Application of High Voltage Pulse Electric Field in Food Industries

Rajeev Prasad Gupta

Department of Electrical & Electronics Engineering,
Skyline Institute of Engineering. &Technology, Greater Noida
Email id: rajeev_akgec1@yahoo.co.in

Abstract— **Microbes are found in very considerable niche of human environment. A number of techniques are available to get microbes free liquid food and water, for instance, heat treatment, autoclaving, pasteurization, radiation and ultrasonic and sonic wave treatment, but these techniques are limited by many factors and thus are not able to give the results as desired. The present paper is based on high voltage pulsed electric field treatment where the contaminated liquid food and water are subjected to impulse wave of 1.2/50 µs to keep in parallel plate static treatment chamber. The field intensity was varied from 0 to 250 KV/cm and the number of pulses were varied from 0 to 100.the survival ratio of all kinds of microbes was significantly low at the peak voltage of 160kv and n=100 pulses. Since the resistance of different kinds of bacteria vary depending on the shape, size and the genetic makeup. This experiment was designed to check the survival ratio of five kinds of bacteria namely Escherichia coli, E.aerogenes, S.aureus, Listeria monocytogenes and Acetobacter inoculated in nutrient broth. Complete inactivation of E.coli was observed at 40kv.**

Keywords: **Pulse Electric Field, Sterilization Process, Transmembrane Potential, Pore Formation**

I. Introduction

In the past, heat treatment has been the preferred method used for food pasteurization. However, thermal damage to liquid foods can adversely affect flavour and taste and can result in loss of nutrients. Thus, non-thermal food pasteurization technologies are receiving increased attention. One of the most promising of the non-thermal pasteurization methods is the use of high electric field pulses. High electric field pulses rely on the lethal effect of strong electric fields, in contrast to ohmic heating which uses electricity to generate heat for inactivation of micro-organisms. Pulsed electric field pasteurization involves application of one or more short pulses of HV with the duration t of each pulse being in the range 1 ns < Δt < 100 ns. Such pulses produce only a small increase in food temperature and may yield biologically safe food that has been minimally processed .In non-thermal pasteurization, irreversible membrane damage is the objective. Microbe inactivation is assumed to start when the voltage drop across the membrane exceeds 1 V. To create a membrane voltage drop of 1 V, electric fields of the order of 250 kV/cm have been applied to a variety of microbes. Five different types of bacteria of various shape, size and genetic makeup namely E. coli, E. aerogenes, S. aureus, L. monocytogenes and Acetobacter have been subjected to test.

II. Sterilization Process with PEF

In sterilization processing with PEF technique, a lower order pulsed voltage is applied to the suspension of living organisms to kill the micro-organisms through electrolysis or ohmic heating, or a high voltage pulse is applied to induce short-term arc discharge for causing a lethal effect on the micro organisms. The primary mechanism is due to an intense shock wave generated by the arc discharge. To describe mechanism of sterilization processing with PEFs, an equivalent circuit model of cell and voltage build-up across cell membrane is first presented and then, its mechanism is addressed in Fig.1.

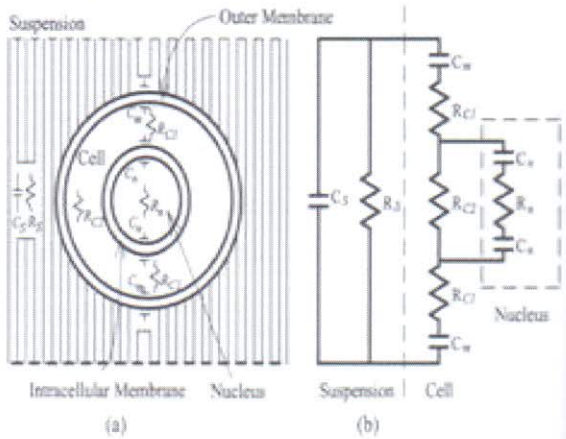

Fig. 1 Equivalent model of cells inside suspension

Circuit Model of Cell

To obtain an equivalent circuit model of cell, a concept of electric field and cell interactions has been presented as shown in Fig.1 (a). Its effects caused by high electric field are based on the charging of membranes. Although cell modelling is complex and extremely difficult, many known high intensity effects can be explained by a simple cell model, as shown in Fig. 1(b). In Fig. 1(b), Rs and Cs represent the

