**Paper No.: 07**

**Paper Title: TECHNOLOGY OF MILK AND MILK PRODUCTS**

**Module – 35: New technologies and product development in dairy industry**

## INTRODUCTION

Preservation of dairy products is an action or a method of maintaining dairy product at a desired level of properties or nature for their maximum benefits. In general, each step of handling, processing, storage, and distribution affects the characteristics of dairy product, which may be desirable or undesirable. Thus, understanding the effects of each preservation method and handling procedure on dairy product is critical in dairy industry. The processing of dairy product is no longer as simple or straightforward as in the past. It is now moving from an art to a highly interdisciplinary science. A number of new preservation techniques are being developed to satisfy current demands of economic preservation and consumer satisfaction in nutritional and sensory aspects, convenience, absence of preservatives, low demand of energy, and environmental safety. New and alternative dairy processing methods and novel combinations of existing methods are continually being sought by industry in pursuit of producing better quality dairy products more economically. Hence, new innovations, technologies, and concepts continue to emerge. In general, several years are necessary for new technologies to become successful in the commercial performance. Over the years, many traditional technologies have been optimized for producing better quality dairy products with the use of aseptic processing, membrane processing, microwave, radio frequency and ohmic heating, high-pressure processing and electrical pulse processing. These new technologies, although emerging as strong alternatives to conventional processing, still need to be rigorously tested and proved to be safe and commercially viable.

## NEW TECHNOLOGIES IN DAIRY INDUSTRY

### MEMBRANE PROCESSING

The pressure driven membrane processes are based on the ability of semi-permeable membranes of appropriate physical and chemical nature to discriminate between molecule – primarily on the basis of size and to a lesser extent on shape and chemical composition. In these processes, the membrane acts as a selective barrier, enriching certain components in a feed stream, and depleting it of others. The first breakthrough in membrane processing was desalination of water using cellulose acetate (CA) membranes. The most attractive feature of the process is its simplicity. It involves only bulk movement of fluids using mechanical energy (i.e., pumping). Membrane concentration processes have several advantages over conventional concentration processes, i.e., evaporation. Undesirable heat-related changes such as color, aroma, and viscosity characteristics are avoided because membrane processes can be operated at room temperature. Unlike evaporation or freeze concentration, membrane separation does not involve a phase change for separation, thereby energy is used more efficiently. The main membrane systems in ascending order of pore size are: reverse osmosis, nanofiltration, ultrafiltration and microfiltration. Membrane processes have been investigated in dairy food industry for concentration of fluid milk and whey. Cheese prepared from ultrafiltration of milk have advantages of 16% – 20% increase in the yield of cheese, better control of dry matter and milk fat in the cheese, reduction in the quantity of coagulant up to 80%, and reduced environmental pollution due to protein/fat-free permeate/whey.

**Principles of Membrane Separation**

Membrane processes include a wide range of unit operations from sieving to reverse osmosis (RO). Filtration of coarse particles, i.e., in the micron range, is carried out by conventional dead-end filtration where particles are retained by the filter that later form a cake layer resulting in increased resistance to filtration. This requires frequent cleaning and replacement of filters. The most common membrane configuration used in the industrial setup is cross-flow membrane filtration. It is continuous type and used to separate particles, which are about 10 μm to solute molecules that are a few Angstroms. In crossflow membrane separation, the bulk phase is forced to flow along the membrane surface using external pressure. The permeate (less particle concentration) is collected on the low-pressure side of the membrane, while on the high-pressure side the concentrate sweeps the retained particles so that the cake layer remains relatively thin and the resistance to filtration remains low. Flow of the liquid through the membrane is driven by hydraulic pressure gradient, while flow of the solute through the membrane is diffusion driven and by concentration gradient.

