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REVIEW ARTICLE **OPEN ACCESS**

Cooling and Chilling of Milk- An Overview

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ABSTRACT
Milk cooling is one of the most indispensible operations before processing of milk and milk products. It is the factor which is responsible for deciding the quality of end product. Various methods of milk cooling has already been devised but due to small milk production size, lack of awareness and absence of infrastructural support, milk producers in developing countries do not inclined for milk cooling devices. This paper deals with need of cooling, various cooling systems, their performance evaluation and effect of cooling on chemical and microbiological properties of milk. The essential step in growth of dairy industry is establishment of cold chain fulfilling the cooling needs during production, processing, storage and distribution of milk and milk products.
Keywords: Cooling, Chilling, Milk, Bulk milk cooler, Quality of milk, refrigeration systems

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INTRODUCTION

India is the leading producer of milk in the world. The current milk production is around 146.3 million tonnes [1] and the per capita availability of milk is around 315 g/day/person [2]. Production of milk in India is very widely scattered in the rural areas and at vast distances from the places of high consumption in the urban area. High ambient temperature throughout the year in India causes a disadvantage since the bacterial growth is very rapid if the temperature of milk, as produced, is not brought down, immediately after production.

In India, milking of animal is done either at community milking center or at the houses of the farmers. In most of the other parts, milking is done at the farmer's home and then delivered to the village cooperative centers. At the community milking centers, animals are brought and milking is done which is collected and then sent to the chilling centers. This is practiced only by few big dairy farms.

It is very essential to cool the milk immediately after milking to maintain the quality of milk, since pooling from small farmers and transporting in bulk to processing plant may take 8 h or more from the time of milking. The chilling of milk to about 4°C or less is done to check the growth of bacteria and preserve the quality as produced, until it is subjected to pasteurization process. Chilling not only destroys the bacteria already present in the milk but also lowers the growth of bacteria which will otherwise be very rapid at the high ambient temperature. Therefore, milk chilling centres were established to bring down the temperature of milk. In fact, the chilling of milk at or nearby production centers is an important factor which has directly influenced the growth of the milk industry in India [3].

Various methods of milk cooling

In developed countries like U.S., Russia etc. milking is done through automatic milking system (AMS) where in cows are brought to the milking parlour and milked by a robotic milking system without direct human intervention. In automatic milking systems, milk is extracted by means of a milking machine which is then immediately pumped to a tank for cooling and for storage of milk.

Where milk is available in sufficient quantity, cooling of milk at the production and the collection centers are mainly done by In-churn coolers, Immersion coolers, Roto freezers or by Surface coolers. But for small quantities of milk produced, it is recommended that the milk should be cooled in the cans with the help of water tanks, cooling ring. These systems are sometimes adopted by small or medium capacity milk producers. For large scale milk production, in-tank or bulk tank cooling systems are also practiced.

Surface cooling systems were also used for any size of milk production. Now, chilling centers have been established at smaller towns which handle milk of more than ten thousand liters collected from the village level collection centers [4].

Present status of milk cooling in India
Although India produces half of the Asia's milk output but still bears a loss due to substandard quality that arises due to un-hygienic practices and poor cooling and processing of milk [5]. The cooling and storage of milk produced in the rural area is still not up to the desired standard, mainly due to non-adoption of efficient milk cooling systems. The common milk micro-organisms grow best between 20 and 40°C. The micro organisms develop faster in severely contaminated milk than in milk with a low bacterial count. Under conditions of poor hygiene, plate counts of half a million are no exception, and with plate counts that are four times as high (2 Millions), biological changes of fat, protein and sugar become noticeable. Hence, with milk production, immediate cooling of milk is necessary. High ambient temperature particularly during summer months is an additional disadvantage since the bacterial growth is very rapid if the temperature of milk is not brought down immediately after production. Bacterial growth is invariably accompanied by deterioration in market quality due to development of off-flovours, acidity, etc. Due to inappropriate cooling, undesirable biochemical reactions between ions present in the milk will be boosted. Prompt cooling of milk to temperatures below 10 to 15°C will usually be sufficient if the production of acid has to be prevented for short periods i.e. for 12 - 24 hours.

