Spoilage and preservation of milk and milk products: A review

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Abstract: Milk and milk products which provide nutrition have fundamental importance from historical period. These are aids for enhancing economic status of farmers as well as sellers and improve health of customers. However, these products may get spoiled due to microbial contamination leading to potential loss of not only producers and sellers but also consumers. As a result, there is urgent need to analyze reasons of spoilage of such products along with their preservation for their long term uses. In this review, we inspected basic reasons of spoilage of products under study and highlighted their preservation methods so that these can be used to meet needs and demands of global growing population with respect to food.

Index Terms **- Milk, Contamination, Spoilage, Preservation, Products, Microorganisms, Utensil.**

INTRODUCTION:

India is agricultural country which has been passed through white revolution and diverse dairy products meeting food demands of growing population. Dairy products such as *lussy*, *shrikhand, basundi*, ice-cream, badam shake etc. are being consumed by Indian nationals in considerable amount, as desserts in many cases. However, these food items have been always suffering from long term preservation errors from beginning of human civilizations. Owing to improper preservation and storage facilities in India in cold environmental settings (Neelam Khetarpaul 2012), Indians are losing such value added food stuffs leading to loss in manufacturer's economy as well as accelerating undernourishment problems in the nation, especially in poverty areas.

In this review, we highlighted the major problems regarding spoilage and preservation of milk and milk products and their probable solutions supporting economy and improved health of people resulting into high quality economic status of producers.

Microbial Spoilage

Microorganisms are the microscopic living entities that are responsible for heavy spoilage of milk and milk products. Milk is lacteal secretion that is clean, fresh and whole which is obtained from milking animals (De S 2001). According to Sowmya Y (2017), milk spoilage can be described as deterioration of flavor, texture and color of it leading to unsuitability of it for human consumption. Number of microorganisms can grow in milk as it is potentially nutritious growth medium (D K Sandrou and I S Arvanitoyannis 2000). Similarly, spoilage of milk and its products may lead to change in flavor and texture. Alike, moldiness as well as a bitter flavor can be developed in milk product (Srinivasan and Anantakrishnan 1964). Dairy products become inedible owing to spoilage altering flavor, value in relation with nutrition and texture (Mahendra Pal and Vijay J Jadhav 2013) that are important. Mahendra Pal and Vijay J Jadhav (2013) proposed similar view and reported that spoilage is responsible for alteration of texture, flavor along with nutritive value of dairy products making it unsafe for consumption.

Microbial contamination of milk and its products is a serious problem in the world. It occurs when process of dairy products such as Khoa goes on (Ghodekar *et al*. 1974). Khoa available in market was infected by microorganisms owing to gap of processing and selling, primary bioburden on used utensils and incorrect handling operation and improper storage settings (Ghodekar *et al*. 1974). Spoilage of food materials by microorganisms is owing to degradation process of fats, proteins as well as carbohydrates by either microorganisms themselves or enzymes produced by them (Zereu G and Lijalem T 2016; Hyrslova I *et al*. 2016; Maldonado NC and Nader-Macías MEF 2016; Beyene T *et al*. 2016; Sharma GRK 2016).

There are various sources of contamination of milk and milk products. Fecal matter can contaminate *pera, burfi* as well as *khoa* (Ghodekar D R *et al*. 1974). Numerous microflora is involed in spoilage of milk and milk related items. Bhat *et al*. (1948) supported this view and stated that pathogenic microflora *viz. Salmonella typhi*, *E.coli* etc. can persist for longer period in *khoa.* Likewise, wastage of dairy products resulted due to staphylococci and other food spoiling organisms exposing customers to substantial health risk (Ghodekar D R *et al*. 1974). Higher water content of milk exposes itself to microbial growth. Similarly, since milk has considerable water content and biochemical components, it acts as ideal growth medium for numerous microbiota (Karthikeyan N and Pandiyan C 2013). Furthermore, it provides essential ingredients that are required for microbial growth.

In addition, sanitization practices that are not up to the mark contribute to milk spoilage. In opinion of Khan A Q (2006), low quality cleaning in production unit results into microbial contamination reducing shelf life of final products and many products are launched in markets with careless packaging and exposure to environmental contamination. Similarly, milk and milk products get contaminated by improper storing and handling during their marketing. Khoa and sweets obtained from it get contaminated even if those are processed in strict clean environmental settings and in India, moulds spoil dairy food items because of humid environments (Karthikeyan N and Pandiyan C 2013).

