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# Design of High Voltage Pulse Generator for Pasteurization by Pulse Electric Field (PEF)

Ratna Ika Putri[†], Ika Noer Syamsiana[*] and La Choviya Hawa [#]

***Abstract*—Pulse electric field (PEF) is method of non-thermal food processing system by using high voltage pulse into the food through electrode applied to the chamber for a few seconds at room temperature. The purpose of this paper is to design a high voltage pulse generator using high voltage transformer in pasteurized apple juice-based on pulse electric field (PEF) with a treatment time control and analyzing the input specific energy needs during the process and change the number of microbes contained, in apple juice pasteurization results with processing time variations. Microcontroller is used as control unit to control treatment time by generating PWM pulse with duty cycle 0.5. It will obtained a simple and low cost equipment. To examine the equipment affectivity which applied to apple juice pasteurization is to adjust time processing compatibility from 10 seconds to 60 seconds.. Based on measurement result indicates that average of voltage and current used is 17kV and 0,48mA. Electric field strength delivered to chamber is 0,65kV/cm. The longer time treatment of PEF it will reveal the number of microbes contained in apple juice will be decrease and specific input energy will be increases. According to Zeleny analisys, the best time processing of apple juice pasteurization is 10 seconds processing.**

***Index Term*—PEF, Pasteurization, Energy, Electric Field Strength**

## I. Introduction

The use of high voltage pulse generator for juice processing with pulse electric field (PEF). PEF represent a new non-thermal technology for preserving liquid food product such as fruit juice. [27]. The process involves the application of short pulse of high voltage electric field to foods flowing through or placed between two electrodes, which constitute a treatment chamber gap. [18]

The use of high voltage pulse has some advantages i.e. inactivating micro organisms and enzyme in low temperature , the product nutrition is still high that will make the product is in high quality, safe and fresh with shorter process time so loss of energy caused by heating process can be eliminate [2][3][4][16]. The damage of micro organism cell and bacteria membrane will occur if high voltage more than 25 KV with pulse times 100 – 200 ns is applied [27]. With the advantages of Pulse Electric Field (PEF) preservation technology, PEF is the most required manner by food processing industries in the future.

The most important parameters which should be addressing more attention in PEF method are the process parameters there are; electric field strength, pulse width, number of pulse and the design of processing chamber. Bacterium membrane cells will damaged which will caused these bacterium dead if it exposed to the electric field strength bigger than 25 KV/cm and pulse width between 100 – 200 ns ( Van Heesch Bert dkk 2004). The electric field strength was depend on the high of pulse strength which applied to the chamber, while the number of pulse depend on how long the processing time will take place ( Liang Ziwei dkk, 2006 ). To get the electric field strength which matching with microorganism activations it's required regulation of the level of high voltage pulse which can be applied to the chamber and controlling of treatment time. Treatment time is defined as the number of pulse multiply by the pulse width, which depends on pulse waveform. Electric field strength depends on high voltage pulse passed to chamber, while number of pulse depends on treatment time [17].

High voltage pulse generator can be produced through some circuit depended waveform which will be produced. To increase effectiveness inactivation micro organisms required certain electric field and treatment time. Rectangular pulse increase inactivation micro organism and circuit with high voltage (HV) transformer produce higher efficiency with shorter rise time and rectangular pulse [17]

Using of HV transformer can be applied to quasi resonant fly back converter circuit which has an advantage of producing higher pulse frequency which will reveal the shorter time processing more simpler and more effective circuit [5]. In order to increase the effectiveness of PEF technology, it requires high voltage pulse generator with high effectiveness, better energy efficient, and flexible circuit design for fruit juice processing. The result of the research is expected to produce high voltage pulse generator for PEF equipped with voltage and treatment time regulator by using microcontroller. Pulse were programmed by using microcontroller with it's number according to treatment time setting.