resistance and capacitance of the suspension medium, respectively, and Cm, Rc1 and Rc2 respectively represent capacitance of outer membrane, resistance of outer membrane and resistance of cytoplasm of a cell. Capacitor Cn and resistor Rn are the capacitance and resistance of the nucleus. Usually, capacitance of Cm is higher than Cn.

Voltage builds up across cell membrane

In general, the electric pulses do not affect the intracellular membranes because the outer membrane shields the interior from the influence of electric fields. However, if the pulse duration becomes very short and consequently, the cut-off frequency of its Fourier spectrum becomes very high, the electric field can penetrate the outer membrane and affect intracellular membrane. This will modify its permeability but without permanent damage to the outer cell membrane.

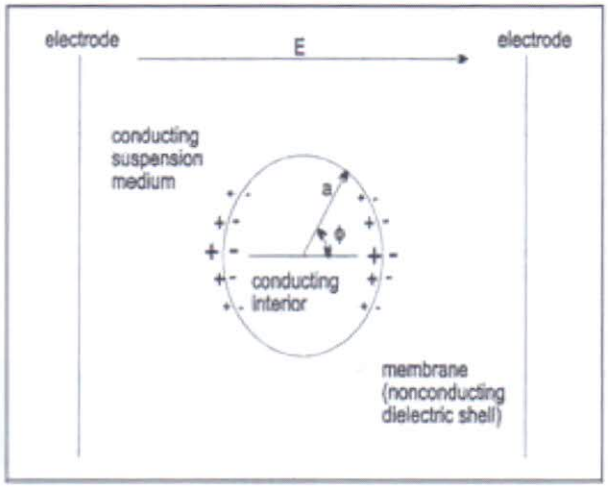

Fig. 2 Electrical equivalent of biological cell in uniform electric field

Applying the laws of electrostatics to above model gives the Transmembrane potential, Vm as:

(a) $Vm = -1.5\ E\ a \cos\acute{o}$ (1)

(b) Where 'E' is the magnitude of the applied electric field (V/cm), 'a' is the cell radius (cm) and ó is the angle (radian) from a point on the cell surface to the axis which is parallel to the applied electric field and passes through the cell origin .

(c) When the induced Transmembrane potential, Vm exceeds a critical value Vc (of the order of 1 V), the field within the cell membrane is high enough to cause an electrical breakdown of the lipid bilayer. This breakdown causes micro-pores in the membrane. From Eq. (1) it can be seen that the magnitude of the transmembrane potential is proportional to the radius of the cell. That is, the membranes of small cell will be more difficult to break down than those of larger cell.

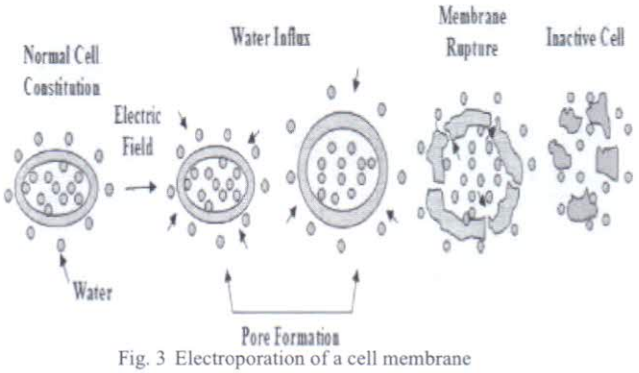

Fig. 3 Electroporation of a cell membrane

E. Experimental set up for the generation of PEF

Diagram of the electrical setup of the modified Marx generator used in investigations

