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Ensuring safety and enhancing health promoting quality of food using non-thermal technology: Review

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Abstract
Non thermal processing retains the food quality while avoiding the need for excessive thermal treatments or chemical preservation. Consumers gives more preference for convenient, fresh-like, healthy, minimal-processed food products with natural colour, flavor and taste and long shelf-life. Non thermal process inactivates the vegetative microorganisms, most commonly related to food-borne diseases allowing most foods to be preserved with minimal effect on taste, texture or nutritional characteristics. These novel non thermal technologies have the ability to inactivate microorganisms at ambient or near-ambient temperatures, thereby avoiding the deleterious effects that heat has on the flavour, colour and nutrient value of foods. These process provides a unique opportunity for food processors to develop a new generation of value-added food products having superior quality and extended the shelf-life to those produced.

Keywords: Ensuring safety, health promoting, quality of food, non-thermal technology

1. Introduction
Food preservation technique ensuring safety and quality of food has been a prime objective of food processors. Thermal pasteurization and commercial sterilization of foods provide safe and nutritious foods but unfortunately, are often heated beyond a safety factor that results in unacceptable quality and nutrient retention. Non thermal processing technologies offer unprecedented opportunities and challenges for the food industry to market safe, high quality health-promoting foods. The development of non-thermal processing technologies for food processing is providing an excellent balance between safety and minimal processing, between acceptable economic constraints and superior quality, and between unique approaches and traditional processing resources (Zhang *et al.*, 2011) [21]. Non thermal technologies are useful not only for inactivation of microorganisms and enzymes, but also to improve yield and development of ingredients and marketable foods with novel quality and nutritional characteristics (Morris *et al.*, 2007) [14]. Non thermal processing is effectively combined with thermal processing to provide improved food safety and quality. The factors to consider when conducting research into novel non thermal and thermal technologies as

1) target microorganisms to provide safety;
2) target enzymes to extend quality shelf life;
3) maximization of potential synergistic effects;
4) alteration of quality attributes;
5) engineering aspects;
6) conservation of energy and water;
7) potential for convenient scale-up of pilot scale processes;
8) reliability and economics of technologies;
9) consumer perception of the technologies

"The search for new approaches to processing foods should be driven, above all, to maximize safety, quality, convenience, costs, and consumer wellness" (Tokusoglu, 2015) [19]

2. Non-thermal processing technologies
The term 'non-thermal processing' is often used to designate technologies that are effective at ambient or sub lethal temperatures. These processing techniques have little or no thermal effects on foods, they are commonly referred to as non-thermal preservation technologies.

High hydrostatic pressure, pulsed electric fields, high-intensity ultrasound, ultraviolet light, pulsed light, ionizing radiation and oscillating magnetic fields have the ability to inactivate micro-organisms to varying degrees (Butz & Tauscher, 2002) [4]. Some of these treatments may involve heat due to the generation of internal energy (e.g. adiabatic heating and resistive heating during HHP and PEF, respectively), however, they are classified as non-thermal once, contrarily to thermal processing technologies, they can eliminate the use of high temperatures to kill the microorganisms, avoiding the deleterious effects of heat on flavor, color and nutritive value of foods (Pereira and Vicente., 2010) [15].

The most extensively researched and promising non-thermal processes for preservation of foods appear to be pulsed electric fields (PEF) and high hydrostatic pressure (HHP) (Ross *et al.*, 2003) [17], which are being commercially applied mostly for the processing of juices and other fruit-derived products (Leistner & Gould, 2002) [12], ultrasonic, ultra-violet light, ionizing irradiation (electron beams) and hurdle technologies also leading the way. In addition, pulsed X-rays, pulsed high intensity light, high voltage arc discharge, magnetic fields, dense phase carbon dioxide, plasma, ozone, chlorine dioxide, and electrolyzed water are receiving attention individually and as a hurdle in minimal processing.