The membrane filtration is divided into four narrower ranges based on particle size: microfiltration, ultrafiltration, nanofiltration, and RO (Table 1). The size of particles retained in these processes ranges from 0.1 to 10 μm (microfiltration), 1000–500,000 molecular weight cut-off (ultrafiltration), and 100–1000 molecular weight cutoff (nanofiltration). The RO membranes can retain the smallest solute molecules such as sodium chloride and are classified by percentage rejection of sodium chloride in an aqueous solution under specified conditions and range from 95% to 99.5%. The operating pressure ranges are 10–50 psi (microfiltration), 20–200 psi (ultrafiltration), 100–500 psi (nanofiltration), and 200–1500 psi (RO). The mechanisms of membrane transport proposed are sieve mechanism, hydrogen-bonding mechanisms, solution-diffusion mechanism, and preferential sorption– capillary flow mechanism.

**Table: 1 Membrane Filtration Range**

| Filtration Spectrum | Diameter of Pores in Membrane (µm) | Molecular Weight (of Solute) |
|---|---|---|
| Microfiltration | 0.05–5.0 | > 1,000,000 |
| Ultrafiltration | 0.005–0.1 | 4000–10,000 |
| Nanofiltration | 0.0005–0.01 | 100–5000 |
| Reverse osmosis | 0.0001–0.001 | < 800 |

**Membrane Modules**

A wide variety of materials are used for manufacturing of membranes, including sintered metals, ceramics, and polymers. The membrane structure varies in its chemical nature, microcrystalline structure, pore size and pore size distribution, and degree of asymmetry. Two simple parameters—membrane permeate flux and solute rejection—are used to describe the characteristics of membranes. Since the properties of membrane material can be influenced by environmental conditions and time, secondary properties such as resistance to compaction, temperature and chemical stability, and resistance to microbial attack are also important. Additional requirements for food processing are good tolerance of cleaning and disinfecting solutions, and lack of toxicity of the contact materials.

Membranes are assembled as modules that are easily integrated into systems containing hydraulic components. The modules are designed to contain large membrane area in a small volume, withstand the pressures required during separation, and cross-flow velocities required to maintain a clean membrane surface. The most common module configurations are flat plate, tubular, hollow fiber, and spiral wound. The selection of module configuration and membrane material depends on the feed type and economics.

**Ultrafiltration**

Ultrafiltration has a wide range of applications in the dairy industry. Ultrafiltration membranes allows separation of smaller molecular weight substances ranging from 10,000 – 75,000 daltons with operating pressure ranging between 10 – 200 psig. Ultrafiltration produces from milk a permeate containing water, lactose, soluble minerals, non-protein nitrogen and water-soluble vitamins and a retentate in which proteins, fat and colloidal salts content increase in proportion to the amount of permeate removed. The ultrafiltration process has been used for milk protein standardization, deproteinization of whey, fractionation of proteins, preparation of biological peptides, manufacture of rasogolla mix powder, preparation of protein rich milk, low lactose powder, manufacture of milk protein concentrates, manufacture of whey protein concentrates, etc. Ultrafiltration process has also been used for the manufacture of several fermented dairy products like yoghurt, shrikhand and various types of soft and semi soft varieties of cheeses.

**Reverse Osmosis**

Reverse osmosis is essentially a dewatering technique. It can be used for pre-concentration of liquid feed for different purposes. The reverse osmosis membranes are characterized by a molecular weight cut off of nearly 100 daltons and pressure involved are 5 – 10 times greater than those used in ultrafiltration. The potential applications of reverse osmosis technology are: bulk transportation of reverse osmosis concentrated milks, pre-concentration of milk for khoa making and spray drying, utilization of pasteurized reverse osmosis concentrate in place of market milk, partial concentration of whey, partial concentrate of milk and buttermilk.

**Nanofiltration**

Nanofiltration is a demineralization process. Acid whey can be partially demineralized (about 40%), particularly with respect to the monovalent ions, and concentrated simultaneously to approximately 25% total solids using nanofiltration process. It separates particles with molecular weights in the range of 300 – 1000 daltons. Operating pressures required are nearly 300 psig.

