Pulsed Electric Field For Food Preservation

K.M Anitha
Assisstant professor
Dept. of IT,
Sri Sairam Engineering College
Chennai, India

K Gayathri
Final year
Dept. of IT
Sri Sairam Engineering College
Chennai, India

S Saravana Priya
Final year
Dept. of IT
Sri Sairam Engineering College
Chennai, India

***Abstract* - Food treatment has been carried by thermal or non-thermal methods. In recent days, a possible method of microbial deactivation in food is carried out by application of Pulsed Electric Fields (PEF). In the present work, pulse forming network (PFN) for generating high voltage rectangular pulses has been designed and developed. Simulation has been carried out and the effect of last stage inductance on the overshoot of the output waveform is studied. A sterilisable food processing chamber was designed & fabricated. A reduction of about 69% in microbial count was observed.**

Keywords – Pulse forming network, Rectangular pulses, Food processing, Food chamber, Electric field, Microbial count.

I. INTRODUCTION

Food is a very basic requirement of life. Human food is a good source of nutrition for microorganisms. Under favorable conditions like temperature, humidity, moisture content. etc. microbial growth happens at a rapid rate in food materials when microorganisms comes into contact the food material [1,2]. Microbial contamination in food causes loss of sensory qualities, nutritional values, safety, shelf life and aesthetic appeal of food. Microbial deactivation is done by either thermal or non-thermal process. In thermal process, uniform heat is applied for the desired duration of time and the microorganism gets killed [2,3]. Application of Pulsed Electric fields (PEF) is an advanced non-thermal method employed for food preservation. PEF method greatly reduces detrimental changes in the sensory and physical properties like maintaining the original aroma, flavor, texture and other important properties [4,5].

Shenglang [6] subjected the raw milk to high intensity pulsed electric fields of 50 kV/cm. Qunghua et al. [7] subjected the apple juice to PEF of 50 kV/cm. 10 pulses were applied and each pulse is of pulse width 2μs. Sudhir Kumar et al. [8] designed a 15 kV high voltage pulse generator with microcontroller and fly back transformer. It was used for water pasteurization. Rivas et al. [9] subjected the blended beverage to high voltage pulses of 31.2 kV/cm at a frequency of 100 Hz [9].In general, generation of rectangular pulses is done by any Pulse forming network (PFN) Type-A, Type-B, Type -C or Type-E. Type-B is most commonly used because of its simplicity in construction [10].

In the present work, attempts have been made to design, analyze and fabricate a high voltage type-B pulse forming network for the generation of rectangular pulses. Simulation has been carried out to visualize the pulse shape and compare with experiments. Food chamber was designed and fabricated. The electric field in the food cell has been performed using ANSYS software. High voltage rectangular pulses are applied to the milk to kill the microorganisms.

In our proposed system, we use electrical inductance to preserve fruits and vegetables from microbial infections without using pesticides. By the application of Pulse Electric Field, a sterilizable food processing chamber will be designed. Through the chamber high voltage electric pulses are applied to the food materials.

Also, we can extend its lifetime without the usage of pesticides.

II. DESIGN OF TYPE-B PULSE FORMING NETWORK

In the Present work, Type-B PFN comprising of ten stages has been designed and developed. Each stage capacitor is of rating 10 nF & 20 kV. Stage inductor was of rating 1 μH.

III. SIMULATION OF TYPE-B PULSE FORMING NETWORK

The equivalent circuit of Type-B PFN is shown in Fig.1 and the simulation has been carried out using PSPICE. To improve the output waveform shape and reduce the overshoot, it is preferred to change the first and last stage inductor values [10,11]. The best results were obtained with L_1 & L_{10} values as 0.5 μH and 1.8 μH. The simulated discharge waveform is shown in Fig.2.

