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Non thermal techniques for dairy food processing applications

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Abstract : Processing and preservation of food is essential for value addition it require a variety of different methods and heat treatment is the most widely used methods due to its high efficiency on microbial inactivation. But exposure to high temperature causes undesirable changes such as reduction in organoleptic quality as well as reduction in heat-sensitive nutrients. Additionally, increasing consumer demand for minimally processed good quality and safe food products with natural flavor and taste, free from additives and preservatives, causes the need for the development of non-thermal methods for food preservation. There are a number of non-thermal methods used for food preservation all over the world. Foods can be non-thermally processed by High pressure processing, Pulsed electric field, Ohmic heating, Ultrasound treatment, etc. These novel technologies result in pathogen free foods with improved texture and improved shelf life. These techniques retain natural freshness, color and nutritive characteristics as compared to heat processing. The present review discusses the various novel non thermal techniques used today for food preservation.

Key words : Non thermal, Processing, Non-thermal preservation, Temperature, Heating

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Food systems are complex mixtures of different biochemical molecules, biological polymers, inorganic salts, and water. Good quality food is required to meet consumer needs.The processing methods which were used for preservation affect the quality and safety of the food produce. So there is need of non-thermal food processing technologies which satisfies the demands of consumers for natural and healthy food with minimal damage of its natural nutritional and organoleptic properties. This paper summarizes non-thermal processing technologies currently available for the inactivation of microorganisms. Processes include ultra-high pressure, including ultrasound, pulsed light and pulsed electric fields, microwave, Ohmic heating, radio frequency and hurdle technologies as shown in Fig. 1

High-pressure processing :

High pressure processing is a non-thermal technique for food preservation which uses high pressure for microbial inactivation. High pressure processing is carried out with pressure in the range of 100-1000 MPa, with exposure time ranges from millisecond pulse to 1200 seconds *i.e.* 20 minutes (Kunio *et al.*, 1994).The main advantage of high pressure processing in comparison to thermal processing is the maintenance of sensory and nutritional characteristic of treated food products (Balasubramaniam *et al.*, 2008). High pressure processing is also known as high hydrostatic pressure (HHP) or ultra-high pressure (UHP) processing in which