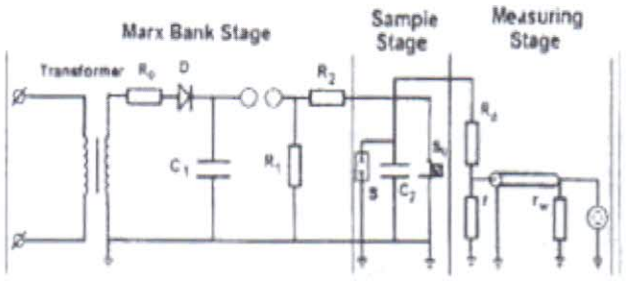

Fig. 4 Electrical setup of the modified Marx generator used in investigations

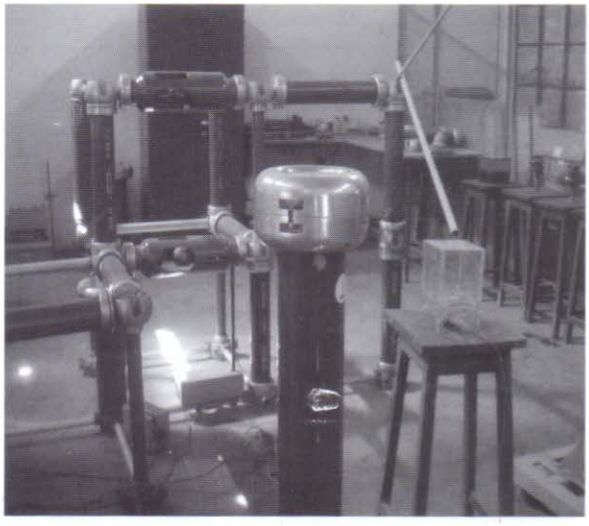

Fig. 5 PEF Generating circuits with container

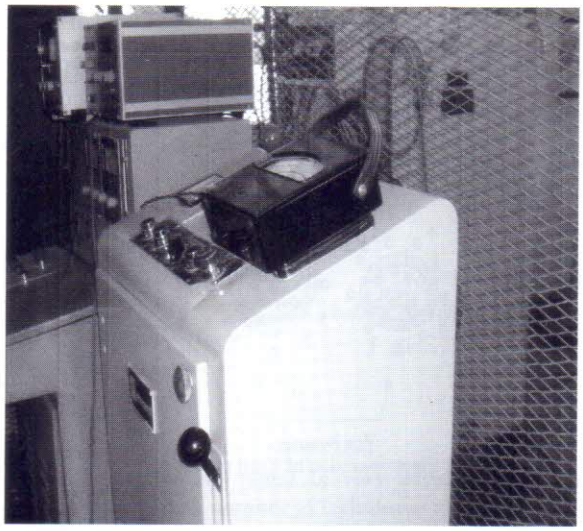

Fig 6 Control *Circuit for PEF*

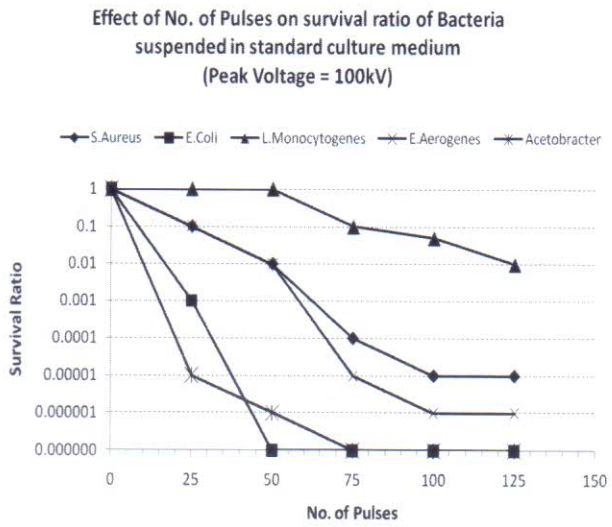

Fig. 7 Effect of number of pulses on survival ratio of Bacteria in standard culture medium

