds, reduce floor space and boost throughput by multiple product conveyors in a single machine.

**V.Future Scope**

Design and development of controlled cooling system for commercial application in dairy and food sector is demanded. There is need for innovations and optimization of cooling parameters for developed cooling system. Computer aided simulation technology can be used to develop commercial scale equipment based on the data collected from pilot/prototype model. Moreover, there is also a need to design mechanized continuous controlled cooling systems for different dairy products to have better product quality and to increase the market share with lot of export potential.

**VI.Conclusion**

Mechanization of continuous controlled cooling system for different dairy and food products especially TIDP is untouched area therefore, there is an urgent need and huge scope of research and development (R&D), which is the prime requirement for the better product quality and to increase the export potentials. A lot of works on technological innovations in dairy and food sector has been done however, collaborative efforts of industry, unorganized sector, equipment manufacturer and R&D institutions is required for developing controlled cooling system and food sector.

**Reference**

1. <https://www.nddb.coop/information/stats/milkprodindia>
2. Kumar, M. (2015). Up-gradation of *khoa* Production and Preservation Technologies. Samriddhi, 4 (1), 37-46.
3. Velpula, S., Bhadania, A. G. Aravind, T., &Umapathy, K. S. (2018). Commercial Production Scenario of Traditional Indian Dairy Products: A Review. *Bulletin of Environment, Pharmacology and Life Sciences.* 7(3):82-87.
4. Gawde, A. M. (2005) Shelf life studies of Kalakand. Master Thesis, Dr. BalasahebSawant Konkan KrishiVidyapeeth, Dapoli.
5. Bandyopadhyay, P. (2006). Technological advancement on traditional Indian desiccated and heat coagulated dairy products. *Indian Dairyman*, 58(11):59-65.
6. Chauhan, I. A., Bhadania, A.G., & Patel, A.D. (2018) Mechanized Production of Kheer. Indian Journal of Dairy Science,71(1):20-27.
7. Rao, K. H., & Raju, P. N. (2003). Prospects and challenges for Indian dairy industry to export dairy products. Indian Journal of Dairy and Biosciences, 14(2), 72-78
8. Gokhale, S. V., &Lele, S. S. (2014). Retort process modelling for Indian traditional foods. *Journal of food science and technology*, *51*(11):3134-3143.
9. Choudhary, S., Kumari, A., & Arora, S. (2015). Heat induced changes in *khoa*: A Review. Indian Journal of Dairy Science, 68(5):415-424.
10. 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):133-135.
11. Pal, D. (2006). BPVI-015 Dairy products II. Packaging, shelf life and storage of *khoa* and *khoa* based sweets. Indira Gandhi National Open University School of Agriculture, pp, 54-58.
12. Punjrath, J.S., Veeranjaneyulu, B., Mathunni, M.I., Samal, S.K. and Aneja, R.P. (1990). Inclined scraped surface heat exchanger for continuous *khoa*making. *Indian Journal of Dairy Science*, 43(2):225-230.
13. Dodeja, A.K., Abichandani, H., Sarma, S.C. and Pal, D. (1992). Continuous *khoa*making system- design, operation and performance. *Indian Journal of Dairy Science*, 45(12):671-674.
14. Kumar,A.,Agrawala,S.P.,Dodeja,A.K.,&Pal,D.(2009).Effectofmodificationsinthe3*rd*stagescrapedsurfaceheat exchanger for continuous *khoa* production*, Indian Journal of Dairy Science*, 62(3),175-181.
15. Dodeja,A,K.,&Deep,A.(2012).MechanizedManufactureofDanedar*khoa*usingThreeStageSSHE.*IndianJournal of Dairy Scienece*,65(4):274-284.
16. Kumawat M, Kumar B, MinzPS(2012) Optimization of process parameters for manufacture of khoa using response surface methodology. *Indian J of Dairy Sci* 65(2):106-114
17. Minz PS, Kumar B,Sawhney IK(2013) Application of in-line design configuration for manufacture of Indian traditional dairy products. NDRI Newsletter 18(2):11-12
18. Banerjee, A.K., Verma, I.S. and Bagchi, B., 1968. Pilot plant for continuous manufacture of khoa. Indian Dairyman, 20:81-86.
