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Pulsed Electric Field Processing: An Emerging Technology in Food Preservation

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Food preservation technologies are primarily designed either to inhibit microbial growth or to inactivate microorganisms. This chapter aims to provide fundamental insights into pulsed electric field (PEF) technology as an emerging method for food preservation. Traditionally, foods are preserved by controlling factors that influence microbial growth and survival, such as temperature, water activity, pH, addition of preservatives, and modification of the surrounding atmosphere. However, increasing consumer demand for minimally processed foods with high nutritional value and fresh-like characteristics has driven the development of non-thermal preservation techniques. Pulsed electric field technology is one such non-thermal method that utilizes short bursts of high-voltage electrical pulses to inactivate microorganisms, while causing minimal adverse effects on the nutritional and sensory qualities of food.

Introduction

Milder preservation and processing techniques have been developed in response to the growing customer demand for fresh foods that don't lose too many flavors or nutrients during processing. Due to the rising demand for foods with a high nourishing contented and fresh-like qualities as an alternative to traditional thermal treatments, non-thermal techniques have gained prominence in recent years and fresh-like features, representing a substitute to conventional thermal actions a developing technology called pulsed electric fields (PEF) has been thoroughly researched for non-thermal food processing. Many researchers have looked into PEF processing for a variety of liquid foods. It has also been demonstrated that processed yoghurt drinks, apple sauce, and salad dressing can maintain their freshness while having a longer shelf life. Other PEF-processed diets comprise milk, tomato juice (Min *et al.*, 2003), carrot juice, pea sou, liquid whole egg, and liquid egg products. Pulsed electric fields (PEF) is a non-thermal food conservation method that uses brief electrical pulses to inactivate microorganisms while having a minimally negative impact on food quality features. PEF technology is thought to be better to conventional thermal processing techniques for food quality because it prevents or considerably decreases harmful changes in the sensory and physical characteristics of food. Because it prevents or significantly decreases harmful variations in the sensory and physical assets of foods, PEF technology is thought to be better to conventional thermal processing methods in terms of food quality features (Alvarez *et al.*, 2003). PEF technology has been touted as superior to, say, heat treatments since it removes bacteria though better preserving the unprocessed food's natural colour, flavour, texture, and nutritional value. It entails applying high voltage pulses to foods that are either liquid or semi-solid and are sandwiched between two electrodes. However, while PEF has published a sizable number of investigation articles on the microbiological essentials of food protection, there is less evidence available about how this technology affects the components of food as well as food's overall quality and acceptability. The use of pulsed electric fields (PEF) in the processed of food has rekindled interest recently. The PEF treatment was demonstrated to be highly effective for deactivating microorganisms, enhancing juice extraction from food plants, raising pressing efficiency, and intensifying food dehydration and drying (Bajgai and Hashinaga, 2001). Cell membranes may become temporarily or permanently permeable when pulsed electric fields of high intensity and duration are applied for periods of time ranging from microseconds to milliseconds. Since the usage of PEF has drawn significant interest in a number of scientific fields, including cell biology, biotechnology, medicine, and food technology, the effects of PEF on bio membranes have been intensively investigate. The goal of this unit chapter is to deliver some basic material about the pulsed electric field technology for extension of shelf life of food.

Principles and Mechanism of Pulsed Electric Field (PEF)

The deployment of brief, high-intensity electric field pulses with durations between microseconds and milliseconds and intensities between 10 and 80 kV/cm is the fundamental idea behind PEF technology. By reproducing the number of pulses by the effective pulse duration, one may get the processing time. The method is based on the delivery of pulsed electrical currents to a product sandwiched among a set of electrodes; the space between the electrodes is known as the PEF chamber's treatment gap. The apparatus comprises of a high voltage pulse generator, a treatment chamber, and the required monitoring and control mechanisms (Fig. 1). A static or continuous design of food product is placed in the treatment chamber, which has two electrodes coupled with a non-conductive substance to prevent electrical flow from one electrode to the other. The irreversible disintegration of the cell membrane in microorganisms is caused by a force per unit charge, or so-called electric field that is experienced by the food product. This causes the bacterial cell membranes to dielectrically break down and causes them to interact with the charged food molecules. A high voltage pulse generator, a treatment chamber, and a control system for monitoring the process parameters make up a PEF system in general (Fig. 1) for the processing of food (Loeffler, 2006).

Pulsed Electric Field Technology Modules

It is possible to see the pulse waveform using an oscilloscope. A high voltage DC generator transforms a utility line's (110 V) voltage into high voltage AC, which is subsequently rectified to a high voltage. Food is held during PEF processing in treatment chambers, which also contain the discharging electrodes. Depending on the type of food, the finished product is cooled, aseptically packaged, and then kept at either ambient or refrigeration temperatures.