**Microfiltration**

Microfiltration is essentially used as a clarifying process to remove macromaterials and suspended solids, milk fat globules, bacteria and colloidal particles. In microfiltration, membranes with pore size ranging from 0.1 – 10 micron and the operating pressure in the range of 1 – 25 psig are used. The most significant application of microfiltration is for selective separation of bacteria from milk.

**UHT PROCESSING**

Ultra High Temperature (UHT) processing of milk refers to a processing know how wherein milk is heated to a temperature of 135°- 150°C for 2-10 sec in a continuous flow and subsequently packaged under aseptic conditions in sterile containers. Processing in a continuous system involves pumping the product to heat exchanger, heating, holding for fixed duration in holding tube, flash cooling in heat exchanger followed by packaging in a neat and sterile containers. There are two major types of steam/hot water based continuous flow UHT processing systems: (1) indirect heating and (2) direct heating.

In case of indirect heating systems, heating of milk to the sterilizing temperature can be achieved in heat exchanger based on corrugated plates, tube or scraped surface cylinders. Whereas direct heating UHT systems involves either injection of steam into milk or spraying of milk in a steam filled chamber (infusion). The equipment for ultra-high-temperature (UHT) pasteurizers is much the same as for HTST units. The controls are similar but the operating temperature points are higher. The holder is, of course, much smaller for minimum pasteurizing time.

**OHMIC HEATING**

Ohmic heating, also known as Joule heating, electric resistance heating, direct electric resistance heating, electroheating, and electroconductive heating, is a process in which alternating electric current is passed through food material; heat is internally generated within the material owing to its resistance to the applied electrical current. In conventional heating, heat transfer occurs from a heated surface to the product interior by means of convection and conduction and is time consuming, especially with longer conduction or convection paths that may exist in the heating process. Electroresistive or ohmic heating is volumetric in nature and thus has the potential to reduce over processing by virtue of its inside–outside heat transfer pattern. Ohmic heating is not a new technology; it was used as a commercial process in the early twentieth century for the pasteurization of milk. However, the “electropure process” was discontinued between the late 1930s and 1960s, ostensibly because of the prohibitive cost of electricity and a lack of suitable electrode materials. Interest in ohmic heating was rekindled in the 1980s, when investigators were searching for viable methods to effectively sterilize liquid–large particle mixtures, a scenario for which aseptic processing alone was unsatisfactory.

Ohmic heating is a direct heating method that uses the food itself as a conductor of electricity that is taken from mains. The most important benefit of ohmic heating is that heating is very rapid and uniform. The process is ideal for shear-sensitive products. Ohmic heating can heat the food continuously without needing the hot heat transfer surface of a scraped-surface heat exchanger (SSHE) or a tubular heat exchanger. The process is quiet in operation as rotating parts are not used in the system to ensure temperature uniformity. A high level of control and automation ensure safety during the operation. Finally, it is easier to design a heating time / temperature profile that will ensure sterility because heat is generated within the solids independent of thermal conductivity through the liquid.

**MICROWAVE HEATING**

Thermal processing has been a major processing technology in the food industry ever since the discovery of the process by Nicholas Appert and its subsequent commercialization. The purpose of thermal processing was to extend the shelf life of food products without compromising food safety. Various thermal treatments such as pasteurization and sterilization can be selected on the basis of severity of the heat treatment and the intended purpose. Apart from inactivation of pathogens, thermal treatment can also result in some other desirable changes, such as protein coagulation, texture softening, and formation of aromatic components. However, the process has also got some limitation by way of partial destruction of quality attributes of food products, especially heat-labile nutrients, and sensory attributes.

The technological revolution, nutritional awareness, and continuous demand of the new generation have necessitated search for new or improved food processing technologies. Presently, several new food processing technologies, including microwave and radio frequency heating, pulse-electric field treatment, high-pressure processing, ultrasonic applications, irradiation, and oscillating magnetic fields, are being investigated to improve, replace, or complement conventional processing technology.