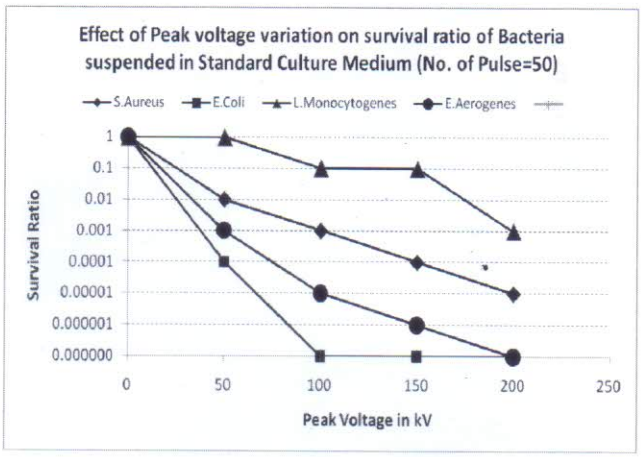

Fig. 8 Effect of Peak voltage on Survival ratio of Bacteria in standard culture medium

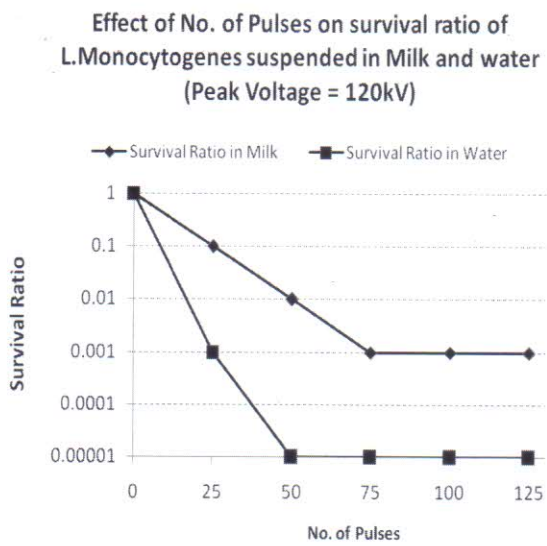

Fig. 9 Effect of No of Pulses on Survival ratio of L.monocytogenes suspended in Milk & Water

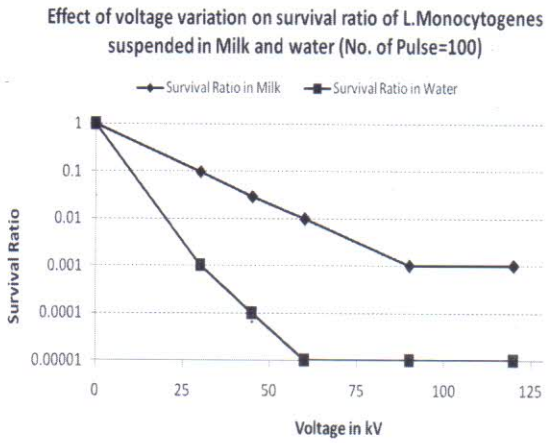

Fig.10 Effect of Peak voltage on Survival ratio of L.monocytogenes suspended in Milk & Water

III. Conclusions

(i) The objective of this paper had been to study the various destroying methods on bacteria of different sizes and shape suspended in a standard media (Nutrient Broth) and develops sterilization techniques which should be non- thermal. By the use of PEF (Pulsed Electric Field) both these objective have been met satisfactorily. Primarily the bacteria were destroyed due to field-induced rupture of the wall and not due to ohmic heating. With increase in peak voltage and number of pulses Survival ratio of 'microbes' decreases for different level of inactivation of bacteria has been observed. Lethal effect of pulsed electric field depends on shape, size and morphology of the micro-organism. On pasteurization of milk and water treatment, HV pulsed electric field can be