

Innovative Techniques in Food Processing

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The food industry is in the process of revolutionary change with new processing technologies that allow foods to keep possession of superior quality without refrigeration (Sastry, 2008). It is fact that not only the shelf life but also the quality of food is important to consumers led to the concept of preserving foods using preservation methods. Therefore, alternative or novel food processing technologies are being explored and implemented such as Microwave heating, High Pressure Processing (HPP), Ohmic heating, Ozone processing, Atmospheric Pressure Plasma (APP), Ultrasonic (Knorr *et al.*, 2009). It is important to understand that no single technology can replace the shelf-stable capabilities of either classical retorting or aseptic processing. Nowadays, many of the innovative thermal and non-thermal processing technologies can be used either additively or synergistically to build “hurdles” in working together with an objective to produce superior products with minimize heat-induced damages (Zhang *et al.*, 2010). The importance of novel processing techniques are to improve microbial safety and nutritional quality, to improve physical-chemical properties of foods by minimizing process intensities for sensory evaluation or technological function, to reduce operating cost requirements, to reduce waste load, to increase production and process efficiency (Steinhart, 2006).

Microwave Processing

Microwave heating refers to dielectric heating due to polarization effects at a selected frequency band in a nonconductor. There are two major mechanisms of interaction of foods with microwaves. One is ionic conduction and the other is dipolar rotation. 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 (Oliveira and Franca, 2002).

Microwave equipment is consisted of three major components i.e. the power supply and microwave generator, the applicator, and the control circuitry. The magnetron is the heart of the microwave heating equipment. Microwaves are generated by a magnetron, which is attached to the applicator controlled by a waveguide. The magnetron consists of the two elements of an electron tube - a cathode and an anode - each of which is in a circular form with anode resonant cavities.

The major applications of microwave heating in food industry are baking of bread, blanching of vegetables, pasteurization and sterilization of different foods, tempering of frozen meat and poultry products, sausage cooking, drying of various foods and thawing of frozen products etc. The low temperature and fast mass transfer conferred by vacuum combined with rapid energy transfer by microwave heating leads to rapid and low temperature drying and thus it has the potential to improve energy efficiency and product quality (Duan *et al.*, 2010). Sharma and Prasad (2001) established a reduction in drying time from 80% to 90% when they added microwave to convective drying. A similar reduction was stated by Kaensup and Wongwises (2004) when using FBD + MW in comparison to FBD, at a power of 800 W. Lin *et al.*, (1998) dried carrot slices by microwave vacuum drying. Giri and Prasad (2007) evaluated the drying characteristics of carrot cubes by microwave hot air drying results in a substantial decrease (25-90%) in the drying time and better product quality. Sharma



and Prasad (2001) reported that the microwave convective drying results in saving to an extent of about 91% of total drying time. Al-Hilphy and Ali (2013) have pasteurized cow milk by microwave flash pasteurizer. Kasuriya and Atong (2004) compared the energy consumption of continuous microwave system and conventional oven drying for the baking of bread.

High Pressure Processing (HPP)

The governing principle of HPP is based on two principles: Isostatic rule and Le Chatelier-Braun principle for a hermetically sealed flexible package. Therefore, in contrast to thermal processing, the time necessary for HPP should be independent of the sample size (Norton *et al.*, 2008). It can preserve food, by applying intensive pressure in the range at 300-900 MPa which is distributed instantly and uniformly throughout the food in isostatic manner (Patterson, 2005). High pressure affects only noncovalent bonds (hydrogen, ionic, and hydrophobic bonds), causes unfolding of protein chains, and has little effect on chemical constituents associated with desirable food qualities such as flavor, color, or nutritional content. Small molecules such as amino acids, vitamins, and flavor compounds remain unaffected by high pressure, whereas the structure of large molecules such as proteins, enzymes, polysaccharides, and nucleic acid may be altered (Rastogi *et al.*, 2007).

In HPP equipment involve pressure vessel and high pressure pump. There are two way for processing foods in high pressure vessels: In-container (one by one continuous container) and bulk container processing at desired pressure level. It has several advantages such as being applicable on both solid and liquid foods with minimal risk of post processing contamination, easy material handling with high system efficiency, and being suitable for pumpable and aseptic packed foods.

The effects of high pressure treatment in milk include dissociation of caseins micelles from the colloidal to the soluble phase, resulting in reduced turbidity of milk, decreased RCT and reduction in whiteness. Flavour and aroma components contributing to the sensory and nutritional quality remain unaffected (Naik *et al.*, 2013). Sierra *et al.*, (2000) showed that HPP of milk is a gentler process than conventional procedures for extending shelf

