PG Institute of Dairy Education and Research, Mehsana
Doctoral Seminar (DM-692)

Shelf life Extension of Milk and Milk Products

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1. Introduction

"Food" is the basic necessity of lives. Amongst it, milk plays a vital role; since the born till death of human being. It is the only food considered as an almost complete food on the earth and hence, sole source of nutrition for new born[1]. Milk production in India is expected to reach 196 MMT by the end of 2019[2]. The consumption of liquid milk accounts for 70%[3]. Because of its high nutritional value and animal origin, it comes under the category of perishable food and undergo for microbial or chemical spoilage[4]. On contrary, emerging pathogen causes several diseases across the world that increases the economic burden of industry and government (Book). So, the preservation of nutritional quality of milk leads the conversion into various milk based products through processing i.e. heat treatment. To improve the shelf life of dairy products three major aspects; processing, additives and packaging are being emphasized.

2. Processing (Thermal and Non-thermal):

Preservation of milk can be achieved by exposing milk to various conventional or thermal treatments like pasteurization, sterilization, freezing, chilling, drying, and addition of chemical preservatives throughout the world[5]. Chilling delays the growth of bacteria by slowing down the metabolic activity whereas drying inhibits growth due to lowering water activity ($a_{w)}$. Both, pasteurization and sterilization are well adopted industrial processes to make milk safe for consumption and increasing shelf life. The pasteurization makes milk free from pathogens and few spoilage causing microorganisms whereas sterilization destroys all vegetative cell. The time-temperature employ for pasteurization and sterilization is 63 ^{0}C /30 min or 72 ^{0}C/15 sec and 115-120 ^{0}C/15-20 min or >135 ^{0}C/1-3 sec (Ultra High Temperature), respectively[6]. On the other hand, microwave (MW) offers volumetric heating and rapid increase in temperature with minimum adverse effects on nutrients over other heat treatments. It can be recognized as the advanced version of heat treatment given at a frequency of 915 (commercial) and 2450 (Domestic) MHz[7]. Exposure of milk, paneer, burfi, etc. to MW reduced the microbial cell numbers below detection level and also decreased the toxin content[8-13.]

However, these processes diminish the nutritional and sensorial profile of milk and milk products. The increasing consumer demands for fresh less processed possesses well nutritional and organoleptic quality with extended shelf life forced food industry to search over the new technologies alone or in combination of

traditional one[14]. This has resulted into an innovative approach of dairy industry towards non-thermal technologies such as High Pressure Processing (HPP), Pulsed Electric Field (PEF), Cold Plasma, Irradiation, Ultrasonication, Ohmic heating, Microfiltration, Bactofugation, etc to enhance shelf life of products[7]. All these processes would facilitate their operation at ambient temperature or less than conventional heat treatments, therefore helps in retaining the natural content of the milk and milk products. Microfiltration helps in removing bacterial cells as well as somatic cells through filters having pore size of 0.1-10 µm[15]. It can be applied in combination with pasteurization for ESL products. Bactofugation remove bacterial spores by applying centrifugal force followed by pasteurization. Few non-thermal techniques are discussed in brief as below.

2.1 High pressure processing (HPP): The first time Hite has demonstrated the shelf life extension of raw milk by applying HPP (Book). It works on two principles; 1) Le Chatelier's: pressure favors all structural reactions and changes that involve a decrease in volume and 2) Isostatic principle: the distribution of pressure is proportional in all parts of a foodstuff irrespective of its shape and size (). The food is exposed in the range of 100-1000MPa pressures[16]. Water or mixture of oil used as pressure transmitting medium. The pressure increases at a tune of 2-3 ^{0}C per 100MPa. Pressure below 420 MPa produces effect similar to pasteurization and above 700 MPa gives similar to sterilization. The products undergone HP processing includes cheeses, milk, infant formula, whey lime beverages and showed extended shelf life for various periods[17-24]. Microbial activation takes place due to denaturation of cell membrane, cell wall, etc.

