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Efficacy of Non-thermal Technologies for Extending Shelf Life of Food Products: A Review

Anchal Jaiswal[1*], S. L. Swamy[1], Abhay Bisen[1], Payal Vyas[1] and Deepak Sahu[2]

[1]College of Agriculture and Research Station, Korba, IGKV, (CG), India
[2]Department of Agricultural Processing & Food Engineering, SVCAET & RS, IGKV, (CG), India

**Corresponding author*

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Increasing consumer demand for more convenient and varied food products have grown exponentially, together with the need for faster production rates, improved quality and extension in shelf life and another side food contains many heat sensitive nutrients which include vitamins, minerals, and nutrients having functional properties such as pigments, antioxidant, Bioactive compounds. Many processes during manufacturing of food cause detrimental effects on these nutrients. Retention of these nutrients in food products requires innovative approaches for process design because of their sensitivity to a variety of physical and chemical factors, which causes either loss of biological functionality, chemical degradation and premature or incomplete release. These requests together with the severity of the traditional food processing technologies were driving forces for development of non thermal food preservation technologies. The aim of this review is to discuss alternative methods of thermal processing of food with minimally-processed fresh-like food products with high sensory and nutritional qualities. Alternative methods for thermal processing of food are gaining importance, due to increased consumer demand for new methods of food processing that have a reduced impact on nutritional content and overall food quality.

Introduction

Food preservation is a continuous fight against microorganisms spoiling the food making it unsafe. During food preservation processing, the safety and quality of food need to be considered. The traditional food technologies, such as pasteurization, high temperature sterilization, drying and evaporation, can guarantee the microbiological safety or stability of their products, but can destroy some of the food ingredients, especially the heat sensitive vitamins and polyphenols, which were related to the quality of the food(Lima *et al.*, 2014). Higher processing temperatures and longer process times during food processing also produce some potentially harmful components that threaten human (Hellwig & Henle, 2014). Food industry investigates more and more the replacement of traditional food preservation techniques (intense heat treatments, salting, acidification, drying and chemical preservation) by new preservation techniques due to the increased consumer demand for tasty, nutritious, natural and easy-to-handle food products. The most investigated new preservation technologies are non-thermal inactivation technologies such as high hydrostatic pressure (HHP) and pulsed electric fields (PEF), new packaging systems such as modified atmosphere packaging (MAP) and active packaging, natural antimicrobial compounds and bio preservation (Jan *et al.*, 2017).

Therefore, non-thermal technologies in food processing have been researched extensively in recent years (Frewer *et al.*, 2011). The non-thermal technology has the potential ability to partially, or completely, replaced the traditional well established preservation processes.

Non-thermal emerging technologies in food processing sector

Non-thermal emerging technologies in the sector of food processing have often been cited by researchers as an alternative to conventionally heat treatments for food processing in order to develop safe foods with minimal damage to nutritional and sensory properties. Non-thermal technologies, such as UV-light (UV), pulsed electric fields (PEF), high hydrostatic pressure (HPP) and ultrasound (US), can ensure the sensory quality and nutrient values of food in shorter processing times and lower temperature conditions and still be used to enhance food safety and extend the shelf life of food products (Alexandre *et al.*, 2012). Non-thermal technologies could inhibit the activity of enzymes in foods, such as lipoxygenase (LOX), polyphenoloxidase (PPO), peroxidase (PO) and pectin esterase (PE) (Fellows, 2009; Cullen *et al.*, 2011).

Food irradiation

Food irradiation is process in which ionizing radiation are exposed to the food products for insect disinfestations, microbial decontamination and also to inhibit the germination of the root crop, and thus extends the shelf life of products. It is safe and effective non-thermal process for extending shelf life of foods. The mechanism by which ionising radiation inactivates microorganisms is mainly due to the direct damage or indirect damage of the nucleic acids (DNA) of microbial, which is affected by free radicals (OH) derived from the radiolysis of water. Decontamination of spices, herbs and condiments remains the single largest application of irradiation (Mostafavi *et al.*, 2012). Irradiation processes minimize post-harvest loss, decrease perishability and inhibit sprout formation in products such as potatoes. Post-packaging potentials for irradiation includes the disinfection of grains, legumes, spices, fruits, melons, lettuces, vegetables and tubers; colour retention in fresh meats; and microbiological control in eggs, pork, poultry and meat. The safety of consumption and wholesomeness of irradiated food have been extensively studied and the process endorsed by WHO, FAO, IAEA, FSSAI and CAC. Applications of food irradiation have been approved by national legislations in over 55 countries worldwide. Irradiating food has the same benefits as when it is heated, refrigerated, frozen or treated with chemicals, but without changing the temperature or leaving residues (Fig. 1).