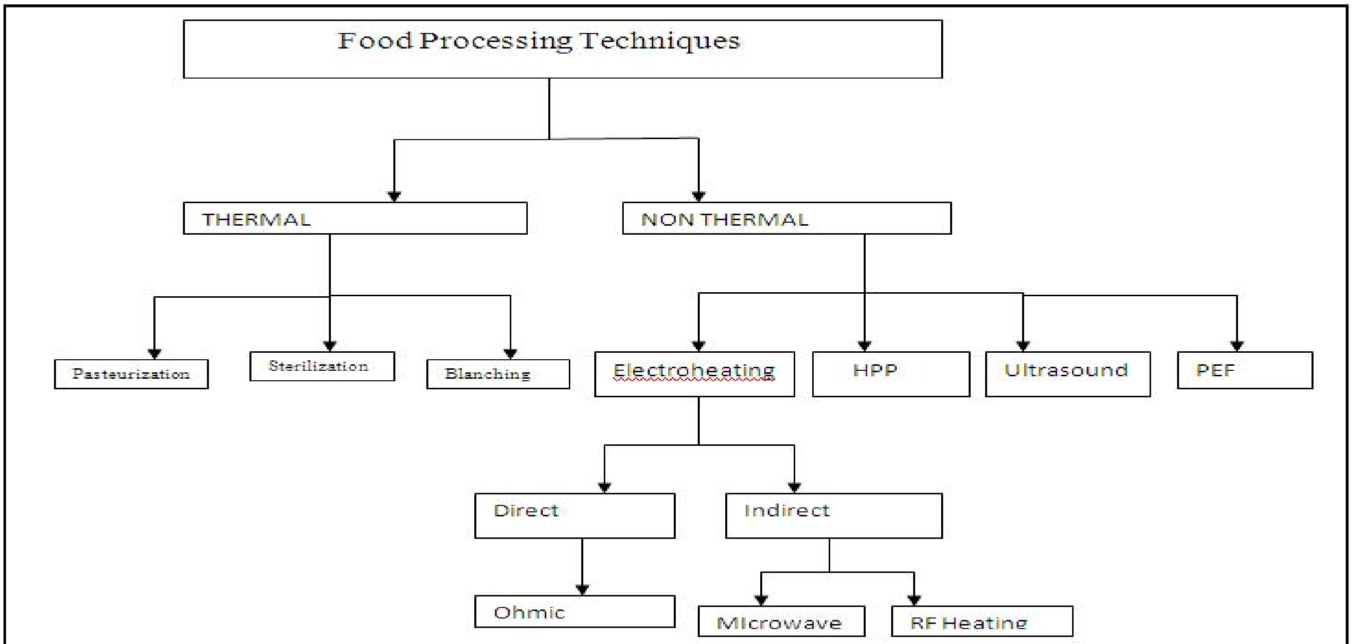

Fig. 1 : Food processing techniques

the process temperature during the pressure treatment can be specified from below 0°C to above 100°C (Kunio *et al*., 1994).

The basic principles involved in the high pressure processing of foods are:

Le Chatelier's principle:

It states that any reaction which may be conformational change, phase transition accompanied by a decrease in volume is enhanced by pressure (Cheftel, 1995, Farkas and Hoover, 2000 and Ledward, 1995).

Isostatic principle:

In high pressure processing the food products are compressed by uniform pressure from every direction and when the pressure is released, and then the food returned to their original shape (Olsson, 1995).

A high pressure system consists of a pressure vessel and pressure generating device. The food products are packaged in a flexible packaging usually a pouch or plastic bottle. Food packages are loaded into the vessel and then the top of pressure system is closed, after which the pressure transmitting fluids are pumped into the vessel from the bottom. The mostly used fluids for this purpose are water, glycol solutions, silicone oil, sodium benzoate solutions, ethanol solutions, inert gases and castor oil (Yaldagard *et al.*, 2008). The process is Isostatic, so pressure is transmitted rapidly and uniformly throughout both the pressure medium and the food with little or no heating. It is equally from all sides so that the product is not affected. For most applications, products are held for 3-5 min at 600 MPa. After pressure treatment, the processed product is removed from the vessel and stored in a conventional way (Anonymous, 2002).

As the pressure is transmitted uniformly in all direct ions simultaneously, food retains its shape, even at extreme pressures and because no heat is needed, treated food retains their natural flavor, color and texture without loss in vitamin or nutrient content. There are a number of applications of HPP in fruits and vegetables, meat and fish, dairy and egg industry etc. (Kadam *et al.*, 2012).

Hurdle technology :

Hurdle technology is the combined use of several preservation methods, *i.e.* hurdles to make a product microbiologically stable, resulting in increase of shelf life of the food product as well as to preserve the sensory and nutritional quality of foods (Leistner, 1996).

It was first introduced by Leistner in 1978.The most important hurdles commonly used in food preservation are temperature (low or high), water activity (a_w), preservatives (Sorbate, nitrite etc.), acidity (pH) and competitive microorganisms (eg.Lactic acid bacteria).

The main principle behind hurdle technology is that the microorganisms could not be able to jump over all the hurdles present in the food product. Till today more than 60 hurdles have already been described (Leistner, 2000).

Let us take an Example of a hurdle in food preservation *i.e.* High Temperature which mainly involves pasteurization and sterilization. Pasteurization which is mild heat treatment used to kill pathogenic microorganisms (63°C for 30 min; 100°C for 12sec) acts as a hurdle for microorganisms, which destroys vegetative pathogens (disease-causing microbes) thus reduces total microbial load, increases shelf-life. On the other hands Sterilization involves complete destruction of microorganisms in which severe heat treatment (equivalent to several min at 121.1°C) destroys spores and gives "shelf-stable" product (Wang, 2002).

Example of foods preserved by hurdle technology involves salami-type fermented sausages which are stable at ambient temperature for extended periods of time. The microbial stability is achieved by the use of a combination of hurdles. Important hurdles in the early stage of the ripening process of salami are the preservatives salt and nitrite, which inhibit many of the bacteria present in the meat batter. On the other hand, a_w decreases with time, and thus becomes the main hurdle in long-ripened raw sausage (Leistner, 1995).