2.2 Pulsed electric field (PEF): The food is placed between two electrodes and short pulses (1-10 µs) are generated through high voltage (20-80 kV) pulse generator. It forms pore (electroporation) in the cytoplasmic membrane. Both, static and continuous system is used to process food[25]. The PEF treatment given to milk at 15-50 kV/10-235 µs/ 20-60 ^{0}C resulted in increase of shelf life and inactivation of enzymes [26-30].

2.3 Cold plasma: Plasma is a *Greek* word meaning Moldable substances first explained by Irving Langmuir in 1920's[31]. It is referred as fourth state of matter, electrically neutral and produced in the presence of energy source (i.e. electricity) and gas. The products of plasma includes N_2, NO, NO_2, nitric oxide radical NO+, atomic oxygen (O), ozone (O_3), ions, neutrons, protons and reactive oxygen, hydroxyl radicals (OH+) and nitrogen specie[14]. Plasma produced at atmospheric temperature is known as cold plasma. Cold plasma is generated by various methods such as Dielectric barrier discharge **(**DBD) method, atmospheric plasma jet discharge, corona discharge and gliding arc discharge. Air or nitrogen or the mixture of noble gases like argon, neon and helium are used in the presence of electric field. The most commonly used method in dairy is DBD. It has been successfully applied to destroy pathogenic as well as spoilage causing organisms in cheese, raw milk, cheese slices, etc [32-39]. The radical bombardment causes several phenomenon on/in cell i.e. lesions, damage DNA, RNA, lipid oxidation in cell membrane, protein & enzyme denaturation[14]. However, the low penetration power is the major limitation for the application of cold plasma.

2.4 Ultrasonication: Refers to the application of sound waves (at the frequency (>16 kHz) greater than the upper limit of human hearing) through liquid, solid or gases which causes formation of small bubles (known as cavitation). The size of bubble increases and implodes violently at higher intensity waves. Both, the temperature and pressure are high during implosion[40-41]. The combination of heat and ultrasonication is more lethal (known as thermosonication). Another approach includes pressure+ ultrasonication (Manosonication) and heat+pressure+sonication (Manothermosonication)[40]. Exposing milk and cheese ultrasonication /thermosonication improved the shelf life considerably [42-45].Cell inactivation occurs by disrupting both cell wall structure and function through cavitation in ultrasonicator.

2.5 Irradiation: Food is exposed to ionizing radiation in the form of Gamma, X-rays, Ultra-Violet light and electron beams. WHO endorsed the irradiation doses up to 10 kGy. UV-light can potentially reduce the microbial count without affecting other properties of food (Roberts, 2016). Based on wavelength, UV rays are classified as UV-A (315 & 400 nm,), UV-B (280–315nm), and UV-C (200-280 nm) [46]. UV-C is most effective for processing of food. The composition and transparency of food affect the efficiency of UV light. It damages the DNA of bacterial cell and cause mutation. Irradiation of cheese significantly increases the shelf life along with inactivation of microbes[47-49].

2.6 Ohmic heating: It was in practice in the early 19th century. It is also known as joule heater. The movement of ions in the liquid causes collision, which in turn, results in creating resistance and generation of heat[50-51]. OH of milk products improves the texture as well as shelf life of products [52-54].

3. Bio-preservation

Bio-preservation makes the use of metabolites/substances produced by micro-organisms or entire cells or present naturally in milk. Bacteriocins, lysozyme, lactoferrin, natamycin, bacteriophage, and endolysins are the different kinds of biopreservatives employed to enhance the shelf life of milk and milk products [55-69]. Nisin and pediocin are the well known examples of bacteriocins, which are basically proteinaceous compounds, produced by LAB to inhibit the growth of similar or closely related bacterial strain(s).These compounds alone or in combination with other antimicrobial agents (like sorbic acid, EDTA) have shown to inhibit the growth of spoilage and pathogenic bacteria (*E.coli*, *Bacillus* sp., *L. monocytogenes*, *Staph. aureus*, etc.) in several milk products[55, 66]. Natamycin (E235) is an antifungal compound produced as a secondary metabolite by some species of *Streptomyces*; it is effective at very low levels (MIC is less than 10 ppm) for most molds. It has been successfully used to preserve various types of cheeses, sour cream, yogurt, and packaged salad mixes [56]. Lysozyme is a glycoside hydrolase that catalyzes the hydrolysis of 1,4-beta-linkages between N-acetyl-D-glucosamine and N-acetylmuramic acid residues in peptidoglycan- the major component of Gram-positive bacterial cell wall. Furthermore, several studies had shown the successful application of host specific bacteriophages and endolysins which are hydrolytic enzymes synthesized by bacteriophages to cleave the host cell's cell wall during the final stage of the lytic cycle.

