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Utilization of non-thermal technologies for food preservation: Comparative analysis

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Abstract
This review article looks into the evolving landscape of non-thermal food preservation technologies as alternatives to conventional thermal methods. While conventional thermal technologies may degrade the nutritional value and sensory characteristics of food, non-thermal approaches have become attractive alternatives to preserve nutrients and lengthen shelf life. In this study, a number of non-thermal techniques are investigated, including the pulsed electric fields, high hydrostatic pressure, ionizing radiation, high-intensity ultrasound, ozone treatment, ultraviolet light, and oscillating magnetic fields. As an instance, cold plasma incapacitates biological cells by causing long-lasting molecular alterations. On food surfaces and contact materials, pulsed light shows promise for lowering bacterial populations. Ozone therapy has gained momentum as a successful preservation approach due to its potent antibacterial characteristics and ability to preserve nutrients. Despite its effectiveness in disinfecting water, ultraviolet (UV) radiation also causes health dangers to people, including skin problems and eye impairment. The benefits and drawbacks of non-thermal methods in terms of food safety and preservation are explained in this study. This study is a thorough resource for academics, business people, and decision-makers interested in learning about the potential of non-thermal preservation techniques.

Keywords: Non-thermal technologies, preservation, application, UV-C, cold plasma, pulsed light, irradiation, ozone, ultrasound

Introduction
Food and vegetables spoil when microorganisms begin to multiply in them, making them poisonous for consumption. Traditional food preservation techniques such as adding salts, drying, and utilizing chemicals, all of which require heat, were previously used to substantially damage the nutritional benefits of the food. Heat treatment can lead to the formation of toxic compounds and can eradicate some of the vital nutrients. However, when people around the globe began to adopt a healthier lifestyle, the need for nutrition in their diets soared. Non-thermal technology was thus developed to avoid lowering nutritional content while meeting people's demands. It is essentially food preparation without the use of heat by decreasing the projected adverse effects that heating can produce and reducing enzyme activity.

Non-thermal technologies feed inert microorganisms with mechanical, electromagnetic, light, or electrical energy. By avoiding the changes brought on by heat processing it results to natural (preservative-free), and safe (pathogen-free) products with extended shelf-life. The objectives of this technology are that:

- These technologies are used in the extraction of compounds through cell rupture and to prevent growth of microorganism, extending the duration of expiration of food. As because mechanical effect can be a cause of damage for the phenomenon of cavitation also known as electroporation.
- In this method we can process foods at a temperature which is used during the thermal pasteurization of essential nutrients, vitamins and flavours undergoing almost no change during processing.

Some approaches that have been developed for non-thermal technologies and are currently being researched are covered below.

Cold Plasma

Plasma is the presence of both positive and sometimes negative ions. It is also referred to as the Fourth State of Matter. The electron fragment of a matrix is supervised by the non-uniform energy of the particle in which heat exchange puts up with place by the collision of electrons with heavy particles. 35 °C is the steady medium temperature that is intended for high-resolution food products. The inactivation of microbial compartments in cold plasma is conditional upon the reactiveness of species. Benefits of cold plasma in food and vegetable processing are:-

- Destruction of microorganisms.
- Enhancement of shelf vitality.
- Reduce agrochemicals residues.
- Dormant endogenous enzymes.

In one of the instances, the obstacle discharge plasma presentation is attained by setting dielectric electrodes among two electrodes. Originally the exposition of ozone gas was accomplished utilizing this operation but currently, it possesses a tremendous utility in the food enterprise. The security of food developments is accomplished in two manners; Firstly by safeguarding bioactive components and secondly by upholding food from microorganisms. The possibility of mutation in a cell is lessened by the consequence of the plasma treatment. Hereafter its wreck on biological material is desirable (Selvamuthukumaran 2022) [9].