life, because no significant variation in the content of B₁ and B₆ vitamins was observed. Yoghurt making from high pressure treated milk and pressurization of yoghurt to inactivate microbiota. The properties of acid-set gels prepared from high pressure treated milk have been reported by Johnston *et al.*, (1994). He found the improved texture (rigidity and resistance to breaking) and syneresis resistance of the gels. Raffalli *et al.*, (1994) suggested that it is possible to reduce significantly the microbial load of a dairy cream (35% fat) by HP at 450 MPa and 250°C for 10 to 30 min. High Pressure Treatment (HPT) of milk affects its coagulation process and cheese making properties indirectly through a number of effects on milk proteins, including reduction in the size of casein micelles, probably followed by interaction with micellar k-casein. Huppertz *et al.*, (2005) evaluated that yield of cheese curd from high pressure treated and subsequently heated milk was greater than that from unheated and unpressurized milk. A reduction of 40 % in oil uptake during frying was observed, when thermally blanched frozen potatoes were replaced by high pressure blanched frozen potatoes (Knorr, 1999; Rastogi and Niranjana, 1998). HPT was found to decrease oil uptake during frying of potato, which may be due to a reduction in moisture content caused by compression and decompression (Rastogi and Niranjana 1998).

Ohmic Heating

The principle of ohmic heating is based on ohm's law. It is also called Joule heating, electrical resistance heating, direct electrical resistance heating, electro-heating, or electro conductive heating. It is defined as a process where electric currents are passed through foods to heat them. Heat is internally generated due to electrical resistance (Fryer and Alwis, 1990). Ohmic heating is distinguished from other electrical heating methods by (a) presence of electrodes contacting the foods (b) frequency applied (c) Waveform (Vicente *et al.*, 2010).

Ohmic heating used in blanching, evaporation, dehydration, fermentation, extraction and value added process. There is no significance difference for sensory attributes and rheological properties between Ohmic heated jam and jam prepared by



another method (Lindbom Ingela *et al.*, 2006). Ohmic heating technology offers great potential to reduce the over processing of high protein liquid foods products, such as milk or protein solutions. Pereira (Pereira *et al.*, 2007, 2008) studied the effects of HTST ohmic pasteurization and conventional treatment on quality of goat milk and concluded that there is no negative effect on the flavor quality of goat milk. In fact, using ohmic heating for milk pasteurization at 72°C for 15 sec with 220 Volts produce low quality pasteurized milk because whey proteins became denatured and reaction between poles and milk and constituted deposits on the poles and fouling (Sagar and Suresh Kumar, 2010).

Ozone Processing

Importance

In 1982, Ozone was declared as Generally Recognized As Safe (GRAS) for treatment of bottled water. Since 2001, FDA approved its use as an antimicrobial agent in foods. Ozone also is useful in deodorizing air and water. Commercial applications of ozone include purification of drinking water, sterilization of containers for aseptic packaging, decontamination of fresh produce and food preservation in cold storage. Gaseous or aqueous ozone generators are commercially available and relatively inexpensive instruments (Balasubramaniam *et al.*, 2014). Ozone is now being used as a safe, powerful disinfectant to control biological growth of unwanted organisms in products and its equipment used in the food and beverage industries (Sopher *et al.*, 2002). The diffusers permit ozone gas to pass through a venturi-injector thus creating many small ozone bubbles in the water, similar to a fish tank air stone. As the ozone bubble rises, the gas at the bubbles edge will transfer into the water. Using a diffuser requires enough pressure to overcome the height of the water and any restrictions in the diffusers due to hole size. Mainly two equipments are used in ozone processing in fluids i.e. venture injectors and bubble diffusers (source: www.ozonesolution.com). There are three way of treatment of food 1. Sanitization 2. Controlling the spoilage and over ripening 3. Removing the contaminates (Baratharaj, 2009).

Ozone processing is used in food Storage, washing fruits and vegetables, disinfection of stainless steel surfaces in UHT plant, dairy biofilms on stainless steel surface, CIP system, pest management, air quality in beverage production. However, ozone processing's no required chemical storage, more germicidal than chlorine and instant pathogen kill with eco-friendly.

Atmospheric Pressure Plasma Technology (APP)

Atmospheric Plasma can be defined as the state of ionized gas consisting of positively and negatively charged ions, free electrons and activated neutral species, and are generally classified into two types, thermal plasma and cold plasma based on the difference in characteristics (Banu *et al.*, 2012). Non Thermal Plasma (NTP) is a new discipline in food processing. Plasma is electrically energized matter in a gaseous state that can be generated by electrical discharge. Electrical discharges in atmospheric pressure and low temperature make this process practical, inexpensive and suitable for decontamination of products where heat is not desirable (Afshari and Hosseini, 2012). Most studies carried out so far have used particulate food products. However, liquid foods, e.g. juices, can also be plasma-treated. The use of plasma to decontaminate the surface of sensitive products, e.g. freshly cut foods is also being investigated (Eisenbrand, 2013).

Cold plasma can be used for decontamination of products where micro-organisms are externally located. Unlike light (e.g. Ultraviolet light decontamination), plasma flows around objects, which means "shadow effects" do not occur ensuring all parts of a product are treated. For products such as cut vegetables and fresh meat, there is no mild surface decontamination technology available currently; cold plasma could be used for this purpose. Cold plasma could also be used to disinfect surfaces before packaging or included as part of the packaging process. Energy consumption would be similar to existing UV-C systems and the treatment of foods would be highly cost-effective; the electronics and lifetime of plasma technologies are comparable to UV-C systems even with the additional need for a carrier



gas (Banu *et al.*, 2012). NTP has been applied in the food industry including decontamination of raw agricultural products (Golden Delicious apple, lettuce, almond, mangoes, and melon), egg surface and real food system (cooked meat, cheese) (Afshari and Hosseini, 2012).