To add, microbial evaluation of milk and milk products is recommended to launch high quality produces in international market. This view was supported by Agarwal and Rachappa (2006) who claimed that dairy products must be evaluated since they may get contaminated at any step starting from farm and ending with consumption stage including the steps such as storing, transportation and packaging. In comparison with organized areas, khoa specimens collected from local level vendors showed to have greater coliform numbers (Kumar and Sinha 1989) that are indicators of pathogenic existence.

To continue, washing related operations play their role in spoilage of dairy products. In the same way, lower quality cleaning and water employed for utensil washing lead to contamination of khoa and products based on it by bacteria (Karthikeyan N and Pandiyan C 2013). Besides, authors concluded that the contamination in sweets made from khoa was due to advance preparation of product in bulk amount and its longer storage at room environmental conditions such as temperature and results of this were in accordance with Ghodeker *et al*. (1980). Shockingly, in 1977, the limits set by Indian Standards Bureau 1479 were crossed by mould, coliform along with yeast in Khoa samples obtained from private manufacturing units as well as local level vendors (Karthikeyan N and Pandiyan C 2013). Erroneous process of pasteurization and adulteration in the milk that is pasteurized and handling procedures with unsanitary situations are responsible for milk spoilage (Melisa Anderson *et al*. 2011). Additionally, storage time and place also affect quality of milk and milk products. As well, microbial contamination might due to use of khoa that is stored for longer duration to make sweets (Yadav *et al.* 1993).

To add, the persons who are involved in handling of milk and milk products have their crucial roles in protecting quality of milk and its products. Well trained persons are required to handle the processes regarding the food products in question. ICMSF (1998) reported that milking, utensil handling sources related with person and environment may contaminate sterile milk. To support this claim, Karthikeyan N and Pandiyan C (2013), Kumar and Sinha (1989), Grewal and Tiwari (1990) and Kulshrestha (1990) stated that contamination by bacteria is a result of messy worker hands, inferior milk quality, dirty manufacturing cabinets, low quality raw material and water that is used for cleaning of utensils. Pathogens on such devices and agents are responsible for food spoilage.

In addition, Karthikeyan N and Pandiyan C (2013) stated that local level vendors should take care of customer health, maintaining clean environment during pre as well as post manufacturing process, lower microbiota of final products during storage and marketing. Quality of food is indicated by bioburden and presence of food pathogens (Rosmini *et al*. 2004) along with cleaning conditions during production (Guerreiro *et al*. 2005). The packaging facilities as well as environmental parameters available in dairy industries can't be ignored in order to regulate microbial standards of milk and food items based on it. Equipments used during pasteurization of milk and plastic employed for its packaging increase mesophilic spoilage microorganisms in it (Mahari and Gashe 1990). Insufficient packing (Singh *et al*. 2012), inadequate control of temperature (Moussa *et al*. 2013) bringing unwanted alterations shortens milk shelf life (Fromm and Boor 2004) and contamination of milk by bacteria displays poor quality raw milk in relation with microbiota (Ahmed and Abdellatif 2013).

Even microorganisms growing at lower temperature are responsible for milk spoilage. Some psychrotrophs viz. *Pseudomonas fluorescens, Pseudomonas fragi* can be heat stable and spoil milk even if most psychotrophs are killed by pasteurization process (Sowmya Y 2017). Pasteurized milk can be easily contaminated by psychrotrophic bacteria (Ranieri *et al*. 2009) that reduce shelf life of milk (Durak *et al*. 2006; Fromm and Boor 2004; Meer *et al*. 1991). As well, Simon and Hansen (2001) observed that maximum growth of bacteria occurred at 86 °C in pasteurized milk.

To continue, Griffiths (1992) reported that shelf life of pasteurized milk can be reduced by psychrotrophic bacteria during refrigeration. Even refrigerated raw milk contains bacteria belonging to genera like *Enterococcus, Lactococcus* etc. (V Singh 2011). Milk can be spoiled even after treatment for microbial reduction from the related food product. Gram positive and Gram negative bacteria are responsible for spoilage of post pasteurized milk (Boor and Murphy 2002; Ternstrom *et al*. 1993). While processing as well as production of milk products, Gram positive bacteria can enter in it and human activities along with poor cleaning conditions are considerably involved in spoilage of milk as well as milk products (V Singh 2011).