2.1 Pulsed Electric Fields

PEF technology is the application of short pulse of high electric field with duration of micro to mini seconds and intensity in order of 10-80kV/cm. The process is based on the pulse electric current delivered to a product placed between a setoff 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 cause microbial inactivation. Destruction of microbial cells by PEF is due to irreversible electro oration of the cell membrane, which leads to leakage of intracellular contents and eventually lysis of the cell**.** Pulsed electric fields is used in food industry to process and preserve liquid and semi liquid foods. It is more efficient than traditional heat treatments of food and consequently it presents several advantages over conventional heat treatments: better retention of flavour, colour and nutritional value, improved protein functionality, increased shelf-life and reduced pathogen levels (Amaili *et al.*, 2007) [1].

2.2 High Pressure Processing

High-pressure processing (HPP), also known as high hydrostatic pressure (HHP) or Ultra High Pressure Processing, is a relatively new, non-thermal food processing method that subjects foods (liquid or solid) to pressures between 50 and 1000MPa. The pressures applied to foods being processed is transmitted isostatically (all the region of food experience a uniform pressure) and instantaneously; thus the process is not dependent on the shape or size of the food (Smelt, 1998) [18]. Pressure treatment can be used to process both liquid and high-moisture-content solid foods. Pressure processing is a lethal to microorganisms but at relatively low temperatures (0-40 ^{0}C) covalent bonds are almost unaffected. Pressure induces a number of changes in the microbial cell membrane, cell morphology, and biochemical reactions, which can ultimately lead to microbial inactivation. Cell membranes are the primary site of action for pressure damage to microbial cells. The microbial membranes play an important role in the transport and respiration functions; thus, a great change in membrane permeability can cause death of the cell. Enzymes can be inactivated through pressure action by disrupting their active site.

Pressure treatment can also be used to alter the functional and sensory properties of various food components, especially proteins. The tertiary and quaternary structures of molecules which are maintained mainly by hydrophobic and ionic interactions are beneficially altered by high pressure above 200 MPa (25). The main advantage of high pressure processing compared to thermal sterilization and pasteurization is maintenance of sensory and nutritional characteristic of treated food products.

The inactivation effect of high pressure processing results in extending shelf-life and improving the microbial safety of food products. High pressure treatment could be accepted as a food safety intervention for eliminating *Listeria monocytogenesin* processed meat products and cheese (Yaldagard *et al.*, 2008) [20]. Hydrostatic pressure treatment is also effective in inactivating other hazardous microorganisms such as E. coli, Salmonella, and *Vibrio*, as well as many yeasts, molds, and bactseria responsible for food spoilage. the microbiological shelf-life and food quality can be substantially extended by the use of HPP (Hayman *et al.*, 2004) [7]. Pressure inactivation of yeast and moulds has been reported in citrus juices. Juices pressurized at 400 MPa for 10 min at 40 ^{0}C did not spoil during 2-3 months of storage (Hoover *et al.*, 1989, Hugas *et al.*, 2002) [8, 9].

2.3 Pulse light or high intensity light technology

Ultraviolet light, broad spectrum white light and near infrared light can be used for pulsed light processing (Green *et al.*, 2005) [6]. it can be used for rapid inactivation of microorganism on food surfaces, equipments and food packaging materials. The treatment is effective on smooth, non-reflecting surface or in liquid with no suspended material. The rough surface hinders inactivation due to cell hiding. The pulsed light processing can be described as a sterilization or decontamination technique used mainly to inactivate surface micro-organisms on foods, packaging material and equipments. This technique uses light energy in concentrated form and exposes the substrate to intense short bursts of light (pulses). Typically for food processing about one to twenty flashes per second are applied. Application of pulse light: a) this treatment given to eggs for surface decontamination, b) shelf-life extension and inactivation of *Listeria monocytogenes* on ready to eat cooked meat products, c) for freshly cut mushroom d) for decontamination of chicken from food pathogens, e) decontamination of packaging material, f) mitigation of allergen (peanut and soybean allergen). The intensity of light, that lasts for only a second, is 20,000 times brighter than sunlight, but there is no thermal effect, so quality and nutrient content are retained (Brown, 2008) [3].