Importance of milk cooling
Any cooling is better than no cooling, if the milk has to be stored on the farm for longer periods. When small amounts of milk are produced, the cooling of milk should be centralized in collection centers. Pre-cooling of bulk milk restricted the growth of bacteria population in milk and that milk could be transported in chilled conditions for longer distances. To control undesirable bacterial development and to maintain high microbiological standards, the milk should be cooled as early as possible after milking, preferably within two hours. Besides, bacterial multiplication is quite rapid as temperature of storage increases. Quick cooling stops the development of micro organisms at an early stage in the lag phase of the growth curve. If the development is stopped at a later stage, the milk may apparently be of acceptable chemical quality, but its keeping quality will be short, especially if the temperature rises again [6].
The fresh raw milk is known to possess bactericidal properties due to the presences of a number of antimicrobial substances like immunoglobulins, leucocytes, lactoferrin, lactanin, lysozyme and lactoperoxidase. This bactericidal stage which lasts for few hours after milking depends on the temperature of storage. If raw milk is cooled properly, its bactericidal character lasts for longer time and vice-versa. In fact, this stage of chilling the milk at the production centers is the most important factor which has direct influence on the growth of the dairy industry in India.

Realization of the cooling needs
In many parts of India, it is difficult to implement the requirement of cooling milk within two hours after milking, especially because the milk is often produced in small amounts and the producers are scattered over large areas. Milk collection and transportation is a time-consuming process which generally takes more than 8 hours. In this course of time, microbial count keeps on rising logarithmically and needs controlling. Therefore, the milk has to be pooled and subsequently cooled as far as possible at the village level itself. Though, cooling of milk at the village level is identified as the missing links in the cold chain, bulk milk cooling units are establishing this link. The dairy industry has taken up the bulk cooling of milk at village level to overcome these drawbacks.
The Indian dairy industry as it stands today, needs to improve upon the overall quality of the milk. The bacterial load is a reflection on the hygienic quality of milk. This aspect has certainly been ignored or could not be realized. There is a lack of facility for proper on-farm cooling of milk immediately after milking. As the battle for quality is won or lost at the village level milk collection itself, it is crucial to contain the bacterial growth at the initial stages by cooling milk immediately after milking. This will also gone increase shelf life in self life milk.
In present age of cut throat competition quality production has become more and more important in every segment of the economy. Milk producers with extra quality will be able to survive the competition particularly in export front [7]. Therefore, milk producers should be prepared to meet the growing requirements. But it was found that small dairy farms produced lower quality milk than large farms [8]. This was due to absences of proper cooling options immediately after milking which resulted in low quality milk.

Refrigeration and milk cooling systems

Refrigeration has a fundamental application in dairy and food industry for preservation of foods. To prevent deterioration, milk and milk products requires refrigeration at all stages from production to distribution. Cooling is also very much required immediately after milking through which shelf life of the milk extends. Refrigeration system has a great potential in dairy and food industry. Some of the reviews concerning refrigeration and cooling systems are listed below.

The uses of refrigeration system in Indian dairy industry, its status and the future. They discussed about the status of various milk chilling systems at the village level and refrigerated transport of milk and milk products. They gave the opinion that non- contractual energy based Vapor Absorption Refrigeration technology offers the most viable option for the dairy industry [8].

The necessity for cooling and refrigeration at all stages of milk production and processing in relation to increasing milk production at the farm level, the handling of milk for immediate consumption, the storage of processed milk and in the manufacture and storage of butter, cheese and yoghurt [9]. Optimum time and temperature must be given for the refrigeration and cooling. Losses caused by unsatisfactory handling of milk on farms are discussed and remedial measures are considered by Jovanovic. In 1961-66, 2.2 - 4.4% of Yugoslavia's annual milk production was lost through souring. Mean monthly losses were presented graphically. Tests on OLRA- Inox Italian refrigerated farm milk tanks of 800 l capacity were satisfactory, and cooling of milk on the farms is advocated [11].

