Alternative Technologies in Food Processing

In recent years, the demand for higher quality products from consumers is on the rise. In an effort to meet this need, researchers have been investigating alternative processing techniques to enhance the quality of processed foods. Some of the alternative thermal techniques that have been investigated include ohmic & infrared heating and the use of microwave & radio frequency waves to heat products. Since thermal treatment diminishes the nutritive value of a product, researchers have attempted novel non-thermal techniques to destroy microorganisms. Some of these techniques include pulsed light, pulsed electric field, ultraviolet radiation, membranes, high pressure, ultrasonic waves, irradiation, and ozone. The advantages offered by these technologies include better product quality, new line of products, convenience, automation, higher throughput, selectivity of heating, lower overall cost, and ability to process heat sensitive products.

**Infrared heating** \((3 \times 10^{11} - 4 \times 10^{14} \text{ Hz})\) serves as a quick means for surface heating and disinfection (seeds, peas, ground beef patties, baked potatoes). Infrared heating is rapid unlike a convection oven, since energy is not transmitted by hot air, but by electromagnetic radiation. However, it rapidly heats up only the surface of the object and then, heat is transferred to the center by conduction. Infrared spectroscopy is used to identify the constituents in various foods.

**Ohmic heating** involves passing electric current through a product (liquid whole eggs, tomato sauces) to heat or sterilize it. The liquid and particulates in a food can be heated at the same (rapid) rate using this technique. However, products might have to be reformulated (to include more salts) to facilitate heating.

The effectiveness of **microwave** \((3 \times 10^{8} - 3 \times 10^{11} \text{ Hz})\) and **radio frequency** \((3 \times 10^{3} - 3 \times 10^{8} \text{ Hz})\) heating depends on the dielectric properties (dielectric constant and loss factor) of the food. In radio frequency heating, the food to be heated is placed between two plates, the polarity of which is reversed at radio frequency. Microwave and radio frequency radiations result in the volumetric heating up of polar molecules within a product. Conventional microwaves operate at 915 or 2450 MHz, while designated frequencies for radio frequency heating of foods are 13.56, 27.12, and 40.68 MHz.

**High pressure** \((100 - 800 \text{ MPa})\) is effective in inactivating many microorganisms during the processing of meats, fruit juices, jams, and jellies and the process does not significantly affect product quality. Water is usually the medium used to transfer pressure (generated by a piston and possibly an intensifier as is the case in an indirect system) to a product within a cylindrical pressure vessel. This results in a decrease in the specific volume & pH and increase in temperature of the medium during treatment. It also causes changes in freezing, thawing, and boiling temperatures. It is important to note that high pressure processing does not cause any change in the covalent bonds in foods. High pressure inactivates microorganisms and denatures proteins at room temperature while preserving the low molecular weight quality carriers in food (vitamins, flavor and fragrance components).

**Ultrasonic waves** cause an irreversible lethal effect to some microorganisms due to cavitation \((5550 \degree \text{C, 50 MPa})\). Cavitation refers to the growth and collapse of microscopic bubbles. When ultrasonic waves are passed through a liquid, alternate compression and
expansion zones are formed which generate bubbles. Small bubbles grow rapidly and reach a resonant size at which it absorbs energy very efficiently, thereby increasing its volume rapidly until it can no longer absorb energy and implodes violently. Ultrasonic waves are also useful in determining the structure, composition, and dimensions of products.

Membrane processing (microfiltration, ultrafiltration, nanofiltration, reverse osmosis, electrodialysis, and pervaporation) has been used for concentration of liquid foods, reduction of microbial counts, demineralization, production of whey protein concentrate, and for aroma recovery. Membrane separation is based on selectively permitting the flow of materials across a membrane based on molecular weight due to the pressure drop applied across the membrane.

The pulsed light technology uses short durations (200-300 microseconds) of intense non-ionizing flashes (0.5 - 1.5 J/cm²) of broad spectrum white light (170 - 2,600 nm) generated by electrically ionizing a xenon gas lamp for 1 to 20 times a second to control bacteria, molds, and yeasts in waste water & drinking water and for surface treatment of meat, poultry, vegetables, and food packaging surfaces.

The pulsed electric field technology involves the use of high intensity electric field (0.5 - 50 kV/cm) at 1 - 5 Hz for a few microseconds to inactivate microorganisms such as E. Coli, Staphylococcus, and Pseudomonas in products such as liquid whole eggs, apple juice, milk, and soup. Inactivation is caused by electroporation. The most widely accepted model is the dielectric rupture theory of Zimmermann which suggests that an electric field induces a transmembrane potential which is greater than the natural potential of the cell and when the overall membrane potential reaches ~ 1 V, rupture of the cell occurs.

Irradiation involves the use of gamma rays produced from Co-60 or Cs-137 (3 x 10¹⁹ - 3 x 10²⁰ Hz), accelerated electrons or X-rays (3 x 10¹⁶ - 3 x 10¹⁹ Hz) to destroy microorganisms (e.g.: E. Coli, Trichinella, and Salmonella) in spices, poultry, and pork; photoelectric effect and the Compton effect being the predominant governing principles. Irradiated foods bear the “Radura” symbol, and the maximum dose of radiation that can be used is 10 kGy. Irradiated foods have been used as early as 1942 (Red Cross used it for the prisoners in Europe during WW-II). Some of the techniques to detect the use of irradiation in foods include electron spin resonance, thermoluminescence, NIR, DNA testing, and the half-embryo method.

Ultraviolet light (7 x 10¹⁴ - 3 x 10¹⁶ Hz) has been used to sterilize air, milk, food packaging surfaces, and packaging equipment and also to minimize souring of vegetables. Ultraviolet light has also been used in conjunction with heat or other processes to obtain higher rates of kill of microorganisms.

Ozone (in gaseous form) is primarily used to purify water. Ozonated water has been used to wash fresh fish, meat, and vegetables. It is also used as a sanitizing agent and performs better than chlorine in this respect. Ozone has been declared as a GRAS (Generally Regarded As Safe) substance by the FDA and the by-products of ozonation are similar to those produced in normal oxidation processes.

All of the technologies discussed above can be used as a stand-alone technology or in conjunction with another technology. Factors such as cost, scale-up issues, range of applicability, establishment of health effects, and development of a database for approval by regulatory agencies are some of the reasons for these technologies not being adopted on a large scale.