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Review

OVERVIEW OF PULSED ELECTRIC FIELD (PEF) PRESERVATION ON FOOD PRODUCTS

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Introduction

The rise in consumer demand for nutritious food options combined with a desire for a more natural taste has prompted the creation of novel gentle food preservation processes as alternatives to traditional methods like heat treatment. New Methods like high hydrostatic pressure and pulsed electric fields (PEFs), have emerged as no thermal pasteurization methods. These methods aim to effectively reduce microbial content while maintaining the quality of the food product. Pulsed electric field processing is particularly suitable for decontaminating heat-sensitive foods. Furthermore, it presents no environmental risks and has shown no indications of toxicity [1].

Pulsed electric field processing stands as an innovative non thermal preservation technique with the capacity to generate foods boasting superb sensory attributes, nutritional value, and extended shelf life. High-intensity pulsed electric field (HIPEF) processing entails delivering

bursts of high voltage (usually ranging from 20 to 80 kV/cm). In this process, the product is placed between or passed through two electrodes. The application of PEF involves disrupting and perforating biological cell membranes [2]. PEF technology is considered superior to traditional heat treatment methods for foods because it has the capability to prevent or greatly minimize the negative changes in sensory and physical characteristics of food products [3]. Research into energy requirements has determined that Pulsed Electric Field (PEF) represents an energy-efficient approach when contrasted with thermal pasteurization, particularly in scenarios where a continuous system is put into practice [4].

Principle of Pulsed Electric Field

The core principle of pulsed electric fields revolves around the application of short bursts of high electric intensity lasting mere microseconds, within an intensity range of 10-80 kV/cm. The processing time is determined by multiplying the pulse count by the effective pulse duration. The application of high voltage generates an electric field, causing the deactivation of organisms as an electric field is employed, electric current permeates the liquid food, diffusing evenly throughout due to the presence of charged molecules [5].

Two distinct mechanisms are postulated to account for the impact of pulsed electric fields on microbial membranes in organisms. The first mechanism involves electroporation, a process in which high-voltage electric field pulses destabilize both the lipid bilayer and the proteins present in the cell membranes. The second mechanism is known as electric breakdown. In both instances, the process

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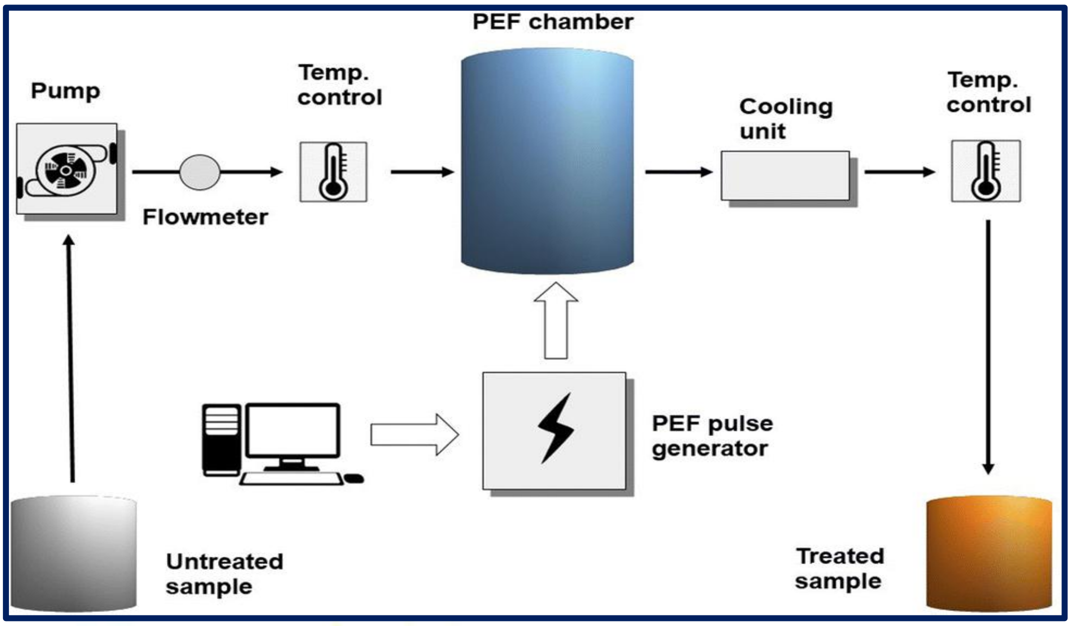
begins with electroporation, which creates perforations in the cell wall, leading to the leakage of cytoplasmic contents and eventual cell demise [6&7].

