ABSTRACT

High intensity pulsed electric field (PEF) application in food preservation is an emerging non-thermal technology complementing the conventional thermal preservations with less processing time, preserved nutritive attributes, more safe, fresh like processed foods with longer shelf life.

A mechanistic study was done on the potential applicability of this new technology for preserving liquid foods as a novel food processing technology and a thrust area providing job opportunities in Engineering for Indian Scenario. Systematic study was performed to identify key processing parameters for successful outcome of the process.

Exposing microbial cells to pulsed electric fields cause build up of charges in the cell membrane which resulted in dielectric breakdown of the membrane depending upon, the electric field intensity ‘E’. Under the influence of E, the induced Trans-membrane potential (TMP) increased and effective electropermeabilization occurred when TMP exceeded the cell potential of 1 V. Finite element analysis (FEM) was done by modeling an E. coli, a standard bacterium which causes major diseases in children and immunocompromised patients. Critical electric field, ‘Ec’ necessary to cause cell breakdown was estimated under various processing conditions. The impact of membrane permeabilization on bacterial cell was investigated. It is shown that the orientation angle influences the Ec and Ec is maximum on the
major axis. Further, $E_c$ increased with increase in the orientation angle. Nearly 15% error was observed when compared to analytical calculation, which can be attributed to the approximation used in analytical derivations. The potential distribution on the surface of the cell membrane was similar to that of the realistic cell. The cell membrane capacitance was in par with one stated in literatures.

The investigation on process and product parameters revealed electric field intensity as a key parameter in microbial inactivation. Uniform field with higher number of pulses of shorter duration (1.2/50 µsec.) was found to be an optimum level for inactivation. For effective liquid food preservation an application of a minimum of 10 pulses as a threshold impulse voltage in the range of 20 kV / cm to 80 kV/cm field strength resulted in breakdown of cell membrane. Electric field requirement to cause breakdown with pre-existing pores on the membrane was estimated for different biological cells. Higher medium conductivity, lesser fat, uniformity and higher electrode space increased the inactivation rate. Investigation of circuit parameters revealed that lesser (10µH) circuit inductance yield higher inactivation due to the minimized effect on peak current and voltage applied to the samples.

Microbial inactivation was investigated in different liquid media. For fruit juice and milk, the applicability to achieve higher inactivation of microbes was shown. The impact of processing parameters was evaluated in order to reduce electric energy requirements. It was observed that electrical field effects were synergetic and varied for different mediums. A combined
effect of PEF and radiation proposed in this study showed effective microbial inactivation in comparison to PEF application alone. Exploration of the digital image processing technique using digital colony counter in food preservation to count the bacterial colonies substituting the conventional manual colony count meter in PEF treatment proved to be an authenticated tool.

The present study signifies the PEF technology in liquid food sterilization as a reliable method, providing an option for chemical free and non-thermal preservation technique that retains the natural taste and aroma of the food. This will definitely improve the food safety chain for future generations to be healthy.