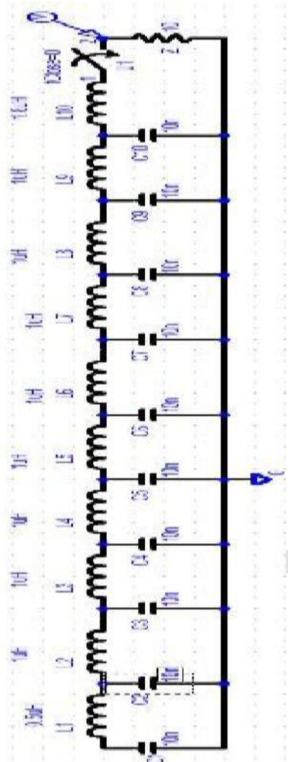


Fig.1 Equivalent circuit of Type-B pulse forming network

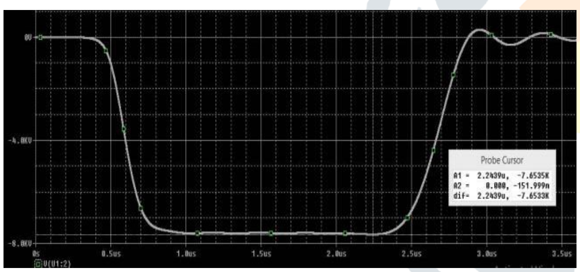


Fig.2 PSPICE voltage waveform of Type-B PFN

The cup type structure is made up of food grade stainless steel and acts as the low voltage (LV) electrode. The top lid is made up of stainless steel with a hole at center. High voltage (HV) electrode is surrounded by Teflon to provide electrical insulation between the HV electrode and the cup

From Fig.2, the pulse width of the simulated waveform (between 90% points in front and tail portion) is 1.76 µs. This matches well with the estimated value (1.8µs) with a difference of merely 2%. For this matched condition, the maximum available pulse voltage is 7.6 kV across a load of 10 Ω when the charging voltage is 15.2 kV for the PFN.

IV. DESIGN OF FOOD PROCESSING CHAMBER AND ESTIMATION OF ELECTRIC FIELD

A reliable and effective PEF treatment for microbial inactivation is highly dependent on the electric field strength in the treatment zone of the PEF chamber. Parallel plate configuration with rounded edges is chosen to have a uniform electric field between the electrodes. The materials used for the chamber design are food grade Teflon and Stainless steel.

A. Food Processing Chamber

The Food processing chamber is made up of cup type structure open at top. The chamber is made air tight with a lid. The diagram of the food chamber is shown in Fig.3. An open view and closed view photographs of food cell are shown in Fig.4(a) & Fig.4(b) respectively.

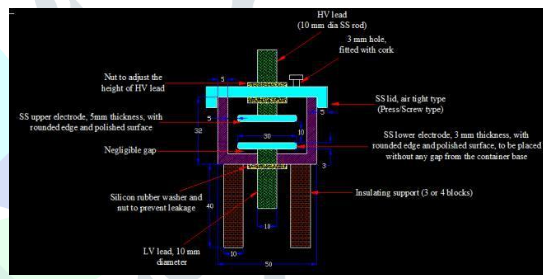


Fig.3 Diagram of Food processing chamber

Fig.4(a) Open view of Stainless steel chamber & steel lid

Fig.4(b) Closed view of Stainless steel chamber & steel lid

as LV. The gap between the electrodes is adjusted to get a load impedance of 10 Ω. Resistance of the load circuit is given by conductivity, of milk is taken as 6 mS/cm [12], with R=10 Ω and above values in equation (5), l=4.3

mm. Therefore, in the present work the gap between the electrodes is set to 4.3 mm.

B. Estimation of Electric field in the Food Processing Chamber

Insulation design plays an important role in the design of any high voltage equipment. Assessment of electric field is carried out to avoid internal flashover and dielectric breakdown. Computation of electric field has been carried out using ANSYS software. The electric field pattern in the food chamber is shown in Fig.5.