Figure 1. Diagram depicting a typical food processing system based on Pulsed Electric Field (PEF) technology: (Source: [8])

The impact of Pulsed Electric Field (PEF) on microbial inactivation.



Pulsed electric fields exert lethal effects on vegetative bacteria, molds, and yeasts; however, they encounter resistance from bacterial spores. Remarkably, yeasts tend to be more vulnerable compared to bacteria. Moreover, it is noteworthy that Gram-positive bacteria display higher resistance to pulsed electric fields in comparison to Gram-negative organisms [9].

Applications of PEF Technology in Food Processing

The primary application of pulsed electric field (PEF) microbial inactivation has been in preserving the quality of various foods. This technique finds application in extending the storage duration of items such as bread, milk, orange juice, liquid eggs, and apple juice. Additionally, it is employed to enhance the fermentation characteristics of brewer's yeast. In terms of spore inactivation, microbial spores exhibit greater resilience compared to vegetative cells when exposed to extreme environmental conditions. These conditions include elevated temperatures, osmotic pressures, wide pH ranges, and mechanical impacts. This resistance doesn't solely result from their reduced size, making their elimination more demanding compared to larger cells, but it also originates from their distinct attributes of dehydration and mineralization.

a. **Processing of apple juice**: Simpson [10] found that subjecting apple juice concentrate to PEF treatment (using parameters of 50 kV/cm, 10 pulses, 2 µsec pulse width, and a maximum temperature of 45°C), the shelf-life of apple juice was prolonged to 28 days, surpassing the 21-day shelf-life of fresh-squeezed juice. Notably, no significant alterations were detected in ascorbic acid content, sugar composition, or sensory characteristics.
b. **Processing of orange juice**: Zhang [11] assessed PEF-treated reconstituted orange juice using a square wave pulse in an integrated system with co-field chambers. The study confirmed the efficacy of the square wave pulse shape for extending shelf-life.

c. **Milk Processing**: Fernandez-Molina [12] treated raw skim milk with PEF (40 kV/cm, 30 pulses, and 2 μsec pulse width) extending shelf-life to 2 weeks at 4˚C. Combining PEF with a 6 treatment at 80˚C extended shelf-life to 22 days at 28˚C processing temperature.

d. **Egg Processing**: Dunn and Pearlman [13] used PEF with different pulse parameters was explored in relation to liquid eggs, emphasizing the significance of adopting a hurdle strategy for extending shelf life, particularly in conjunction with preservatives. The study encompassed varying refrigeration temperatures (4˚C and 10˚C) in its examination.

e. **Processing of green pea soup**: Vega-Mercado [14] applied PEF (35 kV/cm, 2 steps of 16 pulses) to pea soup, maintaining temperature below 55˚C. The treated soup showed over 4 weeks of extended shelf-life without notable sensory or chemical changes.

f. **Beer Processing**: Ulmer [15] Investigated were the impacts of different levels of pulsed electric field (PEF) intensity (ranging from 10 to 19 kV/cm) and overall energy inputs (ranging from 13 to 42 kJ/kg) on both the inactivation and sub-lethal impairment of Lactobacillus plantarum, a microorganism that can spoil beer. This experimentation was carried out in a controlled model system.

Challenges Associated with Pulsed Electric Field (PEF) Processing

a. As PEF technology advances towards broader industrial adoption, certain constraints persist that impede the seamless integration of this technology into various processes within the food industry.

b. A notable challenge in the commercial adoption of PEF technology is the lack of reliable and practical electrical systems, presenting an opportunity for improving process design to enhance energy efficiency.

c. The treatment chamber can experience electrode fouling and corrosion, leading to chemical changes and electrode material migration, potentially disrupting the treatment process and affecting the product [16].

d. The absence of well-defined protocols hinders data comparison between lab-scale and commercial-scale applications. Incorrect PEF treatment parameters can lead to ineffective treatments, potentially reducing bioactive compound content [17].

e. The specific internal energy (J/kg) efficiency for different food applications remains uncertain.

f. Elevated electricity consumption translates to higher CO_2 emissions. Therefore, renewable energy adoption is a critical concern for processors.

Conclusion

Pulsed Electric Field (PEF) technology has potential in extending shelf life and enhancing quality of diverse food products. By subjecting liquids to electric pulses, PEF deactivates microorganisms through electroporation and electric breakdown. Bacterial spores show some resilience, yet PEF remains effective against bacteria, molds, and yeasts. Applications range from extending juice, milk, and egg shelf life to preserving pea soup and beer. PEF improves product longevity, microbial safety, and sensory attributes without major chemical changes, showing promise for diverse food preservation.

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