## II. High Voltage Pulse Generator

Some research has been developed to produce high efficiency generator circuit and pulse wave. it's can be shown at PEF technology. RLC circuit has higher efficiency than RC circuit. Maximum efficiency of RLC circuit is between 40-50% while RC circuit only 38% [7]. It's depend on comparison between threshold voltage (Vth) and capacitor initial voltage (Vco). Highest efficiency for some pulse waveform is rectangular pulse which has maximum efficiency until 100% and for over damped oscillator only 52%. It's depended to short rise time. Based on comparison of energy performance, rectangular pulse has maximum energy efficiency by arranging rise time

[†]Ratna Ika P from Departement of Electronics Engineering, Malang State Politechnic, ikaputri_ratna@yahoo.com

[*]Ika Noer S from Departement of Electrical Engineering, Malang State Politechnic, ikanoers@yahoo.com

[#]La Choviya Hawa from Departement of Food Technology, Brawijaya University,

of pulse as short as possible. Arrangement of rise time depends on selection of resistor and capacitor value is used. According to [17], high voltage pulse generator with HV transformers have shorter rise time than RLC circuit. Rise time of circuit with HV transformer reach nano second.

The use of circuit RLC as the source of PEF as the impuls wave generator will effectively killing S. cerivisiae in apple pasteurization juice if this circuit could produce electric field strength 20 KV/Cm. By using PEF can killing microorganism effectively with out loosing of C vitamin, taste and original aromatic from apple juice pasteurization. This impulse generator is consist of high current DC which supplied into capacitor 0,1 uf and this capacitor will discharge the load into electrode and it's regulated by controller. The pulse time constant resulted was depend on the value of the resistor and capacitor which has been fixed defined but the value of inductor can be regulates to get better oscillation on out put pulse strength. [16].

The high voltage pulse generator with circuit RC and RLC will reveal the oscillation and pulse rise time which depend on the value of component used ( resistor and capacitor ). This circuit than developed by using high voltage (HV) transformer. The high voltage pulse generator by using HV transformer have pulse rise time shorter comparing to RLC circuit. The pulse rise time by using HV transformer have range up to nano seconds. This research is using HV transformer on high voltage pulse generator DC 20 KV for pasteurization apple juice processing. The power is come from alternative current (AC) 110 Volts, which flow through step up transformer to increase the voltage, the out put voltage of the step up transformer then flow trough direct current circuit to get the low voltage direct current (DC). This current then going into capacitor bank which will be actively tyristor to increase the voltage through HV transformer and charge the HV capacitor. The HV capacitor will discharge the load through thyratron on processing chamber.

The thyratron is moved by controlling circuit which resulting the block pulse signal, so that the frequency to activate thyratron can be controlling. Therefore pulse frequency which revealed could be controlling by manual or automatically at frequency 1 – 200 Hz. So that with HV transformer the range of pulse frequency controlling is more wider and easier comparing to RLC circuit (17)

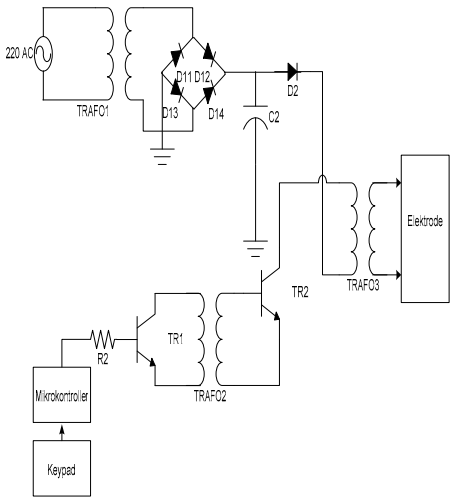


Fig.1 Schematic Diagram of High Voltage Pulse Generator

In this paper to generate high voltage pulse for PEF, using HV transformer and microcontroller. Simple schematic diagram as shown in Fig 1. Microcontroller 8535 IC was used as control unit for PEF device. This microcontroller can reduces the number of external component as well as the cost. Microcontroller was programmed by BASCOM software language.