3.1 Herbs & EO: According to Ayurveda, the herb/spice is used as a whole plant including the root/rhizomes (turmeric), leaves (*tulsi*, *phudina*), bark (cinnamon), flower (clove), fruit (cardamom,

ashwagandha), etc., and specifically herbs contain phytosterols, antioxidant, essential oils, vitamins, and other substances that help to inhibit the growth of microorganisms[70]. On the other hand, essential oils are plant derived aromatic oily liquors and also possess an antimicrobial properties. EOs are produced by steam distillation. Several studies have indicated shelf life extension of different milk products *viz.* milks, fermented milks, & ghee using herbs and EO [71-82].

3.2 Chemical preservatives: Incorporation of chemical agents in food to have antimicrobial activity practiced since ancient time. Benzoic acid or its sodium salt, benzoate were the first molecule approved in USA. The other includes salt, sugar, inorganic salts, etc. (as per the Appendix- A, FSSR, 2011). Another reason to be added in dairy products may deal with the antioxidant property of chemical preservatives.

4. <u>Packaging</u>

Both, packaging system and packaging material of milk and milk products act as an external means of preservation after processing and during transportation & distribution[84, 85]. It performs various functions like protection, convenience, communication, etc. The customer's demand for fresh, convenient, easy to cook food and industrial threat of wastage, non-recyclable packaging & global warming issue brought the technological innovations in form of Vacuum packaging, Modified Atmosphere Packaging (MAP), Active packaging, Edible coating, Intelligent or smart packaging, etc. The focus in the later section is given on various packaging system rather than packaging material.

4.1 MAP: It deals with the modification/ alteration of gaseous environment during packaging of food. The major gases used are CO_2, N_2, and O_2[84]. Atmosphere is modifies either passively or actively[85]. It prevents or slower down the microbial or chemical deterioration of food. The dairy products packed (cheese, jalebi, yoghurt) under MAP showed higher shelf life [86-92].

4.2 Active packaging: The condition of packaged food is changed in order to extend the shelf life by addition of active component into the packaging material. It involves various component that act as active ingredient i.e. O_2 scavangers, CO_2 emitting/absorbing, Anti-oxidants releasing, etc. The incorporation of essential oils, nano-composite of Ag, Zinc oxide, O_2 scavangers into packaging material markedly increase the shelf life of cheese and milk [93-103].

4.3 Edible coating: Biodegradable or edible packaging/coating of food open a new avenue for the industry. It performs in similar way to the conventional packaging material with aided benefits i.e. carrier for active compounds (). The sources of edible coating are polysaccharides, protein, lipids, resins, etc. However, secondary packaging material in addition is still required for proper and hygienic handling of food. Coating made up of chitosan, galactomannan, polylactic acid, whey protein extended the shelf life of various types of cheeses [104-108].

5. Conclusion

Milk, yoghurt, curd or dahi and other milk products have been consumed since thousands of years and considered as an important part of human diet. The extension of shelf life means preserving nutritional quality of milk. The traditional methods of processing and preserving milk and milk products severely affect the vitamins, flavour, color etc. The consumer preferences of minimally processed and healthy food engaging the industry to look after for better alternatives. Hence, three major areas; non-thermal techniques, additives, and packaging are in focus and being continually researched. Many of them are successfully adopted at industry level in order to increase the shelf life. As each area has its own benefits and limitation, needs to be optimized according to the product profile. Further, in depth understanding would definitely help to change the mindset of people and acceptance of new technologies in future.

6. References

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