Besides, the equipments that are employed for processing may contaminate dairy products. Correspondingly, machines that are used for filling of milk are responsible for contamination of milk after pasteurization (Dogan and Boor 2003; Waak *et al*. 2002). In accordance with Salustiano *et al*. (2009), surfaces of equipments contaminate milk repeatedly. Introduction of bacteria in milk is possible from diverse range of sources including faeces, cows udder that is infected, labors, containers of milk as well as other equipments (Melisa Anderson *et al*. 2011). Either raw or pasteurized milk is spoiled by *Pseudomonas* (Sorhaug T and L Stepaniak 1997; Mc Phee J D and M W Griffiths 2002) which arises as a result of improperly cleaned surface structures of milking as well as transportation along with storage equipment (Kumaresan G et al. 2007).

Moreover, filling practices may contaminate post-pasteurized milk (Eneroth A et al. 1998). Existence of supporting temperature for growth of bacteria as well as high gap between milking process and sampling process may lead to increased total bacterial count in not only dairy samples but also samples of milk vendor (Kumaresan G et al. 2007). Surprisingly, long milk handling time at optimum temperature viz. transport and milking may result into increased psychrophilic bacterial load in milk specimens (Kumaresan G *et al*. 2007) and obviously, maintaining less temperature at the time of transportation as well as storage of milk in the form of raw material may lead to high amount of bacteria in question (Kumaresan G *et al*. 2007).

What is more, milk fermenting bacteria keep dairy items on risk of damage. Milk becomes sour because of fermentation by streptococcus or lactobacillus bacteria producing lactic acid and acetic acid from lactose (Li Dai and Peng Zhou 2016; Badem A and Uçar G 2016; Narayanan R *et al*. 2016; Orhevba BA and Taiwo AD 2016). The process of pasteurization is eligible for lowering microorganisms that spoil milk (Sowmya Y 2017).

The composition of milk is also a source of contamination. It comprises minerals, lactose, proteins as well as fats and majority of contaminants in it include not only coliforms but also psychrotrophs (Maheswari N U and Sabitha K 2015). Furthermore, authors claimed that milk is superior source for microbial growth and spoilage microorganisms coming from the milk maid, utensils or animal hair, water and from soil. In addition, grass, feed, soil, and devices that are used for milking are responsible for bacterial contamination of milk in its raw form (Janstova B and Drackova 2006). The milk has not only bacteria but also fungi which spoil it leading to commercial loss of dairy industry. Likewise, bacteria and fungi are responsible for spoilage of milk products (Mahendra Pal

and Vijay J Jadhav 2013) and those can be readily spoiled by diverse organisms (Karthikeyan and Dhanlakshmi 2010; Singh and Prakash 2008; Bhatanagar *et al.* 2007; Gill *et al.* 1994; Yadav *et al.* 1993).

Diseases arise due to contaminated milk consumption. This view was supported by Sarkar S (2016) who stated that contaminated milk is source of outbreak of diseases. Pal M *et al.* (2018) reported that milk as well as milk products is best choices of Indians. Milk may suffer from contamination by microorganisms responsible for spoilage viz. *Achromobacter, Alcaligenes* etc. or pathogens such as *Staphylococcus aureus* leading to diseases (Pal M and Jadhav VJ 2013). Milk as well as dairy food item contamination that occurs in the process starting from farm to placement at consumers is international problem (Pal M *et al.* 2018). However, cleaning process gives protection to consumer health (Pal M *et al.* 2018).

Additionally, contaminated milk may be a source of outbreak of infections. This idea was supported by Pal M *et al.* (2018) who reported that milk can be medium for diverse range of microorganisms leading to either spoilage or diseases. In mesophilic conditions, psychrotrophs have highest damaging potential (J C Ribeiro Júnior 2018). Since considerable numbers of outbreaks through epidemics have been reported due to consumption of raw milk, such uptake should not be entertained (S Sarkar 2015). It is needed to develop not only efficient but also sensitive technique to supervise presence of psychrotrophs that deteriorate foods (J C Ribeiro Júnior 2018). Furthermore, milk is a medium in which microorganisms grow with good growth (V Singh 2011) and may lead to health problems.