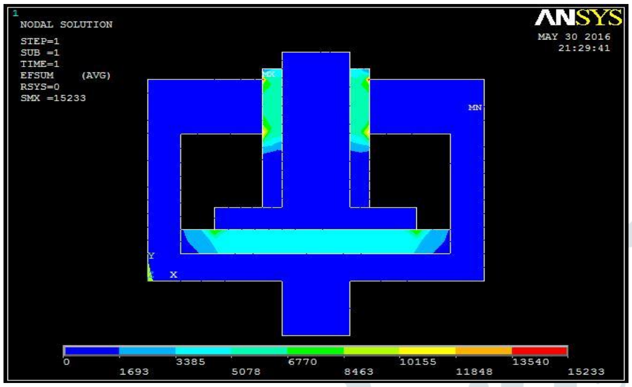
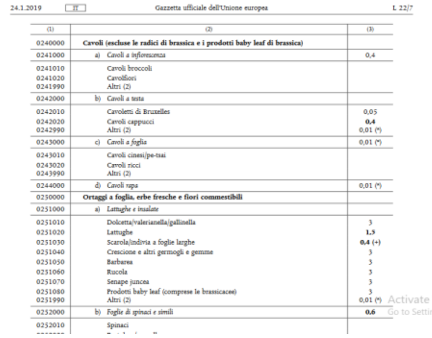


Fig. 5 Electric field pattern in Food cell

In the simulation, 20 kV is applied to the HV electrode and the gap between the electrodes is 4.3 mm. From Fig.5, the electric field in milk is substantially uniform and equal to 4.63 kV/mm. The average electric field in the insulation (Teflon) surrounding the HV electrode is 5.92 kV/mm which is quite safe compared to the breakdown strength of PTFE of 25 kV/mm [13].

V. EXPERIMENTATION AND DISCUSSIONS

The experimental setup of Type-B PFN with source and load is shown in Fig.6. Inductors were fixed on the back side of the wooden plank and connected to the terminals as shown in Fig.6. Capacitors each of rating 10 nF, 20 kV were connected across each stage.



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(1)	(2)	(3)
0240000	**Cavoli (escluse le radici di brassica e i prodotti baby leaf di brassica)**	
0241000	a) *Cavoli a infiorescenza*	0,4
0241010	Cavoli broccoli	
0241020	Cavolfiori	
0241990	Altri (2)	
0242000	b) *Cavoli a testa*	
0242010	Cavoletti di Bruxelles	0,05
0242020	Cavoli cappucci	**0,4**
0242990	Altri (2)	0,01 (*)
0243000	c) *Cavoli a foglia*	0,01 (*)
0243010	Cavoli cinesi/pe-tsai	
0243020	Cavoli ricci	
0243990	Altri (2)	
0244000	d) *Cavoli rapa*	0,01 (*)
0250000	**Ortaggi a foglia, erbe fresche e fiori commestibili**	
0251000	a) *Lattughe e insalate*	
0251010	Dolcetta/valerianella/gallinella	3
0251020	Lattughe	**1,5**
0251030	Scarola/indivia a foglie larghe	**0,4** (+)
0251040	Crescione e altri germogli e gemme	3
0251050	Barbarea	3
0251060	Rucola	3
0251070	Senape juncea	3
0251080	Prodotti baby leaf (comprese le brassicacee)	3
0251990	Altri (2)	0,01 (*)
0252000	b) *Foglie di spinaci e simili*	**0,6**
0252010	Spinaci	

Fig.6 Data set

Standard plate count (SPC) method is a standard procedure to determine viable bacterial load in milk and milk products. In this method, 1 ml milk sample is diluted a number of times to reduce the microbial load. Diluted milk is inoculated, inside Petri-dish, with “plate count” agar medium and incubated at 35 C for 48+2 hours [14,15]. After incubation, visible colonies are counted and multiplied with the reciprocal of dilution of sample to get the bacterial load per millilitre in milk.