Pulsed electric field :

Pulsed electric field (PEF) is a non-thermal technique for food preservation in which short pulses of electricity are used for microbial inactivation. In PEF technology, sensory and physical properties of foods are less affected (Quass, 1997).PEF technology involves the application of pulses of high voltage to liquid or semi-solid foods which are placed between two electrodes. (Qin *et al.*, 1995). Electric fields in the range of 5-50 kV/cm are used for microbial inactivation, which is generated by the application of short high voltage pulses between two electrodes thus causing microbial inactivation at temperatures below those used in thermal processing. Application of pulsed electric fields of high intensity and duration from microseconds to milliseconds may cause temporary or permanent permeabilization of cell membranes (Zimmermann, 1986).The process is based on pulsed electrical currents delivered to the product placed between a set of electrodes; the distance between electrodes is termed as the treatment gap of the PEF chamber. The applied high voltage results in an electric field that causes microbial inactivation. After the treatment, the food is packaged aseptically and stored under refrigeration (Zhang *et al.*, 1995). The equipment consists of a high voltage pulse generator and a treatment chamber with a suitable fluid handling system and necessary monitoring and controlling devices. The Food product is placed in the treatment chamber where two electrodes are connected together with a nonconductive material to avoid electrical flow from one to the other. Generated high voltage electrical pulses are applied to the electrodes, which then conduct the high intensity electrical pulse tothe product placed between the two electrodes. The food product experiences electric field, which is responsible for the irreversible cell membrane breakdown in microorganisms (Zimmermann and Benz, 1980). PEF technology is used for the microbial inactivation in milk, milk products, egg products, juice and other liquid foods and also in simulated milk ultra-filtrate (Qin *et al.*, 1995 and Pothakamury *et al.*, 1995).

Ohmic heating :

Ohmic heating is a process in which alternating electric current passes through food materials, where food acts as an electrical resistance to the electric current passed,which results in the generation of heat which inactivates or kills microorganisms present in the food (Vicente *et al.*, 2006).

It consists of food material placed between two electrodes, and thus electric current is passed through the food. The principal mechanism of microbial inactivation in ohmic heating is thermal in nature, but the principal reason for the additional effect of ohmic heating is due to its low frequency(50-60Hz) which causes electroporation.

Electroporation is defined as the formation of pores in cell membranes due to the presence of an electric field and as consequences, the permeability of the membrane is enhanced and material diffusion throughout the membrane is achieved by electro osmosis (An and King, 2007).The food is to be treated is placed between two electrodes and then electric current of low frequency passes through the food which results in the microbial inactivation.There are a number of applications of ohmic heating which involves blanching, evaporation, dehydration, fermentation, extraction, sterilization, pasteurization and heating of foods to serving temperature for military field and in long-duration space missions (Knirsch *et al.*, 2010).

Ultrasound treatment :

Ultrasound is sound wave transmitted with a frequency higher than the audible frequency of 20 kHz (Butz andTauscher, 2002). The ultrasound equipment usually has frequencies ranging from 20 kHz to 10 MHz (López-Malo *et al*., 2005). Ultrasonic applications in the food industry are divided into two distinct categories, *i.e.* Low energy and High energy ultrasounds. Low energy (low power, low-intensity) ultra- sound applications are performed at frequencies higher than 100 kHz and below 1W/cm^2 intensities. Low intensity ultrasound in the food industry is generally used for analytical measurements to get information about the physicochemical properties of foods such as composition, structure and physical state (Jayasooriya *et al.*, 2004 and Knorr *et al.*, 2004).

High energy (high power, high-intensity) ultrasonic applications are performed generally at frequencies between 18 and 100 kHz and are intensities higher than 1 W/cm^2 (typically in the range 10 - 1000 W/cm^2 (McClements, 1995). High-intensity ultrasound used to generate emulsions, disrupt cells and disperse aggregated materials. It isalso used for degassing of liquid foods, enzyme inactivation, enhanced drying and filtration and the induction of oxidation reactions.

The Ultrasonic wave producing system consists of a generator, transducer and the application system. The Generator produces electrical or mechanical energy and transducer converts this energy at ultrasonic frequencies (Mulet *et al.*, 2003). In application system a coupling device is used to transfer ultrasonic vibrations to the sample. This is obtained by ultrasonic bath and probe system (Leadley and Williams, 2006).

Gas bubbles are produced in liquid media by ultrasonic waves when ultrasound passes through a liquid medium. The bubbles then grow to an unstable size and then burst which results in the high heat and pressure around the collapsing bubbles to break the compounds in the liquid and give localized sterilization effect, at this point particle dispersion and cell disruption occur. The applications of ultrasound treatment include fruit juice processing, milk, egg industry in the microbial inactivation, enzyme inactivation etc. with less effect on food quality (Ercan and Soysal, 2013).

