

# DESIGN AND DEVELOPMENT OF CONTROLLED COOLING SYSTEM FOR DAIRY AND FOOD PRODUCTS: PRESENT NEED

## 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 varieties of khoa i.e. dhap, pindi, & danedar, different varieties of khoa has different textural properties and specific varieties of khoa are used for making specific varieties 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.

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## **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 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 sheep milk 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 developed for production of *khoa*, such as inclined scraped surface heat exchanger (SSHE) [12], two stage scraped surface heat exchanger [13], scraped surface heat exchanger (three stage) [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]. As cited by reviewers that very few of investigators worked on mechanization of *khoa* cooling machine at industrial scale.

Created an automated system utilizing a jacketed enclosed screw conveyor for the continuous cooling of *khoa*. 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 three stage thin film scraped surface heat exchanger with maximum interaction for cooling efficiency 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. The assessment of thermal efficiency was conducted using varying screw speeds (3, 6, 9 rpm) and cooling barrel inclination angles (0°, 5°, 10°). The ideal operational settings for the mechanized cooling system consisted of a screw speed of 9 rpm and inclination angles of 10° [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 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/m<sup>2</sup>oC 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 30°C. Continuous cooling system integrated with *khoa* making machine reduces the manufacturing time and also contributes in hygienic processing.

Burfi, a favored *khoa*-based dessert enjoyed throughout India, is made by heating a blend of concentrated milk solids (*khoa*) and sugar until it reaches a homogenous consistency. This mixture is then cooled and cut into small cube shapes. [24]. The mechanized cooling system with integrating SSHE and conical process vat. Reduction in temperature of burfi from 80°C to 40°C 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. The cooling of burfi within the integrated system demonstrated notably better acceptability compared to the cooling of *burfi* on a tray under 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*, containing 72 percent total solids, is subjected to heating at 60°C, followed by the incorporation of sugar at a proportion equal to 30 percent of the *khoa*'s quantity. Simultaneously, flavors and nuts are introduced. The mixture is then meticulously blended using a planetary mixer. Subsequently, the *peda* mass is cooled and shaped into various forms using diverse techniques, 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 delectable confection with a soft, crumbly, or chewy texture, crafted using sugar, butter, and milk or cream. The main ingredient in fudge is sugar, however rapid cooling and agitation and presence of seed crystals, a chain reaction involving sucrose molecule starts and cyclizes them, resulting in gritty texture. The ideal *halwasan* should possess a characteristic grainy, sticky, and chewy consistency that holds together well. Its texture should be cohesive, and its color should range from golden yellow to brown, while being completely devoid of any unsanitary or undesirable flavors. Optimum temperature, steam pressure and scraper 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. Cooking and sterilization of *payasam* within the packaging using retort pouches extends its shelf life to four months at a temperature of 37°C. Concentrated milk, rice (cleaned and soaked at 30°C for half an hour), and sugar were loaded into retort pouches (with a burst strength of 4 psi for 30 seconds). These pouches were then positioned within a rotary retorting system, which rotated at a speed of 2 revolutions per minute. The content was sterilized at a temperature of 121°C for approximately 25 minutes. Control cooking and cooling is must require in processing to get desired softness in rice and distribution of rice in final product. Chilling certain cooked foods enhances their content of resistant starch, as the heating or cooking process can alter the natural structure of certain starches.

When these starches are cooled subsequent to cooking, they undergo a transformation in structure. Allowing cooked potatoes to cool overnight led to a threefold increase in their content of resistant starch [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 4<sup>0</sup>C for 30 min for achieving the block temperature near to 15<sup>0</sup>C-20<sup>0</sup>C followed by slicing, vacuum packaging, sealing and sterilization (90<sup>0</sup>C for 30 min) followed by blast cooling (-20<sup>0</sup>C) for achieving the block temperature 20-25<sup>0</sup>C and transfer to storage room (-5<sup>0</sup>C) these paneer have shelf life of 45 days at 4<sup>0</sup>C. In diced paneer after dicing at 15<sup>0</sup>C-20<sup>0</sup>C transfer into hardening tunnel (-22<sup>0</sup>C) to achieve the product temperature of -2<sup>0</sup>C then storage is done at -24<sup>0</sup>C having shelf-life of 6 months at -18<sup>0</sup>C. 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<sup>0</sup>C, then cooling it down and causing coagulation at around 80-85<sup>0</sup>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. The dynamic test revealed distinct variations in the G' and G'' values of cheddar cheese as it underwent heating and cooling. These changes were notably influenced by factors such as the cheese's fat content and the proportion of protein to water within it. 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 cheeses that were cooled using air received harsher feedback due to their pronounced acidity, fruity notes, and other flavor imperfections, in contrast to the cheeses cooled in brine. As a result, the brine-cooled cheeses achieved higher scores. Swift cheese cooling clearly demonstrated its effectiveness in creating consistent flavor, body, 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 5<sup>0</sup>C that leads to slow cooling and find a to grainy texture defect in final product. Transfer of curd in to blast room (-20<sup>0</sup>C) for 1-1.5 h and then transfer to storage temperature less than 5<sup>0</sup>C 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 reasons for these defects is rapid cooling. Certain food items like *shrikhand* and sausages possess a significant risk of fouling, yet they require careful treatment to maintain the integrity of the

products. A hydraulic system maneuvers a stainless-steel scraping mechanism, inducing agitation within the substance. These measures contribute to boosting the rates of heat transfer. Additionally, the distinct hydraulic mechanism allows for precise control over the speed of the scrapers. It is possible to tailor the optimization for the specific product undergoing processing, thereby allowing for the delicate handling of materials that are vulnerable to shear stress or pressure-induced damage.

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 20-24°C 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 85-90°C to 45°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 1°C above the melting point of ghee (29°C 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 45°C. 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 90°C after phase inversion process and vacuum chamber for removing the moisture and hence, temperature of ghee decrease to 45°C 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 carefully managed and mild shift from sterilization to cooling prevents sudden temperature changes or unpredictable pressure decreases. Through the utilization of container guides, containers traverse a sequence of shells or towers for the purpose of pre-heating, cooking, and subsequently cooling each individual container within the system. 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 reduced vessel diameter and the narrower gap between the drum and shell lead to cost 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 move directly from the seamer to the rotary sterilizer, seamlessly passing through the cooker and cooler chambers. This process involves the use of water spray jets that offer extra cooling. This advanced water spray technology ensures excellent temperature distribution, leading to noteworthy energy savings in terms of cooling water usage. This results in rapid, efficient, and automated continuous cooling operations.

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. Water, deionized water, glycol, dielectric fluids, liquid nitrogen, and refrigerants are among the frequently utilized cooling agents in liquid cooling scenarios. 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. The plate belt cooler is constructed using solid stainless-steel plates, enabling the treatment of tender and fragile items while removing the usual wire-mesh belt. High performance cooling system are designed with multiple cooling zones having 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. The dual-belt cooler consists of a pair of conveyor belts that function adjacent to each other within a single machine enclosure. Processing two distinct product types using separate belt speed controls not only minimizes floor space requirements but also enhances throughput through the utilization of multiple product conveyors within a singular 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.

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