Irradiation

Irradiation is greatly controversial before its undertaking. Food irradiation is not a novel concept. In the early 19th century due to various circumstances, irradiation was not considered safe. But later on World Health Organization (WHO) allowed irradiation as a secure and nonchemical type methodology. Horticultural products undergo alternation in various traits such as physiological, biochemical, and cellular forms structural and genetic arrangements, and tissue microbiota. Horticultural entities undergo modification depending on the quality of raw material quality and irradiation treatment quality. Food irradiation stands as one of the non-thermal strategies in which food is subjected to a specific amount of ionizing radiations such as UV, visible light, infrared, radio waves, or ionizing radiations like gamma- rays, X-rays, and sped-up electron beams to eradicate microbes like virus, bacteria, etc. in food or agricultural commodities (Nair *et al*. 2016, Pathak *et al* 2018) [13, 14]. It can impact the flavor, color, nutritional value, and additional various other aspects of food (Kalaiselvan 2018) [15].

Advantages of irradiation

- It demands a minimum amount of pesticides.
- Smaller food spoilage

Pulsed light Technology

Pulsed light (PL) technology uses short electricity pulses for microbial inactivation only for a few micro to milliseconds with intensity in the range of 10-80kV/cm while minimizing any adverse effect on food quality (ref. Pulsed electric field technology in food preservation a review, elSSN-23734310). It is one of the new technologies among non-thermal processes that can replace thermal pasteurization. The PL includes a wide wavelength range of 200-1100 nm, which includes ultraviolet (UV): 200-400 nm, visible (VIS): 400-700 nm, and near-infrared region (IR): 700-1100 nm (Bhavya *et al*. 2017) [3]. One of the major benefits of PL over static UV treatment is the speed with which the energy is supplied. The operating expenses of PL systems are comparatively inexpensive, and the amount of solid waste they produce is little (Sauer *et al*. 2009 and Chaine *et al*. 2012) [16, 17]. Foods can be decontaminated and sterilized using this method, which involves applying a high-voltage, high-current short electrical pulse to an inert gas lamp. This causes strong collisions between electrons and gas molecules, which stimulate the latter and induce an intense, extremely brief light pulse. In accordance to the notion governing the emission of high intensity light, a progressive increase in low to moderate power energy can be released in intensely concentrated bursts of higher-powered energy. Regardless of the amount and duration of the pulses, it is anticipated that the power produced by the pulses is at least 20000 times more powerful than that generated by a continuous illumination of an equivalent total energy. Pulse light's inactivation of germs is a very quick process that results in rapid sterilization in an exceedingly brief period of time. It has been found to be a safe technology to be employed on individuals and the environment without creating any dangerous contaminants, chemicals, or byproducts in the meals it cures. Though due to its poor penetrating power and susceptibility to lipid oxidation, the use of pulse light in the meat sector is limiting (Sarika *et al*. 2018) [10]. Its restricted ability to manage food heating still remains an issue.

Ultraviolet (UV) Light Treatment

Ultraviolet (UV) light is a non-ionizing radiation that is divided into UV-A (320-400 nm), UV-B (280- 320 nm), and UV-C (100-280 nm) categories. UV-C light, with its germicidal properties, has gained traction for its ability to inactivate microorganisms. However, limitations such as uneven distribution and potential impact on sensory attributes need consideration. Here's how UV light treatment for food preservation works:

- UV-C light has sufficient energy to disrupt the DNA and RNA of microorganisms. When microorganisms are exposed to UV-C light, their genetic material absorbs the energy, leading to genetic damage and rendering them unable to replicate or function properly. This effectively inactivates the microorganisms.
- UV-C light systems are designed to emit controlled doses of UV-C light onto food surfaces. The treatment can be applied to both solid and liquid foods, depending on the setup and equipment used.