Microwaves are a form of electromagnetic radiation, characterized by wavelength (300 MHz to 300 GHz) and frequency. Microwaves used in the food industry for heating are of ISM (industrial, scientific and medical) frequencies (2450 or 900 MHz, corresponding to 12 or 34 cm in wavelength). In this frequency range the dielectric heating mechanism dominates up to moderated temperatures. Polar molecules, the dominant water, try to align themselves with the rapidly changing direction of the electric field. The energy to achieve this alignment is taken from the electric field. When the field changes direction, the molecule “relaxes” and the energy previously absorbed is dissipated into the surroundings, that is, directly inside the food. This means that the water content of the food is an important factor in the microwave heating performance of foods.

Microwave heating in foods occurs due to coupling of electrical energy from an electromagnetic field in a microwave cavity with the food and its subsequent dissipation within food product. This results in a sharp increase in temperature within the product. Microwave energy is delivered at a molecular level through the molecular interaction with the electromagnetic field, in particular, through molecular friction resulting from dipole rotation of polar solvents and from the conductive migration of dissolved ions. The principal mechanisms involved in microwave heating are therefore dipole rotation and ionic polarization. Water in the food is the primary dipolar component responsible for the dielectric heating. In an alternating current electric field, the polarity of the field is varied at the rate of microwave frequency and molecules attempt to align themselves with the changing field. Heat is generated rapidly as a result of internal molecular friction. The second major mechanism of heating with microwaves is through the polarization of ions as a result of the back and forth movement of the ionic molecules trying to align themselves with the oscillating electric field. Microwave heating is also affected by the state of the constituents, whether they are bound or free, e.g., bound ions have much lower microwave absorptivities.

Microwave heating is preferred for pasteurization and sterilization over the conventional heating for the basic reason that the process is fast and requires minimum come-up time (CUT) to the desired process temperature. The volumetric heat generated by microwaves can significantly reduce the total heating time and severity at the elevated temperatures needed for commercial sterilization whereby bacterial destruction is enhanced, but thermal degradation of the desired components is reduced.

Dairy industry applications of microwave processing include enhancement of pasteurization efficiency, thermising milk prior to cheese manufacturing, inactivation of bacteriophage, in-package paneer making, clarification of butter into ghee, thermisation of yoghurt, cooking of cheese curd, plasticizing provolone and mozzarella cheese and thawing butter.

**HIGH HYDROSTATIC PRESSURE PROCESSING**

Consumer trends and therefore food markets are changing and will change more in the future. Foods with high quality and more fresh-like attributes are in demand; consequently, less extreme treatments or fewer additives are required. To satisfy these demands; some changes in the traditionally used preservation techniques must be achieved. One “new” or emerging technology receiving a great deal of attention is high hydrostatic pressure. The basis of high hydrostatic pressure is the Le Chatelier principle, according to which any reaction, conformational change, or phase transition that is accompanied by a decrease in volume will be favored at high pressures, while reactions involving an increase in volume will be inhibited. However, owing to the complexity of foods and the possibility of changes and reactions that can occur under pressure, predictions of the effects of high-pressure treatments are difficult, as are generalizations about any particular type of food.

High-pressure technology was originally used in the production of ceramics, steels, and superalloys. In the past decade, high-pressure technology was expanded to include the food industry. High pressure presents unique advantages over conventional thermal treatments, including application at low temperatures, which improves the retention of food quality. High-pressure treatments are independent of product size and geometry, and their effect is uniform and instantaneous.

The application of hydrostatic pressure to food results in instantaneous and uniform transmission of the pressure throughout the product independent of the product volume. The hydrostatic treatment is unique in that the effects do not follow a concentration gradient nor do they change as a function of time. Other advantages include the absence of chemical additives and operation at low or ambient temperatures so that the food is essentially raw. Hydrostatic pressure is a physical treatment that will not cause extensive chemical changes in the food system. Once the desired pressure is reached, it can be maintained without the need for further energy input. Liquid foods can be pumped to treatment pressures, held, and then decompressed aseptically for filling as with other aseptic processes. The application of high pressure processing to food preservation started around 1900 when Hite and his coworkers investigated its effects on food microorganisms by subjecting them to pressures of 650 MPa and found a reduction in the viable numbers of microbes.