Lower pathogens in milk result into its higher quality. In order to determine quality of milk, its microbial load is considered as a major feature (Torkar KG and Teger SG 2008) and due to its chemical composition, it is susceptible for microbial spoilage (V Singh 2011) and also, it is potent growth medium for spoilage organisms such as yeasts and molds that are common (V Singh 2011). Pasteurized milk can be spoiled by streptococci that are heat resistant leading to produce lactic acid lowering the pH (Jay JM 1992). Furthermore, the places where milk is collected contaminate milk (V Singh 2011).

Besides, inspection of dairy products in relation with microbial load should be targeted since microflora such as Gram-negative psychrotrophs, moulds and yeasts, lactic acid bacteria as well as coliforms result into their spolilage (Lamye Glory Moh 2017). *E.coli* is employed as indicator of microbial quality of not only milk but also its products (ICMSF 1986). Moulds and yeasts lead to low quality of milk even if they are in small amount (K G Abdel hameed 2011). There are values to milk in relation with nutrition and is not only best medium for microbial growth (Melisa Anderson *et al*. 2011) but also considerably sensitive for microbial spoilage (Gunasekera TS 2002).

Preservation strategies:

There is urgent need to develop preservation strategies in relation with milk and milk products to meet needs and demands of growing population in the world. This view was supported by Mahendra Pal and Vijay J Jadhav (2013) who stated that milk product spoilage should be prevented in order to control economic loss in the dairy field. In accordance with Vineet Kumar *et al.* (2015), microbial investigation of milk and its products would have practical advantages. In order to make milk safe for human consumption, it should be protected from external contamination at the time of its production, storage along with transportation (Sarkar S 2016). The milk preservation strategies may differ across countries depending on available facilities. Indian rural people preserve milk by making khoa and ghee (Vineet Kumar *et al*. 2015) and in India, khoa is considered as an excellent source for milk preservation (Karthikeyan N and Pandiyan C 2013).

Reducing the activity of pathogens may lower risk of infection in certain extent. Pathogens can be reduced and shelf-life of milk can be increased by inactivating microbial load responsible for spoilage (S Sarkar 2015). It is achieved through high temperature treatment (Gedam *et al*. 2007), UV exposure (Matak *et al*. 2007; Reinemann *et al*. 2006), treatment by microwave (Tremonte *et al*. 2014), processing of membrane (Eckner and Zottola 1991) along with microfiltration (Elwell and Barbano 2006). In contrast, S Sarkar (2015) claimed that even if pasteurization is used widely, it doesn't sterilize milk. Sufficient preservation facilities should be made available to increase shelf life of milk and milk and milk products.

Likewise, after completion of milking, the milk may be subsequently stored for only 3 minutes and its shelf life can be expanded to 24 hours at 5°C (Pal M *et al*. 2018), whereas it can be increased to 4 to 7 days using the process of pasteurization (Pal M 2012). In opinion with Redmond (2005), pasteurization of milk with the temperature in the range of 55°C-70°C is able to destroy bacteria and according to Gunasekera (1993), it was introduced to eradicate human pathogens and reduction of growth of microbes that are responsible for spoilage.

Durability of processed milk should be improved in order to preserve it for longer time. Raw milk storage duration, heat exposure, availability of heat resistant microflora, amount of contamination occurring after pasteurization, employed packing platform and storage conditions after pasteurization influence durability of pasteurized milk (Cromie 1991). Moreover, light (Rysstad and Kolstad 2006) and raw milk quality also affect pasteurized milk (Rysstad and Kolstad 2006). The life span of dairy products can be increased by correct packing as well as storage (Pal M *et al*. 2018).

Treatment of milk with high temperature eradicates pathogens in considerable amount. Heat reduces microbial number in food (Hudson *et al*. 2003). According to Jayamanne and Samarajeewa (2010), High Temperature for Short Time as well as Low Temperature for Long Time was able to destroy *L. monocytogenes* present in less concentration. Ranieri *et al*. (2009) reported that bacteria that grow in cold environment and have spore producing ability have potential to grow in the milk that has been processed through pasteurization and according to Meer *et al*. (1991), this problem has become main barrier in increasing shelf life of product beyond 14 days.

