An Investigation on the Non Thermal Pasteurisation Using Pulsed Electric Fields

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Abstract

Increasing consumer demand for new products with high nutritional qualities has spurred a search for new alternatives to food preservation. Pulsed electric field (PEF) is an emerging technology for non thermal food pasteurisation. Using this technology, enzymes, pathogenic and spoilage microorganisms can be inactivated without affecting the colour, flavour, and nutrients of the food. PEF treatment may be provided by applying pulsed electric field to a food product in a treatment zone between two electrodes at ambient , or slightly above ambient temperature. Exposure of microbial cells to the electric field induces a transmembrane potential in the cell membrane, which results in electroporation (the permeabilization of the membranes of cells and organelles) and/or electrofusion (the connection of two separate membranes into one) of the cells.

An innovative pulsed electric field (PEF) unit was designed and constructed in the University of Auckland using modern IGBT technology. The system consists of main equipments, the high voltage pulse generator and the treatment chambers. The main focus of this work was to design an innovative PEF treatment chamber that provide uniform distribution of electric field, minimum increase in liquid temperature, minimum fouling of electrodes and an energy efficient system.

Four multi pass treatment chambers were designed consisting of two stainless steel mesh electrodes in each chamber, with the treated fluid flowing through the openings of the mesh electrodes. The two electrodes are

electrically isolated from each other by an insulator element designed to form a small orifice where most of the electric field is concentrated. Dielectric breakdown inside the chambers was prevented by removing the electrodes far from the narrow gap. The effect of the chambers different geometries on the PEF process in terms of electric parameters and microbial inactivation were investigated.

Electric field intensity in the range of (17-43 kV/cm) was applied with square bipolar pulses of 1.7 μs duration. The effect of PEF treatment on the inactivation of gram-negative Escherichia coli ATCC 25922 suspended in simulated milk ultra-filtrate (SMUF) of 100%, 66.67% and 50% concentration was investigated. Treatments with the same electrical power input but higher electric field strengths provided larger degree of killing. The inactivation rate of E coli was significantly increased with increasing the electric field strength, treatment time and processing temperature.

Morphological changes on E coli as a result of PEF treatment were studied under transmission electron microscopy (TEM). Significant morphological changes on E coli after PEF treatment were observed. The TEM studies suggested that the microbial inactivation was a consequence of electroporation and electrofusion mechanisms.

Kinetic analysis of microbial inactivation due to PEF and thermal treatment of E coli suspended in SUMF were also studied. Comparison between measured (experimental) and predicted (theoretical) variation of E coli concentration with time following the PEF treatment was discussed, taking into consideration the recirculation mode of the PEF treatment. The treated

liquid was circulated more than once through the treatment chamber to provide higher microbial inactivation. Arrhenius constants and activation energies of E coli inactivation using combined PEF and thermal treatment were calculated and generalized correlation for the inactivation rate constant as a function of electric field intensity and treatment temperature was developed.

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List of Symbols

A	*Electrode area,* (cm^2)
a	*Microbial cell radius,* (cm)
b_E	*Regression coefficient*
C_0	*Capacitive of the energy storage capacitor,* $(Colomb/V)$
C_P	*Specific heat,* $(J\ kg^{-1}k^{-1})$
d	*Gap between two electrodes,* (cm)
d	*Diameter,* (cm)
E	*Electric field strength,* (kV/cm)
E_C	*Critical electric field strength,* (kV/cm)
q	*Fluid flow rate,* $(ml/\sec)$
f	*Pulse repetition rate, (Hz)*
$f^{`}$	*Shape Factor, dimensionless*
f^*	*Form factor, dimensionless*
I	*Current,* (A)
k	*Inactivation rate constant (sec^{-1})*
$k_C,\ k_{CO}$	*Constant factors*
k_1, k_2	*Constant factors*

L	*Length,* (cm)
s	*Survival fraction of microorganisms*
n	*Number of pulses applied*
P_e	*Electric compressive force,* $(\mu F.V)$
Q	*Power,* $(J/\sec)$
$Q`$	*Energy density,* (J/cm^3)
R	*Effective resistance of food in the treatment chamber,* (Ω)
ΔT	*Change in food temperature*
t	*Treatment time,* $(\sec)$
V	*Voltage,* (kV)
V_0	*Initial charge voltage over the energy storage capacitor,* (kV)
V_r	*Volume of PEF chamber,* (cm^3)
Z	*Impedance,* (Ω)

Greek Symbols

ε_o	*Permittivity of free space,* $8.84\times10^{-8}(\mu F/cm)$
ε_r	*Relative permittivity of the food material, dimensionless*

σ	*Conductivity of the food, (Siemens/m)*
ρ	*Resistivity of the food,* (Ωcm)
τ	*Pulse width,* (μs)
φ	*Electrical potential, (V)*
ρ_f	*Density of fluid inside the treatment chamber,* (g/cm^3)
δ	*Membrane Thickness,* (cm)
ρ^*	*Density of food (g/cm^3)*
υ	*Treatment volume,* (cm^3)