Raw milk was collected from a local dairy farm, which was immediately cooled to 2-3 C to arrest further microbial growth. Before PEF treatment, the milk was pre-heated to 30-40 C (room temperature). PEF treatment was conducted in aseptic chamber to reduce chances of any microbial contamination from the chamber. 6 ml of raw milk was taken into the sterilized developed PEF chamber. All the stage capacitors of PFN circuit are charged to 15.2 kV and discharged into the PEF chamber containing raw milk. 100 pulses are applied to this chamber. The experimental output current waveform with pulse width 1.6 µs is shown in Fig.7(a).

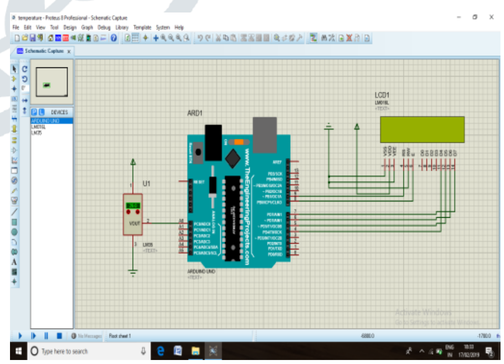

Fig. 7(a) Experimental setup (simulation)

Using a Pearson coil model no. 101 (having sensitivity of 0.01 V/A) the magnitude of output current is 760 A. The output voltage is calculated as (760 A x 10 Ω) equal to 7600 V, where 10 Ω is the estimated resistance of the food cell. This is matching with the simulated value. SPC for raw and treated milk were conducted inside laminar hood’s sterile environment to prevent contamination chances. Total six dilutions were prepared and incubated. After the incubation period, Petri dishes with countable number of colonies were selected i.e. 3rd, 4th and 5th dilution which are shown in Fig. 7 (b) and reported in Table 1.

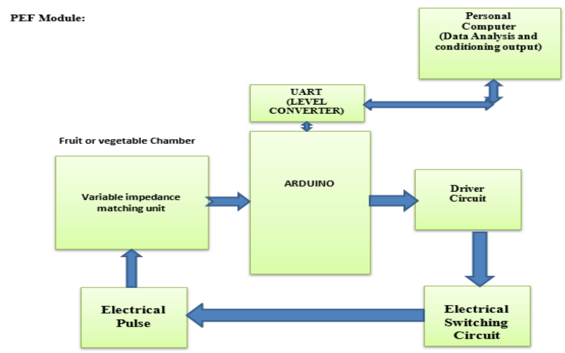

Fig.7(b) Petri dishes with countable number of microbes

TABLE1. MICROBIAL COUNT

Dilution number	10^{0}	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}
Untreated raw milk	PC	PC	PC	PC	78	15
Treated milk	PC	PC	PC	140	24	7

PC: Plate cover, i.e. petri dish containing too many colonies to be counted

Total plate count of microbes in raw milk

= [(78×10000) + (15×100000)] /2= 1140000, Total plate count of microbes in treated milk

= [(140×1000) + (24×10000) + (7×100000)]/3 = 360000

Number of inactivated microbes

= (1140000-360000) =780000,

Therefore, 68.4% of microbes were inactivated from the treated sample of milk. By varying the voltage level and the number of pulses, the level of microbial inactivation can be improved further. This clearly demonstrates the utility of application of pulsed electric fields for food preservation.

VI. CONCLUSION

In this work, an attempt has been made to design and develop a Type-B PFN for generating high voltage rectangular pulses. Simulation has been performed using PSPICE. The difference in voltage magnitude and pulse duration of the simulated & experimental waveforms is very small when compared with estimated values. Electric field analysis has been performed on the food cell using ANSYS.

A gap spacing of 4.3 mm is maintained between the electrodes to get desired load resistance of 10Ω. The milk between these electrodes is subjected to 15.2 kV. From the treated milk it has been observed that 68.4% of microbes are inactivated when compared with untreated milk. Future scope will be to study the effects of other parameters like temperature and composition of milk and optimize the PEF process.

ACKNOWLEDGEMENT

Authors are grateful to the Director, HOD of EEE, Dr. G.R. Nagabhushana & Management of School of Engineering & Technology, Jain University, Bangalore for their constant support and encouragement, in carrying out this work.

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