High hydrostatic pressure processing

High hydrostatic pressure processing (HPP) treatment utilizes water as a medium to transmit pressure to the product and can effectively inactivate most pathogenic and spoilage organisms including yeasts, moulds and Gram-positive and Gram-negative bacteria, such as *B. cereus, C. perfringens, E. coli and S aureus*. HPP has minimal effects on the taste, flavour, texture, appearance and nutritional value of food products (Rendueles *et al.,* 2011). The research on high pressure processing has created new opportunities to improve the balance between the safety and quality of current food products. In this application, HP processing is essentially a non-thermal decontamination process, in which the food is typically subjected to pressures of 400 to 600 MPa at ambient or cooled temperature for 1 to 15 min. Food treated in this way has been shown to keep its original freshness, colour, flavour and taste. These conditions inactivate vegetative microorganisms, providing safety and prolonged shelf life to chill or high-acid (e.g. fruit juices, guacamole) foods While some degree of protein denaturation can take place during HPP treatment of certain high-protein foods, the resulting changes in physical functionality and/or changes in raw product colour are significantly less than those experienced using conventional thermal processing techniques (Patterson, 2005). Unfortunately, bacterial spores are extremely resistant to commercially attainable pressure levels, and therefore low-acid shelf stable products cannot be achieved by elevated pressure only (Black *et al.,* 2007). To reach commercial sterility, an additional inactivating factor is necessary. High hydrostatic pressure has recently been applied in food processing, and several commercial fruit and vegetable products have already been put on sale (Fig. 2).

Fig.1 Food Irradiation Process in Gamma chamber

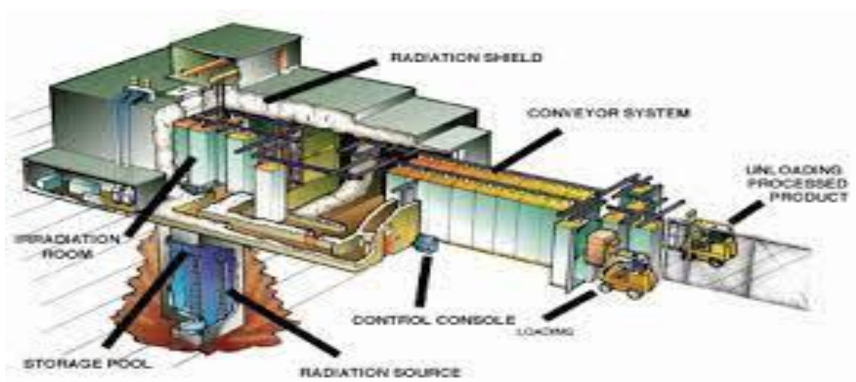


Fig.2 High Pressure Processing system for treating pre- packaged foods

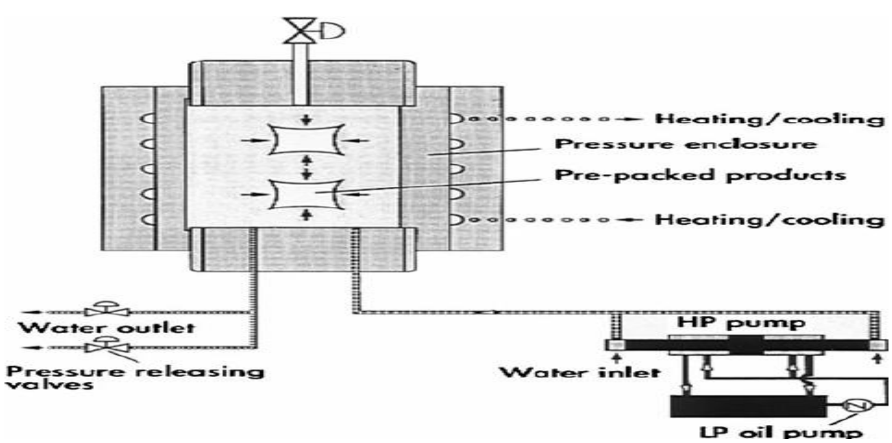
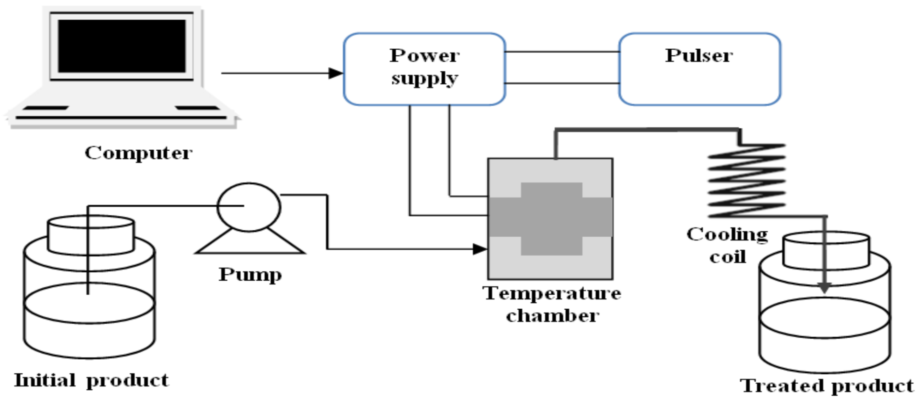