Aseptically drawn milk samples were examined within 1.5 h by standard bacteriological methods. The chief causes of milk contamination with micro organisms were inefficient care of milking equipment and milk containers, faulty milking techniques and primary milk treatment, and delayed or insufficient cooling of milk at the farm. Contamination of milk with salmonellae caused by permitting infected calves to suckle the cows [12].

Milk cooling systems

The various methods of milk cooling are in practice. Simple systems of cooling that use water will bring the milk to a temperature only 3-5°C above that of the water [13]. Immersion cooling and particularly bulk cooling in tanks employing direct expansion or ice-bank refrigeration systems, bulk cooling is dealt with in considerable detail with particular reference to the cooling rate and the final temperature of the cooled milk, electricity requirement and the selection of the bulk tank [14].

The effect of cooling and handling of milk on the farm on its microflora where in 4 methods of milk cooling and handlings were compared. (i) Refrigerated tank cooling, (ii) Churn cooling, (iii) On-pasteur milking with subsequent refrigerated farm tank cooling, and (iv) On-pasteur milking with direct transfer to dairy. The methods generally were subject to seasonal modifications. Samples of milk were taken for bacteriological examination (total bacteria, lactobacilli, caseolytic bacteria and coliforms counts) after a.m. and p.m. milking and at various stages of bulking and handling. A selection of results of approximately 2000 tests is presented and discussed. The main conclusions were: (1) milk with total bacterial counts ranging from 5 lakhs to 1 million/ml, should be provided cooling to 8ºC or below; (ii), sometimes bacterial count ranged between 1 and 3 million/ml; with (iii), on-the-spot cooling was needed, since milk transported to the farm had counts of >2 million/ml; with (iv), uncooled milk transported to factory had counts of >5 million/ml [15].

Bulk Milk Coolers (BMC)

Bulk Milk Coolers are an important tool in maintaining the cold chain of milk between the producers of rural area to the processing at main dairy plant. It provides the cooling and holding milk at a cold temperature until it can be picked up by a milk hauler. The collection and transportation of milk presents several techno-economic problems in tropical countries. Cooling the milk is accepted as the best means of preservation of milk quality [16]. But, cooling is not always practical. It may be due to the high operational costs, frequent breakdowns of equipment, lack of spare parts, erratic supply of electricity and difficulties in repair of equipment in rural areas. Therefore it leads to saving and spoilage of bulk supplies of milk [17].

The importance of bulk milk coolers in maintaining the cold chain and also recorded the advantages and limitations of bulk milk coolers by koshta [18]. The performance of bulk milk cooling units and recorded some of the disadvantages such as cost of equipments, failure of related equipment etc [19]. The refrigerated tanks on the dairy farms wherein open or vacuum tanks with automatic agitation and cooling by ice bank or direct expansion, used on Danish farms. Bulk milk collection was introduced in Denmark in 1960 and now 75% of farm milk is collected and cooled [20].

The effects of temperature on the Total Bacterial Count (TBC) quality of bulk tank raw milk samples and determined the TBC as 2733x103, 3641x103 and 5687x103 cfu/ml at <4°C, 4.1 to 7°C and >7°C respectively [21]. Micrococi, streptococci, coryne bacteria, pseudomonas, coliform bacteria, flavobacteria and other Gram negative rods was found in samples of raw bulk milk. The most predominant mesophilic and psychrotrophic bacteria respectively were Micrococeaceae and Gram negative rods [22]. 200 samples of farm bulk cooled milk, collected during one year, were tested for total and psychrotrophic bacterial counts before and after pre-incubation (PI) at 15°C for 16 h. There was no significant seasonal effect. Before PI, 10% of samples had <10,000, 31% had <25,000 and 46% had <50,000 bacteria/ml; psychrotrophic count was, on average, ~1/6 of the total count. After PI, both counts were found to be of the same order. It is concluded that PI shows little advantage over testing of milk on receipt [23].