19. Gurjar, A. R. (2009). Design and development of mechanized system for continuous cooling of *khoa*. Master Thesis, NDRI, Karnal.
20. Bairwa, V. K. (2012) Studies on cooling of *khoa* in third stage of three stage thin film scraped Surface heat exchanger. Master Thesis, NDRI, Karnal.
21. Avijit Shaw, I K Sawhney and Minz, P, S. (2010) Thermal performance evaluation of continuous khoa cooling system. *Indian Journal of Dairy Science*,68(4), 2015,321-325.
22. Srivastava AK, Goering CE, Rohrbach RP, BuckmasterDR(2006) Engineering Principles of Agricultural Machines, Second Edition, ASABE. American Society of Agricultural and Biological Engineers. Michigan, USA.
23. Zareiforoush H, Komarizadeh MH, Alizadeh MR (2010a) Effects of cropmachine variables on paddy grain damage during handling with an inclined screw auger.BiosystEng 106(3):234-242
24. Kumar, R., Rani, B., Dalmia, K., & Singh, B.K (2018). Effect of Microwave Radiation on Shelf Life of Barfi.*International Journal of Current Microbiology and Applied Sciences*,7(2):193-199.
25. Vekariya Y. V. (2011). Studies on mechanized in-line production of *Burfi*. (Master Thesis, NDRI, Karnal).
26. Singh, G. (2014). Optimization of process parameters for Mechanized formation of khoa-peda. Master Thesis, NDRI, Karnal.
27. Aneja, R. P, Mathur, B. N, Chandan, R. C. and Banerjee, A.K. (2002). Technology of Indian milk products. In Dairy India Publication Delhi, India.
28. Dewani, P. P. and Jayaprakasha, H. M. 2002. Effect of addition of whey protein concentrate on the physic-chemical and sensory characteristics of khoa and khoa based sweets. J. Food Technol. 39(5): 502-506
29. Gayen, D. and Pal, D. 1991b. Studies on the manufacture and storage of Rabri. Indian J. Dairy Sci; 44(1): 84-88
30. Rohini M.V. (2011) Development and Performance Evaluation of Batch type *Halwasan* making Machine Master Thesis
31. Muir, J. G., & O'Dea, K. (1992). Measurement of resistant starch: factors affecting the amount of starch escaping digestion in vitro. *The American journal of clinical nutrition*, *56*(1):123-127.
32. Sonia, S., Witjaksono, F., &Ridwan, R. (2015). Effect of cooling of cooked white rice on resistant starch content and glycemic response. *Asia Pacific journal of clinical nutrition*, *24*(4):620-625.
33. Chandan, R. C; Mathur, B. N; Banerjee, A.K. and Aneja, R. P. (2007). Indian milk products (Chhana and Fermented products). In souvenir of XXXI Dairy Industry Confrence, Mumbai: 58-85.
34. Minz, P. S., & Singh, R. R. B. (2016). Modernization of manufacturing process for traditional Indian dairy products. In Modernization of Traditional Food Processes and Products (pp. 161-174). Springer, Boston, MA.
35. Bandyopadhyay, P. (2006). Technological advancement on traditional Indian desiccated and heat coagulated dairy products. *Indian Dairyman*, 58(11):59-65.
36. Venugopal, V., &Muthukumarappan, K. (2003). Rheological properties of Cheddar cheese during heating and cooling. *International Journal of Food Properties*, *6*(1):99-114.
37. Miah, M. A. H. (1968). *Effect of temperature during early stage of curing upon cheddar cheese characteristics*. Iowa State University.
38. Rangappa K S and Achaya K T (1974) Constituents of ghee. In Indian Dairy Products, p 206. New Delhi: Asia Publishing House.
39. Kumar R and Negi S (2004) Granulation of ghee using emulsifiers, XXXIII Dairy Industry Conference, New Delhi. p. 106
40. Rachana, C. R., Nath, B. S., Reshma, M. V., &Armughan, C. (2013). Variation in grainy texture of commercial ghee in relation to laboratory ghee and its blends. *International Journal of Dairy Technology*, *66*(1): 90-97
41. Speer E. and Mixa A (1998) Milk and dairy product technology. Marcel Dekker Inc. New York: 214-215
42. Sparrow, E. M., Chevalier, P. W., & Abraham, J. P. (2006). The design of cold plates for the thermal management of electronic equipment. *Heat transfer engineering*, *27*(7):6-16.