Power source

A high voltage generator produces high voltage pulses with the requisite pulse waveform, pulse breadth, and electric field intensity for the PEF system. Generally speaking, the capacitor bank is charged and given energy by a high voltage power source. A pump is used to process liquid food either in a static treatment chamber or a continuous treatment chamber. The static treatment chamber is utilised for small-scale laboratory investigations, but continuous treatment chambers are used for pilot plant or large-scale operations. Cold water from the cooling system is continuously cycled over the electrodes to disperse heat produced by the electric current travelling over the food in order to prevent undesired thermal effects.

High-Power Capacitors

Storage capacitors and on/off switches are the essential parts of high-power sources. Inductors are less important than capacitors because of their higher than average ohmic power consumption. Capacitor energy can be utilised to create magnetic or electric fields. Charged particles are accelerated by electric fields, which can result in thermal, chemical, mechanical, electromagnetic wave, or breakdown consequences. Energy is transferred as electromagnetic waves via electromagnetic fields. (Weise and Loeffler, 2001)

Switches

The switch is the second-most crucial component of a high-efficiency pulse generator for power. The connecting components among the storage device and the load are high-power switching systems. The characteristics of the switches in the pulse producing elements have a significant impact on the rising time, shape, and amplitude of the generator output pulse. Closing switches are required for generators with capacitive storage devices, whereas opening switches are needed for generators with inductive storage devices (Bluhm, 2006).

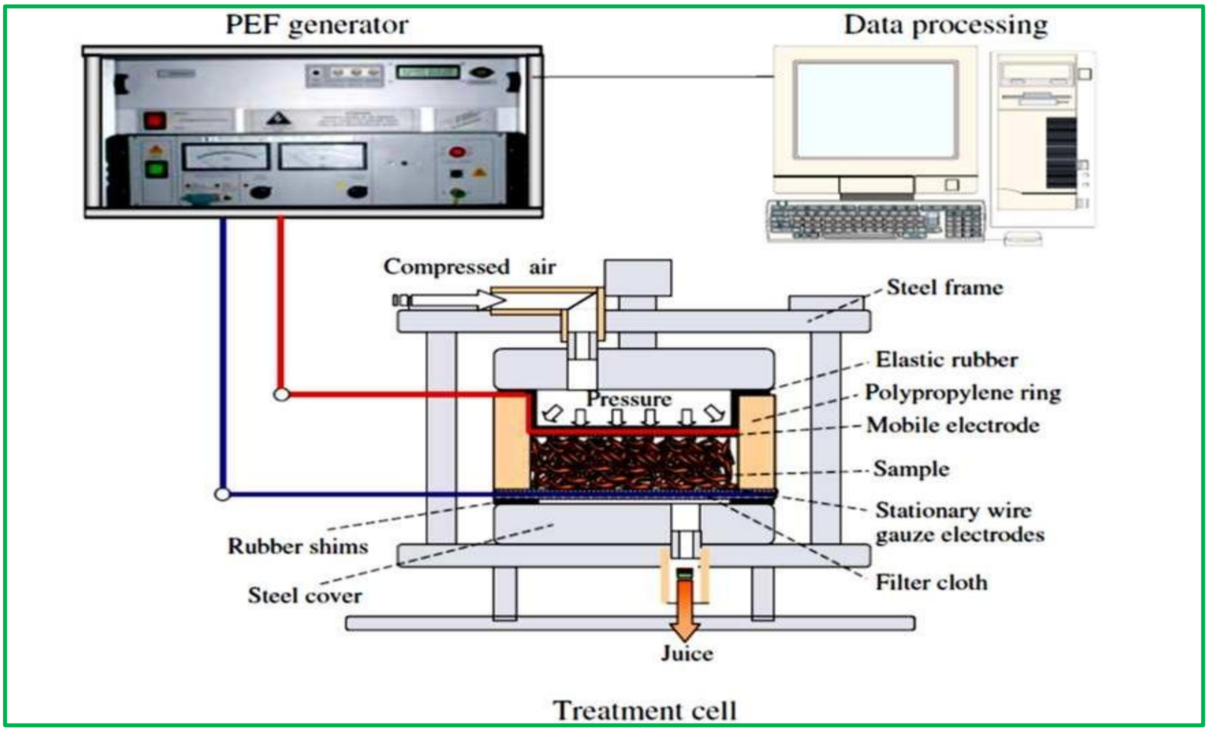

Figure 1. Investigational system of pulsed electric field technology to treatment of liquid food (Source: Loeffler, 2006)

High voltage Pulse Generator

A difficult pulse forming network (PFN) is used by the high voltage pulse generator to produce electrical pulses with the anticipated voltage, shape, and duration. A PFN is an electrical circuit made up of a number of parts, including one or more DC power supply, a charging resistor, a bank of capacitors made up of two or more units linked in parallel, one or more switches, and inductors and resistors for shaping pulses. The capacitor bank is brought up to voltage by the DC power supply. This device converts the utility line's ac power (50–60 Hz) into high voltage AC (A) power, which is subsequently rectified into high voltage direct current.

