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NON-THERMAL FISH PRESERVATION TECHNIQUES

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The emergence of non-thermal technologies for enhancing shelf life and ensuring food safety has sparked a revolution in the food processing sector. Traditional methods of food processing involving heat can lead to undesirable changes in food, such as the loss of temperature-sensitive nutrients, alterations in food texture due to heat exposure, and modifications in the sensory qualities of the food. Non-thermal food processing, on the other hand, refers to techniques that achieve microbiological inactivation in food without direct heat application. These technologies, relatively recent in their development, employ mechanisms beyond conventional heating to reduce or eliminate microorganisms, offering an alternative to traditional thermal processing.

Irradiation

Irradiation refers to the deliberate exposure of an object to radiation. In the context of food, irradiation involves applying low levels of ionizing radiation to food materials to either sterilize them or extend their shelf life. This process effectively deactivates food spoilage organisms, including bacteria, moulds, and yeasts. Irradiation proves highly effective in prolonging the shelf life of fresh fruits and vegetables by controlling the typical biological changes associated with ripening, maturation, sprouting, and aging. Furthermore, it plays a crucial role in destroying disease-causing organisms like parasitic worms and insect pests, which can damage food during storage. It's important to note that while irradiation involves radiation exposure, it is not harmful or noxious to humans when used for food pre-treatment. The radiation dose applied to food is low and safe for consumption. Food irradiated under approved conditions does not become radioactive.

In the realm of agri-food applications, two key terms are often used i.e., Radicidation and Radurization.

Radurization: This application involves applying an ionization dose sufficient to preserve food quality by significantly reducing the number of spoilage bacteria.

Radicidation: Radicidation entails applying an ionization dose to food that is adequate to reduce the specific number of viable pathogenic bacteria to a level so low that they are undetectable by any known method. This term also applies to the destruction of specific parasites. Radicidation and Radurization are used for applications involving less than 10 kGy doses.

Radappertization: Additionally, there is a high-dose application known as Radappertization, which involves subjecting food to a high dose of ionization (ranging from 10 to 60 kGy) to reduce the number and/or activity of living microorganisms to a level where none are detectable by any recognized method. Foods treated with Radappertization can then be stored for extended periods, up to 2 years, at room temperature in sealed plastic packaging.

Supercritical Carbon Dioxide Technology (SC-CO_2)

Supercritical carbon dioxide (SC-CO_2) technology has emerged as an innovative non-thermal extraction method with a wide range of applications. It offers the potential to enhance shelf life, reduce microbial contamination, eliminate lipase-producing microorganisms, deactivate endogenous enzymes responsible for food spoilage, recover health-promoting compounds from plant materials, minimize alteration of phytochemicals, and reduce mycotoxin and pesticide residues. One of the key advantages of SC-CO_2 is its dual nature, behaving as both a gas and a liquid. This unique property allows it to easily penetrate complex matrices and extract compounds effectively. SC-CO_2 treatment is known to eliminate various pathogenic and vegetative microorganisms in food products within a fraction of a second, resulting in extended shelf life, improved texture, and enhanced sensory attributes. Despite its many benefits, there are challenges to adopting SC-CO_2 technology on a commercial scale, mainly due to the expense of equipment and operating SC systems. Nevertheless, researchers have reported positive outcomes using high-pressure CO_2 for preserving the colour, enhancing extraction efficiency, and retaining bioactive compounds in various food products such as fresh-cut fruits and vegetables, dairy products, meat, and fruit and vegetable juices. Compared to other high-pressure processing methods, SC-CO_2 operates at lower pressures (typically 10–20 MPa), which still provides higher diffusivity and mass transfer rates. This results in minimal nutrient degradation, improved yield, shorter processing times, and the preservation of crucial substances in food, making SC-CO_2 a promising technology for the food industry.

Ultraviolet Radiation

Ultraviolet (UV) Radiation is an economical non-thermal technology employed for decontaminating and enhancing both the shelf-life and safety of food products. This method is primarily used to reduce the microbial load on the surface of food materials that are indirectly exposed to radiation due to its limited penetration depth. UV radiation falls under the category of non-ionizing radiation and is known for its germicidal properties, particularly within the wavelength range of 200–280 nm, often referred to as UV-C. UV irradiation has proven effective not only in reducing microbial contamination but also in deactivating enzymes present in plant products.

Pulsed Light Preservation

Pulsed Light (PL) Preservation is an alternative method to continuous ultraviolet treatment for both solid and liquid food products. PL involves the sequential emission of high-power light pulses, characterized by short bursts of intense, broad-spectrum white light. In comparison to regular continuous UV light, PL possesses significantly greater strength, exceeding it by a factor of a thousand. Pulsed xenon UV, a component of PL, harnesses the entire ultraviolet light spectrum to disperse germ-killing energy. This spectrum encompasses wavelengths ranging from 180 to 1100 nm, with a notable concentration of light in the short-wave UV spectrum. Like other non-thermal food processing technologies, PL demonstrates the potential for effectively deactivating or eliminating microbes in food. PL finds applications in various food types, including fish, vegetables, fruits, and meat. Additionally, it can be integrated with other innovative technologies to create a multifaceted approach in the fight against surface microbes on food products.