Design of cooling equipments

Designing of equipment for dairy processing involves consideration of parameters often different from other processing industries. The designer must be aware of the product and process needs. Design considerations of some of the cooling equipments are given below.

The dairy industry needs to improve upon the overall quality of milk by installing new processing facilities along with adoption of improved equipment designs and appropriate technology [24]. The equipment designs and processing trends in dairy industry its current and future status where in dairy equipments are to be developed with a suitable technology [25, 26].

Design of refrigeration systems for milk

An ice bank cooler was developed having the dimensions of 1320 x 580 x 715 mm (L x B x H) to accommodate two 20 liters can with a provision to fill water at 35°C initially. Milk temperature could be brought down to 4°C in 120 min with chilled water at temperature of 1.5°C. An ice-bank type farm tank has an open-top milk tank supported on a movable carrier element in a cabinet structure, from which it may be withdrawn through a side opening for cleaning [27]. A cooler was designed for refrigerated cooling of milk in several cans simultaneously. The cooling agent was stored in a raised tank and passes through coils which are immersed in the milk. Agitation was mechanically done by lowering and raising the coils in the cans [28, 29].

Design of milk cooling systems

A cooler has developed for improved cooling of milk on small farms. This cooler has a coil immersed in water in a cylindrical container which is mounted on the milk can. The milk is filtered then passed through the coil into the can [30]. An immersion cooler was particularly intended for cooling milk, comprising an annular (preferably cylindrical) cooling element accommodating an impeller rotated by a coaxial shaft and arranged to create an axial flow of milk through the cooling element in an upward direction [31]. An immersion cooler (Type: KJ 610 C) the cooling element consists of a hollow cylinder with built-in propeller for circulating milk, which was tested for suitability in cooling from 35 to 4°C and maintaining at that temperature, in a 400 l insulated tank, 100 l batches of milk from 4 successive milkings [32].

The direct expansion cooler is a non –insulated mobile farm milk container which is designed particularly for cooling and maintaining 200 l milk /day, obtained at 2 milking. Testing of this cooler was carried out by using water instead of milk and simulating practical conditions, cooling from 35°C to 8°C took 2 – 2.5 h and to 4°C it took 3.5 h. The power requirements were 0.035 kWh/l including the maintenance of low milk temperature between milkings. Stirring for 5 min for every 2 h substantially delayed creaming. The thermostat was found efficient and reliable and servicing easy but easier dismantling for cleaning is advocated [33].

Mobile raw milk chilling unit was designed for rural areas. This is a feasible alternative for good quality raw milk transportation. Chilling plant can be completely eliminated as mobile chillers are used for transportation of the raw milk [34].

A rapid milk cooling system was designed, built and tested for a variable flow milking machine and tested under various configurations. The system was capable of rapidly cooling a dynamic milk flow over a wide range of operating conditions. The introduction of a control system allows for potentially substantial energy and cost savings [35].

Transport with cooling of milk

There are many types of transport refrigeration systems. Eutectic system consists of hollow tubes, beams or plates filled with a eutectic solution (phase change material) to store energy and produce a cooling effect. In eutectic concept, heat absorption is provided by phase change material rather than direct expansion of refrigerant gas. The plates or beams that contain the eutectic are charged (frozen down) at night on mains power [36, 37]. Vapour compression is the most common refrigeration system used for refrigerated food transport applications. Wide range of compressor drive methods is available for mechanical refrigeration with the vapour compression cycle. They are Vehicle Alternator Unit, Direct Belt Drive, Auxiliary Alternator Unit, Auxiliary Diesel Unit [36]. Two materials generally recommended for vehicle insulation are: High-density Styrofoam and High-density polyurethane (also called PUF, Polyurethane Foam) [38].

The outer skins of the compartments may be made from various materials including Glass Reinforced Plastic (GRP). A combination of plywood and GRP, aluminum, stainless steel GI etc. are used in chilling units [36, 37].