Microwave heating :

Microwaves are electromagnetic waves which consist of both electric and magnetic fields, perpendicular to each other and propagate at the speed of light. Microwaves form part of the electromagnetic spectrum with frequencies ranging from 300MHz to 300GHz and wavelengths ranging from 1m to 1mm, respectively. The frequency of microwave for domestic purposes is 2450 Hz, but for industrial purposes the frequency used is 915 Hz (Bradshaw *et al.*, 1998).

The main principles behind microwave heating are:

Dipole rotation:

It states that when an electrical field is applied, the molecules orient themselves according to the polarity of the field. The polar molecules rotate to maintain alignment with the rapidly changing polarity. Such rotation of molecules leads to friction with the surrounding medium, and thus heat is generated which result in the heating of food material (Buffler, 1993).

Ionic polarization:

It states that when an electrical field is applied to food solutions containing ions, the ions move at an accelerated pace due to their inherent charge. The resulting collisions between the ions cause the conversion of kinetic energy of the moving ions into thermal energy (Data and Anantheswaran, 2001).

A microwave consists of power supply, magnetron, waveguide, stirrer and oven cavity. Power supply draws electrical power from the line and converts it to the high voltage required by the magnetron. Magnetron converts the power supplied into microwave energy. The magnetron emits high-frequency radiant energy. The wave guide transfers the generated energy from the magnetron to the oven cavity. In a domestic oven, the wave guide is a few centimeters long, whereas in an industrial unit sit can be a few meters long And thus stirrer scatters the transmitted energy throughout the oven cavity which encloses the food to be heated within the metallic walls (Metaxas and Mereadith, 1983).There are number of applications of microwave heating in food industries which involves baking, cooking, thawing, tempering, drying, pasteurization, sterilization, blanching etc.

(Shaheen, 2012).

Pulse light method :

It is one of the non-thermal techniques for food preservation which uses short time high peak pulse of broad spectrum white light. Pulse light is used for decontamination of food surfaces and food packages. Temperature of food is increases very little and thus avoids undesirable reaction and by product formation in comparison of other techniques. The pulse light is produced by amplifying the power by storing the electromagnetic energy in a capacitor for fractions of second followed by releasing it in the form of light (Dunn *et al.*,1995).The pulse producing unit consists of one or more xenon lamp units, a high voltage connection and a power unit. High voltage connection permits transfer of high current electric pulse. The wavelength range of pulse light is 1000-11000Å.For effective inactivation of microorganisms the pulse light of 120 flashes per sec with energy range of 0.01-50 joule cm^{-2} should be used (Barbosa-Canovas,1998).

The microbial inactivation by pulse light is due to photochemical effect that results in denaturation of DNA and pyramid formation in dimmers in bacteria, virus and other pathogens. There are number of applications of Pulse light in foods which includes meat and in treatment of packaged products (Gomez-Lopez *et al.*, 2005).

Radio frequency heating :

The RFportion of the electromagnetic spectrum occupies a region between1 and 300 MHz but the main frequencies used for industrial heating lie in the range 10–50 MHz (Tang, 2005). RF heating also involves the use of electrodes (with the product being placed either midway between or on top of one of a pair of electrodes) between which a high frequency directional electrical field is generated by high power electrical valves which transfer energy to the electrodes by a transmission lines (Samaranayake *et al.*, 2005). When an alternating electrical field is applied to a food, one phenomenon that occurs is the movement of positive ions in the material towards negative regions of the electric field and the movement of negative ions towards positive regions of the field (Buffler, 1993). In addition to the movement of ions, dipolar molecules such as water in a material will also attempt to align themselves appropriately with the changing polarity of an electrical field (a phenomenon known as dipole rotation). The movement of these dipoles can also cause friction between molecules which can also lead to heat generation (Buffler, 1993). The applications of RF heating in food processing involves meat industry, post-harvest treatment and disinfestations of fruits, juice industry etc.

Conclusion :

Non-thermal technologies are being investigated due to green consumerism which demands minimally processed, high quality, convenient and safe food. Non-thermal processes gives increase in shelf life without the use of preservatives or additives, while still retaining color, flavor, texture and nutritive qualities. To expand the use of non-thermal processes in the food industry, combinations of these technologies with traditional or emerging food preservation techniques are being studied. Currently, non-thermal technologies are employed for acidic foods, e.g. fruit juice, but more research is needed for the processing and packaging of shelf-stable low acid foods. Besides, a major barrier in the acceptance of these emerging technologies is a lack of information among the consumers and non-thermal food processing is still an evolving field. Non-thermal processes discussed are still in development stages with considerable potential. Still more research is needed to understand all the effects of these non-thermal processing techniques.

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