Pulsed Electric Field Processing

Pulsed Electric Field (PEF) processing is a highly efficient non-thermal technique used in food processing, involving the application of short, high-voltage pulses. Its primary purpose is the inactivation of spoilage and pathogenic microorganisms in various food products, achieved by subjecting them to electric pulses that destroy harmful bacteria. Microbial inactivation through PEF is accomplished by causing dielectric breakdown of bacterial membranes. The food material is positioned between electrodes, with the field intensity typically ranging from 20 to 80 kV/cm. Exposure times are incredibly brief, often measured in milliseconds or even nanoseconds. One of the significant advantages of PEF is its ability to extend the shelf life of food without compromising its quality. This process operates on a mechanism known as electroporation, wherein very short, high-voltage electric pulses are applied to the food. These pulses create tiny pores in the cell membrane of the food, allowing for microbial inactivation without damaging essential compounds like vitamins. PEF processing is typically applied to liquid foods or semi-solid foods that can easily flow. A standard PEF device comprises a food treatment chamber, a control system, and a pulse generator. The food is placed within the treatment chamber between two electrodes, which are usually constructed from stainless steel.

High-Pressure Processing

High-Pressure Processing (HPP), also referred to as high hydrostatic pressure (HHP) or ultra-high pressure (UHL) processing, stands out as a non-thermal method for cold pasteurization. In this approach, food is carefully sealed within flexible, water-resistant packaging and exposed to significant hydrostatic pressure, reaching levels as high as 600 MPa (87,000 psi). This pressure is applied for a span ranging from a few seconds to several minutes (1 – 20 min), with water serving as the medium to convey this force onto the food product. The key advantage of HHP lies in its ability to promptly apply isostatic pressure, typically between

100–1000 MPa, while maintaining low temperatures. Through this process, HHP accomplishes preservation effects that can be equated to those achieved through thermal processing, effectively deactivating unwanted microorganisms and enzymes. An HPP unit comprises a dedicated pressure chamber designed to house the food product, facilitating the introduction of water, which is subsequently utilized to exert pressure on the food, thus ensuring its preservation and safety.

Ultrasound Processing

Ultrasound (US) processing involves the use of compressional waves with a frequency exceeding 20 kHz, which is beyond the range of normal human hearing (typically above 20 kHz). In the food industry, the frequencies of ultrasound used for microbial inactivation typically span from 20 kHz to 10 MHz. The bactericidal effects of ultrasound primarily stem from a phenomenon known as cavitation, where microbubbles are generated and then collapse within a liquid medium. During cavitation, temperatures can soar to as high as 5500 °C, and pressures can surge up to 100 MPa, leading to localized microbial sterilization. Ultrasound achieves microbial inactivation through various mechanisms, including the breaking of cell walls, disruption and thinning of cell membranes, and the generation of free radicals resulting from the collapse of cavitation bubbles.

Cold Plasma Technology

Plasma, considered the fourth state of matter, is formed when the energy applied to gases exceeds a certain threshold, leading to the ionization of gas molecules. Cold plasma, one of two main types of plasma (the other being thermal plasma), is a non-thermal treatment method operating within a temperature range of 25–65 °C. Cold plasma exhibits robust antimicrobial activity and an effective capability to inactivate enzymes. The composition of reactive species within the plasma largely depends on the gas used for ionization, with common choices including argon, helium, oxygen, nitrogen, and air. Cold plasma is produced by subjecting gases to various forms of energy, such as thermal, electrical, or magnetic fields. This process generates plasma containing positive and negative ions, as well as reactive species like ozone and singlet oxygen. Several methods are employed for cold plasma generation, including radio frequency plasma, dielectric barrier discharges, gliding arc discharge, microwave irradiation, and corona discharges.

Ozone Treatment

Ozone is a colourless gas with a distinctive odour, composed of three oxygen molecules and chemically represented as O_3. It forms when molecular oxygen (O_2) combines with singlet oxygen (O). Ozone is highly reactive and notably unstable, making it impractical for storage. It must be generated on-site when needed. Ozone is widely utilized as a potent antibacterial agent against various bacteria in food. Its efficacy stems from its strong oxidizing potential and its capacity to target cellular components, giving it a broad-spectrum disinfection capability.

Ozone treatment is a chemical approach to food decontamination. This method involves exposing contaminated food items, including fruits, vegetables, beverages, spices, herbs, meat, fish, and more, to ozone in both aqueous and gaseous phases to eliminate contaminants and enhance food safety.

Conclusion

Consumer demand for safe and nutritious food has driven the development of non-conventional processing technologies. Non-thermal treatments offer high-quality, healthy, and safe food products, but they come with potential disadvantages, including undesirable changes in food if exposed for too long or at high intensities. Nevertheless, these technologies have numerous advantages over thermal processing. With careful planning and mitigation of limitations, non-thermal technologies hold significant potential for broader development and commercialization in the food processing industry.

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