Cooling of other dairy and agricultural products

One kg, Two kg and Three kg paneer blocks in cubical shapes was cooled in chilled water at 5 and 10°C. The cooling was done for 3 h and 30 minutes and the temperatures at two layers were noted down at 5 minimum intervals. The time temperature distribution curves for paneer were drawn and regression equations were developed. The film heat transfer of chilled water for 3 kg cubical paneer block was varied from 225 to 467.5 W/m^2 °C when chilled water temperature varies from 5 to 10°C. The surface heat transfer coefficient of cubical paneer blocks was found to be 35.8, 35.6 and 34.2 W/m^2°C for 1, 2 and 3 kg paneer blocks, respectively, when cooled by chilled water at 5°C [39].

Batch type hydro cooler was developed for mangoes and other horticulture products. Water was cooled by vapor compression refrigeration system and was sprayed over mangoes. The Food and Nutrition Board of India has designed and developed a "Janata Cooler" for storing fruits and vegetables. In this cooler a storage pot is placed in an earthenware bowl containing water. The pot is then covered with a damp cloth that is dipped in the reservoir of water. Water drawn up to the cloth evaporates keeping the storage pot cool. The bowl is placed on wet sand, to isolate the pot from the hot ground [40].

The adoption of milk cooling technology at the cooperative level is influenced by the farmer's age, household milk consumption, land ownership system, ratio of farmland under fodder production, number of female calves in the farm and number of years one has been a cooperative member. This could include improvements in extension service delivery and promotion of innovative business models that will ensure higher returns for smallholder farmers [41].

Performance evaluation of some cooling equipments

The performance of plate pre-coolers on the farm to enhance the keeping quality of raw milk and recorded significant difference between the qualities of pre-cooled and control milk samples had also evaluated.

The farm cooler, manufactured by L. & H. Rosenmund, 4410 Liestal, Switzerland, accommodates three 40 l cans and is intended for cooling 120 l milk over a 12 h period by chilled water circulation. In tests with water at 35°C (ambient temperature, 25°C) times needed to bring the temperature to 8°C and 4°C respectively were: 1 can, 48 min and 2 h; 2 cans, 1 h 7 min and 2 h 22 min; 3 cans, 1 h 13 min and 2 h 26 minimum The cooler is considered satisfactory for cooling and storage of milk on the farm [43].

Immersion cooler consists of condensing unit mounted on a 2 wheeled cart and a hollow, double- walled immersion evaporator connected to the unit by a flexible tube. The portable milk tank has a capacity of 200 l, is cylindrical in shape and has double walls and bottom with polyurethane insulation. In tests the tank was filled with four 50 l lots of water to simulate 4 milking. Water temperature was 35°C and ambient temperature 32°C. Time required to cool the water to 4°C was 0.83 – 1.27 h, when two 100 l lots of water were cooled, cooling time was 1.49 – 2.38 h. Stirrer efficiency and tank insulation were not considered satisfactory [44, 45].

A test on the horizontal cooler which is used for cooling milk kept in cans wherein the in-can plastics turbine cooler with rotating stirrer was tested in 20 l and 40 l cans filled with water at 36ºC, at an ambient temperature of 18- 30°C, using water at 10°C or chilled water at (1.5-3°C) as the cooling agent. The water was cooled in ~40 min to ≤ 2ºC above the temperature of the cooling agent; 0.05 atmospheric gauge pressures were enough for smooth running. The cooler is recommended for farm use [44].

Performance of any equipment is as important as the designing part. If equipment fails to perform cent percent than the whole objective of developing equipment fails. The effect of milk cooling using village level milk can cooler was also studied in terms of acidity, MBRT, SPC and Coliform counts. It was suggested that on farm cooling is a way to reduce bacterial development and consequently to preserve milk quality [46]. Vapour absorption refrigeration system were used for cooling of milk at farm level. This system has shown good results in curtailing water carryover, but gave low Coefficient of Performance [9].

The use of adsorption refrigeration system as a promising answer to reduce the cost of refrigeration in dairy plants [47].