Ultrasound

The fundamental effect of ultrasound on a fluid is to impose an acoustic pressure (P) in addition to the hydrostatic pressure already acting on the medium. Ultrasound is a deep penetrating modality, capable of producing thermal and non-thermal effects by an Alternating Current (AC) flowing through a piezoelectric crystal. It is versatile and innovative technology due to its wide range of application and increase in knowledge and research studies (Ercan and Soysal, 2013). The frequency of sound waves audible to human ear ranges from 20 Hz to 20 kHz. The sound waves having frequencies > 20 kHz to 100 kHz are called “Ultrasonics” or “Power Ultrasound”. The principle aim of this technology is to reduce the processing time, save energy and improve the shelf life and quality of food products (Chemat *et al.*, 2011). The advantages of ultrasound over the heat treatment include; minimization of flavor loss, greater homogeneity and significant energy savings (Ercan and Soysal, 2013).

Ultrasonic wave producing system contains the generator, transducer and the application system. Generator produces electrical or mechanical energy and transducer converts this energy into the sound energy at ultrasonic frequencies. Three main types of transducers are reported as fluid-driven, magnetostrictive and piezoelectric transducers (Mulet *et al.*, 2003).

The applications of ultrasound in the food industry can be divided into two distinct categories, depending on the adopted ultrasound intensity. Low-intensity ultrasound uses power levels less than 1 W/cm², which are so small that the ultrasonic waves cause no physical or chemical alterations in the properties of the material through which it passes. It is referred to as nondestructive use of ultrasound. The most common application of low-intensity, nondestructive ultrasound is as an analytical technique for providing information

about the physicochemical properties of foods, such as composition, structure, and physical state. In addition, operating conditions such as flow rate also can be monitored. In contrast, the power levels used in high intensity applications are so large (in the range from 10 to 1000 W/cm²) that they cause physical disruption of the material to which they are applied, or promote certain chemical reactions (e.g., oxidation). High-intensity ultrasound can be used for the inoperative of microorganisms and enzymes, generation of emulsions, tenderization of meat, and enhancement of drying, extraction, and filtration operations. In ultrasonic atomization, it is important to recognize between ultrasonic nozzles that produce an aerosol by passing a liquid feed through a vibrating horn and ultrasonic nebulizers that operate at higher ultrasonic frequencies and generate a “fountain-like” structure in a thin liquid film. The droplet sizes produced by an ultrasonic nebulizer are an order of magnitude smaller that is available from an ultrasonic nozzle. Nowadays, Centrifugal and rotary nozzle is widely used in commercial spray dryer but yet not have using ultrasonic nebulizer that gives the lower velocity rate with small particle size so that the profited for small size of spray drying chamber utilized (Ashokkumar *et al.*, 2010). Rastogi *et al.* (2010) stated that osmotic dehydration is widely used for partial removal of water from food materials by immersion in a high osmotic solution. Fernandes *et al.* (2008) evaluated the effect of ultrasound pretreatment applied at atmospheric pressure during osmotic dehydration of melon. Stojanovic and Silva (2007) showed that application of high-frequency ultrasound (850 kHz) on osmotic dehydration of rabbiteye blueberries increased the water diffusion rate, but it resulted in loss of anthocyanins and phenolics. Ertugay *et al.*, (2004) reported the ultrasonic homogenization of milk at 20 kHz and compared the results with those of a conventional homogenizer. The size distribution of the fat globules after the conventional homogenization process (at 200 bar and 55 °C) was about 2–5 µm. The size range of fat globules in ultrasonically homogenized milk samples was much smaller which means size distribution of the fat globules was dependent on the ultrasonic power and length of sonication. They attributed the observed smaller size of fat



globules to the physical effects generated during acoustic cavitation. Tiwari *et al.* (2009) found that vitamin C retention of orange juice after ultrasonic treatment is higher when it is compared to thermal processing. Mahdi *et al.* (2007) showed that emulsions with droplet size below 0.5 mm could be produced by ultrasound in combination with micro fluidization technique. The most significant application in this respect is the use of ultrasonic cutting devices at commercial dairy processing.

Conclusion

The concern behind the thermal processing of food is loss of volatile compounds, nutrients, and flavour. To overcome these problems innovative methods are developed into food industries to increase the production rate and profit. The non-thermal processing is used for all foods for its better quality, acceptance, and for its shelf life also reduces the operational cost. Innovative method have better potential than others conventional method and still an evolving challenging field. The cost of equipments used in the non-thermal processing is high when compared to equipments used in thermal processing. After minimizing the investment costs and energy saving potential of non-thermal processing methods, it can also be employed in small scale industries.

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