2.4 Cold Plasma

Cold plasma is a novel non thermal food processing technology that uses energetic, reactive gases to inactivate contaminating microbes on meats, poultry, fruits, and vegetables. The atmospheric cold plasma is proposed for decontamination of fruits and vegetables, especially, without changes in sensory attributes. Growing demand for fresh produce posses the challenge to the food industry of supplying safe food with minimal processing. Plasma is considered as a distinct state of matter due to its properties; it does not have a regular shape or volume and it can form filaments and/or beams under magnetic fields. Depending on the method of generation used, the plasma can display a broad spectrum of states ranging from extreme no equilibrium to almost complete thermal equilibrium. Plasma technology is fast growing and particularly studied for its use on biomedical materials and devices (Kogelschatz, 2007) [10], surface modification of textiles (Morent *et al.*, 2008) [13], water sterilization (Korachi. 2009) [11] and more recently wound healing and food decontamination (Conrads and Schmidt. 2000) [5]. Pathogens such as Campylobacter and Salmonella contaminate over 70 percent of the raw chicken meat tested. Recent research from a food safety team made use of high-energy, low temperature plasma to eliminate unwanted bacteria while leaving the food basically unchanged.

Cold plasma can be used for decontamination of products where microorganisms 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 without damage the nutrient value of food.

2.5 Ultra sound
This technique used in different important areas, such as determination of food properties, plant sanitation, and food processing. The technology is based on the transmission of sound through liquid media at a frequency beyond the human audible range (e.g., above 18 MHz). Low power-high frequency ultrasound operates at frequencies in the MHz range and with acoustic power ranging from a few mW to several tens of mW. Such acoustic waves are capable of traveling through a media without altering the material, allowing non-destructive measurements of food processes. High power-low frequency ultrasound is operated at frequencies in the kHz range in which the acoustic power can extend from a few mW to kW. Examples of use for high power-low frequency ultrasound include surface sanitation, microbial inactivation, and enzyme activity alterations.

2.6 Oscillating Magnetic Fields (OMF)
OMF involves little thermal energy input, thus avoiding thermal denaturation of food constituents during treatment. However, more research is needed to understand the changes in microbial population and other constituents of foods when treated with OMF.

2.7 Ozone
Ozone is a strong oxidant and potent disinfecting agent. A number of commercial uses have been found for ozone including disinfection of bottled water, swimming pools, prevention of fouling of cooling towers, and wastewater treatment. There are suggested applications of ozone in the food industry such as food surface hygiene, sanitation of food plant equipment, reuse of waste water, lowering biological oxygen demand (BOD) and chemical oxygen demand (COD) of food plant waste Restaino *et al*. (1995) [16] investigated the antimicrobial effects of ozonated water against food related microorganisms and determined that ozone effectively killed such gram positive bacteria as *Listeria mono- cytogenes, Staphylococcus aureus, Bacillus cereus*, *Enterococcus faecalis,* and such Gram negative bacteria as *Pseudomonas aeruginosa*, and *Yersinia enterocolitica* and also determined that ozone destroyed the yeasts *Candida albicans* and *Zygosaccharomyces bacilli* and spores of *Aspergillus niger.*

3. Conclusion
It is therefore of utmost importance for the food industry to continue to seek out more effective methods to reduce undesirable changes in foods associated with food processing, such as loss of colour, flavour, texture, smell and, most importantly, nutritional value. The goal is to further develop, and subsequently promote the use of, innovative and sustainable food processing technologies that improve food safety, and enhance or retain food quality and nutritional value. These technologies holds potential for producing high-quality and safe food products and also energy efficient and environmentally friendly adds to contemporary popularity. The application of emerging thermal and non-thermal Current limitations, related with high investment costs, full control of variables associated with the process operation and lack of regulatory approval have been delaying a wider implementation of these technologies at the industrial scale.

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