Performance evaluation of some refrigeration systems

A refrigerated milk tank which cools can milk was in the form of a rectangular tank, the cans are standing on a grating over the evaporator of an ice-bank type refrigeration unit. The milk is cooled by pumping chilled water from the bottom of the tank to an in-can cooling unit where it passes through a tubular cooling element immersed in the milk. The cooling element is rotated by the pressure of the cooling water which then flows over the exterior of the can back to the ice bank [48].

A type VE 300 refrigerated milk tank with direct expansion cooling and a rated capacity of 1134 l was tested, using water in place of milk. The tank, which has the shape of a horizontal cylinder, was filled to capacity in 4 stages at 12 h intervals with equal amounts of water (at 35°C) at each stage; the ambient temperature was 32°C. Cooling times to 4°C ranged from 2.44 h at 1st filling to 3.08 at last. Construction, finish, insulation, stirring, electrical components and mechanical cleaning were found satisfactory [45].

Tests on three imported refrigerated farm milk tank were carried out and it was found were found to be suitable for farm refrigeration of milk. The designs of three tanks are (i) Zero-7-20 horizontal cylindrical vacuum tank of 1000 l capacity with direct expansion cooling (ii) vertical cylindrical tank of 900 l capacity with direct expansion cooling and (iii) horizontal rectangular tank of 2000 l capacity with ice bank cooling [49].

The effect of environmental conditions on Co-efficient of Performance (COP) of a refrigeration plant during night and early morning so that the plant can be more efficiently used for the purpose of refrigeration and also save electricity in order to make it economically viable [50]. A milk chilling system based on low grade energy such as solar energy. A 10 TR vapour absorption refrigeration system was designed for running by solar energy only. It was calculated that total energy required is about 43.768 kW to run the system and the same was to supply through hot generated using solar energy. Coefficient of performance of the designed system was 0.814 [51].

The procurement cost of co-operative dairy societies was higher than of the private milk collection centres due to increased costs of milk transportation, chilling and reception. The cost of production and manufacturing of dairy products has indicated that the co-operative plant is more efficient in the manufacturing of toned milk, standardized milk, full cream milk and ghee, whereas the private plant has an edge over co-operative dairy plant in the manufacturing of butter and SMP[52].

Quality of milk

Bacteriological quality of raw milk varies according to climatic and storage conditions of the areas. It also varies with vegetation, atmospheric variation in temperature and relative humidity. India being a tropical country temperature influences the bacteriological quality of milk to a greater extent.

Clean milk production is the key to quality management in dairy industry provided cooling of milk is done immediately after procurement [53]. The importance of reducing psychrophilic contamination of milk by improved hygienic conditions, particularly in view of the current practice of holding milk for long periods at low temperature [54].

Effect of cooling milk

The cooling phenomena of milk. The manner and speed of cooling, cooling time and temperature had significant effect on cooling of milk [55]. The initial acidity of raw milk was 0.16% L.A. that increases to 0.5% after 3 days to storage at 12°C [56]. The acid degree value of raw milk have determined from bulk tanks and recorded that 12% of raw milk sample had acid degree value of more than 1.4% and 4.07 log 10 cfu/ml for canned milk and bulk milk respectively [57]. The cell counts /ml were 5 lakhs in 52 % of all the samples; 5 lakhs to 1 million in 33 % samples and over one million in 15 % of the samples [58].

The total counts were 1 to 10 million /ml in 41.6 %, 10-15 million /ml in 38.4 % and over 50 million /ml in 14.9 % of the samples. Similarly, the psychrotrophic counts were 1000 to 10000 /ml in 9.1 %; 10,000 to 1, 00,000 /ml in 21.9 % and 100, 000 to 1 million /ml in 36.3 % and more than 1 million /ml in 29 % of the samples [59].