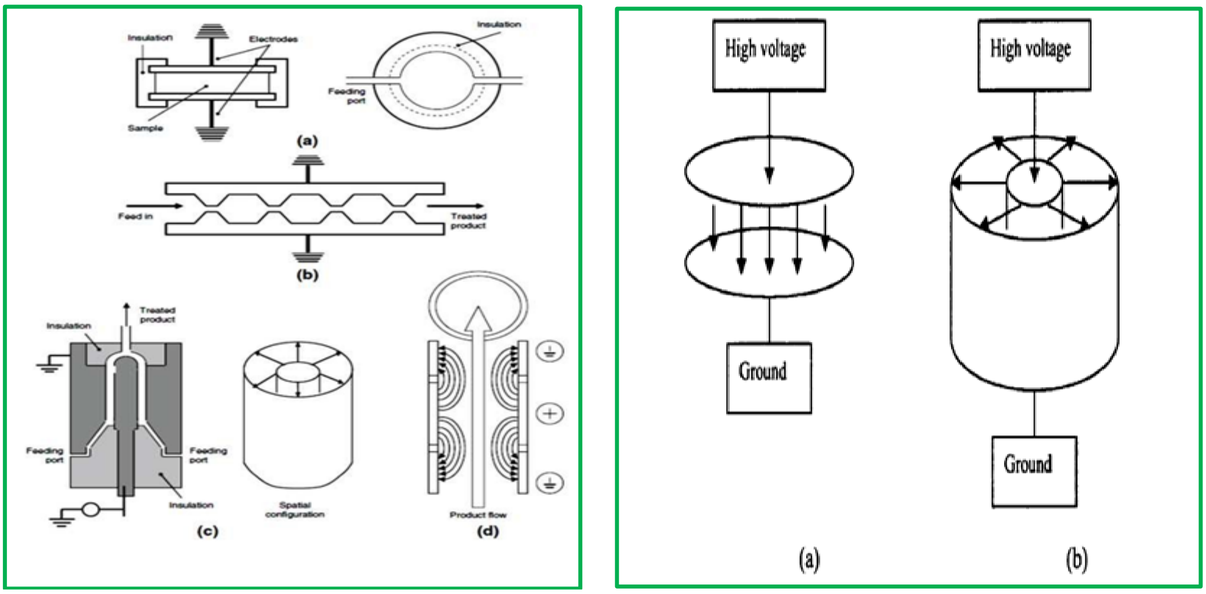

Figure. 2 Common electrode configurations in pulsed electric field treatment chambers (a) parallel-plate (b) coaxial (Source: Loeffler, 2006)

Treatment Cavity

Treatment chamber is one of the important challenging parts of the processing system. Although the main purpose of the is to retain the treated product within during pulsing, the treatment chamber's distinctive design has a significant impact on how uniform the process is. Food breaks down as a spark when the strength of the applied electric fields is greater than the electric field strength of the food product treated in the chamber. In order to handle static amounts of solid or semi-solid meals, batch systems are typically found in early designs. Treatment chambers are typically joined together to function either in a batch or continuous way. There have been designed a number of therapy chambers.

Application of Pulsed Electric Fields Technology for food preservation

Pasteurization of foods such juices, milk, yoghurt, soups, and liquid eggs has been successfully proven using the pulsed electric fields technique. The use of PEF processing is limited to foods with little electrical conductivity and no air bubbles. To guarantee correct action, the liquid's maximum particle size must be less than the gap of the action area in the chamber. The continuous processing technology known as PEF is inappropriate for solid food products that cannot be pumped. PEF is also used to improve sugar and other cellular content extraction from plant cells, such as sugar beetroot cells. Orange, apple, and cranberry juice are just a few examples of the fruit juices with low viscosity and electrical conductivity that have successfully undergone PEF processing. According to a recent study of orange juice that was PEF-treated and stored at 4°C for 112 days, there was less browning than in thermally pasteurised juice, which was explained by the conversion of ascorbic acid to furfural (Yeom et al., 2000). Additionally, the colour change in fruit juices was allegedly fewer in juices treated by PEF. Considerable study has been done to put the PEF treatment technique into practise at an industrial level due to its effectiveness on liquid items including milk, fruit juices, liquid eggs, and any other pumpable food products. In addition to the attainment of biological security of food items, flavour freshness, economic viability, developments in purposeful and textural qualities, and longer shelf life are some of the primary topics of interest. Apple juice, orange juice, milk, liquid eggs, and brine solutions have all seen the most widespread application of PEF Technology amongst all liquid products.

Conclusions

Food preservation technologies aim to control microorganisms by either inhibiting their growth or inactivating them. Pulsed Electric Field (PEF) technology is a non-thermal alternative to conventional heat processing. It involves applying short, high-intensity electric pulses (10–80 kV/cm for micro- to milliseconds) to food placed between two electrodes, usually at ambient temperature. These pulses create pores in microbial cell membranes (electroporation), leading to microbial inactivation. A typical PEF system includes a pulse generator, a treatment chamber with parallel electrodes, and measuring equipment. Research at laboratory and pilot scales has shown that PEF effectively inactivates microorganisms, reduces enzymatic activity, and extends shelf life while maintaining the nutritional and sensory quality of foods.

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