The shelf life of milk can be enhanced by chemical treatment lowering pathogenic bioburden. Microorganisms which are present in biofilm can be effectively inactivated by chlorine (Trachoo and Frank 2002) as well as ozone (Dosti *et al*. 2005). Nada *et al*. (2012) found reduction in microbial load in pasteurized milk and recommended development of automatic disinfection as well as cleaning system. CO_2 can be used for increasing shelf life of milk in raw form (Rajagopal *et al*. 2005; King and Mabbit 1982). This concept was supported by Murray *et al*. (1983) who stated that N2 may be employed for the same purpose. This is possible because of reduction in number of bacteria along with lowering lysis of proteins and breakdown of lipid processes (Rajagopal *et al*. 2005; King and Mabbit 1982).

In contrary to this, heat sensitive food products can't be treated with heat and as a result, other techniques are required to be implemented for pathogen removal including their spores. Equally, Spores that are present in milk can be eradicated efficiently by microfiltration (S Sarkar 2015). Authors further proposed that pasteurization can reduce bioburden of milk and better hygienic operations at the time of milking avoiding milk contamination and microfilteration can be used to complete milk spore removal to avoid contamination of pasteurized milk. Risk of milk contamination in farm as well as in the plant can be lowered by optimum cleaning operations at the time of milking and microbiologically safe milk can be produced by absolute removal of spores by microfiltration (S Sarkar 2015).

Implementation of recommended storage conditions for milk becomes highly necessary to increase working hours of milk. Kumaresan G *et al.* (2007) favored this idea and claimed that before taking the milk for making its products, for instance, cheese; it should be stored at 2°C since shelf life of milk has been found to be increased by two days at the temperature in question. In addition, Sowmya Y (2017) claimed that new preservatives as well as technologies are required for preventing growth of microflora responsible for milk spoilage enhancing the dairy product's shelf life. The process of pasteurization doesn't assure complete eradication of milk when it is heavily contaminated in its raw form and because of contamination that occur after pasteurization (Santana E.H.W. 2004). The milk spoilage can be retarded by not only suppliers but also consumers by storing the milk at proper temperatures (Melisa Anderson *et al.* 2011).

Safety of milk consumption must be given prime importance throughout world since uptake of contaminated milk and milk products may lead to severe health problems putting consumer's life on potential risk. Since milk is prone to growth of microorganisms and may contain pathogens, its consumption may be harmful to health (S Sarkar 2015). Pasteurization is used as safeguard for the milk (S Sarkar 2015). Safe milk processed through pasteurization can be produced by correct pasteurization, milk storage as less temperature, and prevention of contamination after pasteurization (S Sarkar 2015). Pal M et al. (2018) claimed that use of contamination control for availability of safe, acceptable along with wholesome milk as well as milk products for safety of food.

It is essential to develop methodologies for prevention of contamination of dairy products by microorganisms at all steps of the chain related with food supply (Pal M *et al.* 2018). India is the country in which milk along with dairy products that are susceptible to *L. monocytogenes* are widely preferred by people with immune suppression problem (Sheela Mary M and Shrinithivihahshini ND 2017). Sheela Mary M and Shrinithivihahshini ND (2017) observed that in Tiruchirappalli city of India located in Tamilnadu, children as well as elder people were having risks of listeriosis. Melisa Anderson *et al.* (2011) concluded that tests viz. methylene blue reduction along with phosphatase test are recommended for safety of milk for consumption by humans.

Sarkar S (2016) reported that raw milk quality with respect to its hygiene can be achieved by disinfecting as well as cleaning machines that are used for milking. Furthermore, Sarkar S (2016) reported that microbial quality based price incentive of raw milk may increase microbial quality in relation with raw milk. Proper cleaning conditions can lower the existence of bacteria that damage milk products (V Singh 2011).

CONCLUSION:

Spoilage of milk and milk products is serious health concern since it leads to disease outbreaks. The currently available techniques viz. pasteurization that are utilized for preservation of milk and milk products are not up to the mark since they don't give assurance of microbial safety of milk and their products. As a result, there is need to develop next generation techniques and methods for their preservation. Furthermore, standard training of persons, quality cleaning practices, recommended preservation and transportation facilities etc. may aid for meeting demand of milk and milk products across globe for longer period by accelerating their stabilities.

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