The different farm environmental conditions such as air, water, utensils, personnel and animals contributed coliform contamination to the farm environment [60]. Recombined milk from anhydrous milk fat (butter oil), skim powder (Spray dried) and water was prepared and the effect of heating and chilling on electrophoretic characteristics of MFGM proteins was studied. It has been observed that the electrophoretic mobility of FGM proteins isolated from the heat treated and chilled milk were distinctly different than that of control. Pasteurization, boiling and sterilization significantly altered the electrophoretic mobilities while chilling and cooling caused mild changes [61].

Effect of time and temperature on microbiological and chemical quality of milk

The effect of storage temperature on bacterial growth and lipolysis in raw milk. Measurement of FFA levels showed the milk stored at 8ºC had significantly increased FFA level after 48 h [62]. The total count, coliform counts and titratable acidity were measured after storage for 0, 24, 48 and 72 h. at 4, 8, 10 or 15°C. Bacterial growth at lower temperature was higher in the case of psychrotrophic flora [63]. Aerobic mesophilic count, total coliform count of 125 milk samples which were transported in cans at 18.4°C along with 125 samples of bulk milk at 4.5°C had enumerated. They recorded 7.27 log 10 cfu/ml and 6.42 log 10 cfu/ml and they also reported psychrotrophic count as 6.34 log 10 cfu/ml, 5.74 log 10 cfu/ml and coliform count as 5.07 log 10 cfu/ml [64].

The effect of farm cooling on bacteriological quality of milk where in milk with an initial total bacterial count (X) of ~105/ ml was cooled to 3 -5°C or 10 - 15°C either immediately or after holding at 20°C for 2-3 or 4-5 h. In all cases, after 12 h at 3-5°C counts increased 3-5 X, vs. 8-11 X at 10-15ºC. In further experiments, milks with initial counts of 37–63 thousand/ml and 5.3 to 12.4 lakh/ml were stored at the temperature for up to 48 h. Counts increased 4 X and 8 X respectively at the lower storage temperature and ~8 X for both types of milk at the higher. For psychrophilic bacterial counts corresponding increases were 4.4 X and 26 X and 9 X and 50 X [65].

Immediate cooling of the milk to 4ºC reduced the psychrotrophic count after 24 h storage. At 15°C, counts of mesophilic, psychrotrophic, caseolytic and lipolytic bacteria were lower in milk which had been cooled immediately after milking than in milk not cooled. Neither cooling nor storage temperature had any significant effect on count of acidophilic bacteria in milk [66].

Effect of animal health on quality of cooled milk

The bacteriological and chemical changes in raw milk stored over long periods at low temperature. Milk obtained under hygienic conditions, from 6 cows of one producer, was stored at ≤ 5ºC for 0, 25, 30, 49, 54, 78, 102 and 126 h values are given for each period for total bacteria, coliforms, psychrophillic counts and for chemical and organoleptic characteristics. They include the following counts/ml for 0, 49 and 126h: total bacteria, 7000, 14,500 and 1,78,000; coliforms, 10, 340 and 3250; psychrophils, 4400, 10,000 and 21,00,000. Titrable acidity, pH and organoleptic characteristics did not change throughout and the alcohol test remained negative [67].

Bacteria originating from healthy udders appeared to have a minor effect on quality of milk but during storage of milk even at low temperature it was found that udder bacteria could increase and become dominant in the absences of competition from other organisms [68].

Techno – Economic Feasibilities of some cooling equipment

Technical feasibility and economic viability of any process or product or equipment should be calculated as it gives an idea that the developed process or product or equipment is feasible to the prevailing conditions or not. Techno-economic feasibilities of using small capacity dairy equipments for cooling and processing of milk and milk products as they have a greater scope at village/ rural or semi- urban level where the milk production is limited [69]. In can chilling equipment to accommodate 4-6 cans for cooling of milk less than 500 lit at village level. They estimated that milk chilling cost by this unit was 1.5 paisa/lit when the cost of cooler was Rs 15,000/- [70].

Milk chilling cost in a co-operative sector dairy plant in Tamilnadu, the overall average cost of chilling per litre was found to be 28 paise. The cost of chilling of milk varied from a minimum of 19 paise per litre in flush season to a maximum of 35 paise per litre in transitory season [71].

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