The food industry employs the technique of isostatic pressing for applying high pressures to foods. A high-pressure system consists of a high-pressure vessel and its closure, pressure-generation system, temperature-control device, and material-handling system. Once loaded and closed, the vessel is filled with a pressure-transmitting medium. Air is removed from the vessel by means of a low-pressure fast-fill-and-drain pump, in combination with an automatic deaeration valve, and high hydrostatic pressure is then generated. High pressures can be generated by direct or indirect compression or by heating the pressure medium.

**PULSED ELECTRIC FIELD**

High-intensity pulsed electric field processing involves the application of pulses of high voltage (typically from 20 to 80 kV/cm) to foods placed between two electrodes. Pulsed electric field treatment is conducted at ambient, sub-ambient, or slightly above ambient temperatures for less than 1 sec, as a result of which the energy loss due to heating of foods is minimized. Pulsed electric field technology is considered superior to traditional heat treatment of foods because it maintains food quality by avoiding or greatly reducing detrimental changes to the sensory and physical properties of foods.

The use of Pulsed electric fields for inactivating microorganisms is promising non-thermal processing method that can be used for pasteurization and possibly also sterilization, with the integration of other processing parameters such as pH, ionic strength, temperature, and high-pressure processing.

**OSMOTIC DEHYDRATION**

The concentration of food products by means of product immersion in a hypertonic solution is known as osmotic dehydration. Osmotic dehydration consume less energy compared to air drying and freeze drying because water removal occurs without a phase change. Heat damage to the food product is minimum in case of osmotic dehydration as the product is not subjected to high temperature for extended periods. Successful attempts have been made to dehydrate traditional Indian dairy products such as ras malai, rasogolla and paneer using osmotic dehydration technology.

**HURDLE TECHNOLOGY**

Hurdle technology is a concept in which three or more preservation parameters (hurdles) are employed in suitable combination and every hurdle is used at optimum level so that damage to the overall quality of food is kept to minimum. Hurdle technology has been tried for preservation of several Indian dairy products such as milk cake, paneer and paneer curry.

**BIOPRESERVATION**

Biopreservation refers to the extended storage life and ehhanced safety of foods using their natural or controlled microflora and/or their antimicrobial products. The diverse group of lactic acid bacteria synthesize a variety of inhibitory substances such as organic acids, carbon dioxide, $H_2O_2$, diacetyl, bacteriocin, etc. which prevent the development of undesirable bacteria.

**PRODUCT DEVELOPMENTS IN DAIRY INDUSTRY**

Consumers' demands keep changing over time. These changes range from basic considerations such as improving food safety, shelf life, and reducing wastage, to demands for increasingly sophisticated foods having special characteristics in terms of nutritional value, therapeutic value, palatability and convenience.

**Probiotics**

A probiotic is a mono or mixed culture of live microorganisms which benefits host (man or animal) by improving the properties of the indigenous microflora. Regular consumption of probiotic dairy products positively affect the composition of this microflora or extend a range of host benefits including:

- Reduction in serum cholesterol and blood pressure
- Decreased incidences and duration of diarrhea
- Maintenance of mucosal integrity
- Anticarcinogenic and antimutagenic activities
- Immunostimulation and immunomodulation
- Pathogen interference, exclusion and antagonism

**Fat Replacement**

Nutritional experts recommend low fat, no fat or reduced fat foods as consumption of high fat food has been linked to several chronic diseases such as cardiovascular diseases, obesity and certain forms of cancer. Fat mimics and fat substitutes are normally used to produce low fat foods. Fat mimics are substances that help replace the mouthfeel or fat but can not substitute for fat on a gram for gram basis and can not be used for applications involving frying. Substances whose physical or thermal properties resemble fat are termed as fat substitutes and can replace fat on a gram for gram basis and can also be used for frying applications. Low fat cheese, cultured products, frozen desserts, butter and spreads have been successfully developed using commercially available fat mimics/replacers.

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