Benefits of UV Light Treatment for Food Preservation

- UV-C light can effectively reduce the populations of various microorganisms, including bacteria, molds, yeasts, and viruses. This reduction in microbial load can extend the shelf life of foods.
- UV light treatment is a non-thermal process that helps maintain the sensory and nutritional qualities of the food to a greater extent than thermal methods.
- UV light treatment doesn't involve the use of chemicals, so there are no chemical residues left on the treated food.
- UV light treatment can be used for a wide range of food products, from solid surfaces to liquids, and can be applied to packaged and unpackaged foods (Selvamuthukumaran 2022) [9].

Ozone Treatment

Ozone (O_3) is a molecule composed of three oxygen atoms and is a powerful oxidizing agent. Ozone's reactivity with biological molecules, such as lipids, proteins, and enzymes, leads to the disruption of cellular structures in microorganisms and its ability to degrade mycotoxins, pesticides, and other chemical contaminants contributes to improved food safety and microbial inactivation. In ozone treatment for food preservation, ozone gas is generated and introduced into a controlled environment where the food is stored. The ozone gas is introduced into the storage area or a chamber where the food products are located. The ozone gas reacts with microorganisms and other compounds on the surface of the food. Ozone treatment can effectively kill or reduce the populations of various microorganisms, which can help extend the shelf life of foods. It can also reduce the risk of food borne illnesses caused by pathogens.

Benefits of Ozone Treatment for Food Preservation

- Ozone treatment is a non-thermal process thus the food is not subjected to high temperatures that could potentially alter its sensory and nutritional qualities.
- Ozone breaks down into oxygen after its oxidizing action. This means that no chemical residues are left on the treated food, making it a potentially safer alternative to some chemical preservatives.
- Ozone is effective against a wide range of microorganisms, including bacteria, molds, yeasts, and viruses. This versatility makes it suitable for various types of food products.
- By inhibiting microbial growth and spoilage, ozone treatment can help extend the shelf life of perishable foods (Selvamuthukumaran 2022) [9].

Ultrasound

Ultrasound Technology is proven to be one of the valuable method. This method has been used in combination with different processing methods, which yields notable positive results on the food quality, and therefore it is considered efficacious. Numerous researches have opined that ultrasound leads to growth in the performance of the process and improves food quality. There are several types of advantages in ultrasound processing, which when combined with other different technologies (such as microwave, supercritical CO_2, high pressure processing, enzymatic extraction, etc.) are being examined (Chavan *et al*. 2022) [5]. These include an array of effects such as effective mixing, retention of food characteristics, faster energy and mass transfer, reduced thermal and concentration gradients, effective extraction, increased production, and efficient alternative to conventional techniques. Furthermore, the paper presents the necessary theoretical background and details of the technology, technique, and safety precautions about ultrasound (Chavan *et al*. 2022) [5]. As well as depending on its intensity, ultrasound is used for the activation or deactivation of enzymes, mixing and homogenization, preservation, stabilization, dissolution and crystallization, hydrogenation, tenderization of meat, ripening, ageing and oxidation, and as an adjuvant for solid-liquid extraction for maceration to accelerate and to improve the extraction of active ingredients from different matrices, as well as the degassing and atomization of food preparations (Gallo *et al*. 2018) [7].

Conclusion

Due to consumer demands for safe, wholesome food that is free of microbes, non-thermal treatments are among the most heavily researched sectors in the food industry. The nutritional value and sensory qualities of food products are both harmed by thermal processing. Thus the emergence of non-thermal technologies have proven to be sustainable and prolong the shelf life of fruits, vegetables, meat, fish, and other dietary supplements while retaining the food's nutritional value. They detoxify both solid and liquid foods. According to their specific applications, some of these advances may replace or supplement current preservation techniques in the food business. There are already several technologies that are being used in the food industry. Additionally, the establishment of machinery for non-thermal food processing in bulk, awareness of the proper practices, and development of non-thermal processing standards will propel the technology. If this technology is properly developed, there won't be many further setbacks before non-thermal methods are widely used in the food industry.

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