Fig.3 The diagram of a PEF system for treating liquid food



Ultrasound

Ultrasonic waves (energy generated by sound waves of 20,000 Hz or more) generate gas bubbles in liquid media, that produce a high temperature and pressure increase when they immediately burst. The mechanism of microbial killing is mainly due to thinning of cell membranes, localized heating and production of free radicals (Butz *et al.*, 1997).The sound waves resulting from the motion of continuous longitudinal waves when sound travels through a medium can generate the alternate compression and rarefaction of the particles in the medium and the consequent collapse of the bubbles causing cavitation and gas bubbles are formed in the medium (Patist & Bates, 2008). These bubbles have a larger surface area during the expansion cycle, which increases the diffusion of gas, causing the bubble to expand. A point is reached where the ultrasonic energy provided is not sufficient to retain the vapour phase in the bubble; therefore, rapid condensation occurs. The condensed molecules collide violently, creating shock waves. These shock waves create regions of very high temperature and pressure, reaching up to 5500°C and 50,000 kPa. The pressure changes resulting from these implosions are the main bactericidal effect in ultra- sound. The hot zones can kill some bacteria, but they are very localized and do not affect a large enough area.

Pulsed electric fields

The increasing consumer interest for high nutritious fresh-like food products, together with the search for environmentally friendly processing technologies, has aided in the development of emerging non-thermal technologies such as pulsed electric fields. Among all emerging non-thermal technologies, high intensity pulsed electric fields (PEF) is one of the most appealing technologies due to its short treatment times and reduced heating effects with respect to other technologies. Pulsed electric fields (PEF) technology involves applying pulses of high voltage electricity, typically with a field strength from 20 to 80 kV cm^{-1}, to foodstuffs placed between two electrodes for a short time (from several nanoseconds to several milliseconds) to avoid any heating effect (Toepfl *et al.*, 2006). The application of electric field results in cellular death due to generation of pores (electroporation) in the bacterial cell membrane without having an effect on enzymes or proteins present in foods (Wouters *et al.*, 2001). The basic diagram of the PEF treatment is shown in Figure 3. The system includes the pulsed power system, pump, cooling system, operating/control system and the treatment chamber. This process attains a 5 log reduction on most pathogenic bacteria by rupturing the cell membranes in liquid media. It causes only minimal detrimental changes to the physical and sensory properties in foods, helps retain ‘fresh’ quality and assists in nutrient retention. PEF can be applied to the pasteurization of liquid products, in continuous systems, such as milk, yogurt, juices, liquid eggs, soups, brines and other products that can withstand high electric fields.

In conclusion non-thermal technologies are being investigated due to consumer demand for food products that are minimum processed, high quality and safe. Non-thermal processes offer shelf life extension without the use of preservatives or additives, while still retaining colour, flavour, texture, nutritive and functional qualities. Moreover, compared with thermal treatments, such as pasteurization, sterilization, evaporation and drying, these non-thermal processing methods have the advantages of higher energy efficiency, shorter processing times, high level of safety and a longer shelf-life for foods. However, the all these non-thermal technologies have significant limitations in ensuring food quality in terms of sensory properties, such as texture, colour, taste and aroma, and nutritional value, as both are significantly deteriorated due to the extreme processing conditions, such as treatment time, temperature, input energy. Therefore, in order to obtain safer, more healthy and better quality of food products, the combination treatment may be a more effective processing technique for the food industry. For example in order to enhance the antimicrobial effect at the lower process intensities, combining non-thermal technology with conventional preservation methods, antimicrobial agents or other non-thermal treatments could be applied in the food industry, such as combining HPP with nisin or lacticin, or PEF with ultrasonication co-treatment (Ross *et al.*, 2003; Wang *et al.*, 2017)For example, the raw food materials receiving PEF or US treatment before traditional drying and freezing processes, not only make drying and freezing more efficiency but also provide enhanced product quality. In addition, producing industrial scale equipment, defining clear mechanisms, developing standards and correcting the misconceptions of consumers about non-thermal processing will be important for promoting non-thermal technology in the food industry. Once, these issues can be solved, non-thermal technologies will find a much wider application and greater adoption in the food industries.

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