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Pulsed Electric Field Processing of Foods

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ABSTRACT

Natural flavour, colour and sufficient shelf life are some of the basic requirements of processed foods. These can be achieved by minimal processing methods that not only preserve foods but also retain to a greater extent their nutritional quality and sensory characteristics by reducing the reliance on heat as the main preservative action. The resulting products have higher quality and consumer appeal. Out of the different non-thermal processing techniques viz pulsed electric fields, high pressure processing, high intensity light and ultrasound; pulsed electric field (PEF) is one of the more promising processing methods. Inactivation of microorganisms exposed to high voltage PEFs is related to the electromechanical instability of the cell membrane. Electric field strength and treatment time are the two most important factors involved in PEF processing. When exposed to high electrical field pulses in the range of 12-35 KV/cm cell membranes develop pores either by enlargement of existing pores or by creation of new ones. These pores may be permanent or temporary depending on the condition of treatment. The pores increase membrane permeability allowing loss of cell contents or intrusion of surrounding media either of which can cause cell death. Application of PEF technology has been successfully applied for the pasteurization of foods such as juices, milk, yogurt, soups and liquid eggs. Its application is restricted to food products with no air bubbles and with low electrical conductivity and is also not suitable for solid food products that cannot be pumped. The high initial cost of setting up the PEF processing system is the major obstacle confronting those who would encourage the system's industrial application. Innovative developments in high voltage pulse technology will reduce the cost of pulse generation and will make PEF processing competitive with thermal processing methods.

Keywords: PEF, non-thermal processing, electric field strength, membrane permeability, industrial application

INTRODUCTION

Thermal processes used for food preservation can alter the nutritional and sensory qualities of the food. High temperature short-time (HTST) pasteurisation has been effectively used for decades as a method of choice to extend the shelf life of milk and to inactivate its pathogenic bacteria however it can affect the organoleptic and nutritional properties of milk. The most common organoleptic change in pasteurised milk is the generation of 'cooked flavour' while Vitamins B and

C and bioactive compounds can also be affected. The quest for energy conservation by the manufacturers to reduce carbon footprint of the processes involved in food processing and preservation and the increasing consumers' demand for fresh-like quality foods have given rise to the development of innovative non-thermal food processing technologies including ionizing radiation, high-intensity light pulses, high isobaric pressure, electric or magnetic fields, antimicrobial chemicals, polycationic polymers, lytic enzymes as well as pulsed electric fields (Mertens and Knorr 1992, Pothakamury et al 1993). The pulsed electric field (PEF) technology can be considered as a potential alternative to traditional thermal pasteurisation for milk with the advantages of minimising sensory and nutritional damage thus providing fresh-like products. However more investigation is required to understand the nature of PEF effects to achieve a controlled rate of enzymatic and higher microbial inactivation in order to make PEF technology applicable in the food industry. Most PEF systems used for treatment of dairy or food products have been limited to bench top or small pilot scale systems. The PEF technology as a non-thermal process is able to partially inactivate microorganisms and enzymes in liquid foods such as milk and fruit juices and is reported to have minimum adverse effect on the sensory attributes of the products. The PEF process is considered to be energy efficient. The microbial inactivation is achieved at ambient or moderately elevated temperatures by the application of short bursts of high intensity electric fields to liquid foods flowing between two electrodes. Liquid foods (eg milk or fruit juices) due to their chemical composition and physical properties and in the presence of electrical charge carriers may have different conductivities resulting in various flux of electrical current through the food (Zhang et al 1995, Barbosa-Canovas et al 2000).

History of pulsed electric field technology

The use of electricity in food processing was introduced in the early 1900s and was first applied for the pasteurisation of milk using a process known as the Electro-Pure method (Anderson and Finkelstein 1919, Fetterman 1928, Getchell 1935). However this method was in fact a thermal process as the milk was heated up by ohmic resistance. The treatment voltages applied to milk ranged from 220 V to 4200 V and only those researchers who had applied high voltages reported the ability of the process to kill the bacteria below their thermal death point (Beattie 1915, Beattie and Lewis 1925). In the late 1940s electric fields were used to increase the permeability of fruits to facilitate the subsequent extraction of juice which is currently an important application of PEF technology (Heinz and Knorr 2001). Sale and Hamilton (1967) and Hamilton and Sale (1967) published a short series of articles on microbial inactivation by PEF.

In the field of genetic engineering a method was developed by Zimmermann et al (1974) to promote in vitro cell-to-cell fusion using PEF which increased the permeability in localized zones of the membrane currently known as the reversible electrical breakdown, electro-permeabilization or electroporation. Hulsheger et al in early 1980s published a series of papers discussing the sensitivity of various bacteria to PEF and also mathematically simulated the effect of the electric fields intensity and treatment time on microbial kills (Hulsheger and Niemann 1980, Hulsheger et al 1983). Up to the late 1980s many researchers continued to develop PEF applications for preservation of foods and several patents were filed and by 1992 PEF was recognised as a non-thermal preservation technology a novel method which was able to provide consumers with fresh-like foods and valuable sensory properties. The PEF technology as a non-thermal process is able to partially inactivate microorganisms and enzymes in liquid foods such as milk and fruit juices and is reported to have minimum adverse effect on the sensory attributes of the products.

Pre-treatment system

A typical PEF system consists of the components: a high-voltage power supply, a pulse generator, a number of energy storage capacitors, treatment chambers (either static or continuous) that house the electrodes, a pump to pass the liquid food through the treatment chambers (if the system is continuous), cooling and heating baths, measurement devices (voltage, current and temperature) and a central process unit to control operations (Fig 1). The average electric field strength (E) is calculated by dividing the peak voltage (kV) by the gap distance (in cm) between the electrodes (d). The configuration of a PEF system is a function of food characteristics, geometry of chambers, product flow-rate, and high voltage switching devices. Some important aspects in pulsed electric field technology are the generation of high electric field intensities, the design of chambers to impart uniform treatment of foods with minimum increase in its temperature, and the design of electrodes that minimize the effect of electrolysis. High field intensities are achieved through storing a large amount of energy from a DC power supply in a capacitor bank in series with a charging resistor which is then discharged in the form of high voltage pulses. The two major factors affecting PEF system design are the conductivity and flow rate of the liquid. Conductivity determines the impedance of the food in the treatment chamber. The electric field is set by the treatment protocol so the energy required to deliver this field to a litre of food is a direct function of the fluid conductivity.