Microcontroller is a controller, which makes fixed frequency and constant pulse voltage. Also it has timers too. Timer can be set to pass keypad as processing time, limits on and off period for switching component. Pulses generated by microcontroller using PWM (Pulse Width Modulation) method. Microcontroller sends out a block wave pulse to switching component. In this way, the PEF device can be controlled and processing time can be set by using 8535 IC. The processing time can be set from the keypad and will displayed on LCD (Liquid Crystal Display).

The driver receives pulse which produced by microcontroller and it's used to drive switching components. The switching components are use power transistor and OT transformer as connector switches between HV transformer and microcontroller as the regulator. HV transformer is a step up transformer which will increase the voltage. The output voltage of HV transformer is in the form of high voltage pulse which depends on output pulse through switching circuit. High voltage pulse produced is then connected to two electrodes placed in the chamber.

## III. Treatment Chamber

Size of Treatment chamber that is used determined electric field strength generated by high voltage generator. The raw material for treatment chamber is a 4 mm stainless steel plate, it was safe for all food products. The treatment chamber shape is in the form of four legs cylinder equipped with output tap and cover on the top. The dimension of treatment chamber is 45 cm height and 7 cm diameter. Output tap is made from stainless steel with a diameter of 1.25 cm. Treatment chamber can accommodates up to 1.7 liters apple juice.

The chamber can be modeled as a parallel combination of capacitors and resistors [18]. If the shape of the chamber is a tube, the equation can be expressed as:

$$R = \frac{\ln(R_{LV} / R_{HV})}{2\pi\sigma\ell} \quad (1)$$

$$C = \frac{2\pi\varepsilon o.\varepsilon r}{\ln(R_{LV} / R_{HV})}\ell \quad (2)$$

Where l = length of electrode, δ = conductivity of food, $R_{LV}$ = diameter of low voltage electrodes, $R_{HV}$ = diameter of high voltage electrodes and εr = the relative permittivity of food, εo = 8.8 x 10 -12 F / m.

Conductivity of apple juice is 0.07 and permittivity of apple juice depends on the temperature. In this research, the temperature of apple juice is set at 20°C so the permittivity resulted is 75.

The length of the electrode is 45cm. High voltage is connected to the electrodes while low voltage is connected to the body of the chamber and directly connected to the ground. The diameter of high voltage electrode is 0.1 cm and the low voltage electrodes are 7cm. So, the value of the resistance and capacitance for the chamber is equivalent to

0,22 Ω and 0,44 nF. Cylindrical chamber can be modeled as a parallel combination of resistors and capacitors with a value of 0.2 Ω and 0.44 nF. Treatment chamber is shown on Fig. 2.

Fig 2. *Treatment Chamber*

## IV. PEF TECHNOLOGY APPLIED TO APPLE JUICE PASTEURIZATION

Indonesia is a tropical and agricultural country which produce a lot of fruit one of it is apple [1]. Apple has high nutrition contents fruit but it's notice becomes decomposed and damaged at natural condition, therefore to prevent damaged of the fruit, it is need to be processed. One variant of its product is apple juice. To keep the apple juice fresh, preservation is needed by inactivating enzyme and press down the number of micro organisms in the juice [16].

Generally the apple juice preservation is use thermal pasteurization by heating the juice up until 76°C – 87.7°C. Thermal pasteurization will cause chemical and nutrition changes in the juice which will affect the quality of the products [10]. Pulse Electric Field (PEF) as one of food processing technologies which uses high voltage pulse to expand apple juice preservation.

The product of apple juice which processed using PEF method has a same taste, same color, same aroma and same quality with fresh apple fruit which with out conserving process and has longer time storage comparing to who process using pasteurization HTST [12]. The fruit juice pasteurization which using high voltage pulse only need shorten time (micro second), therefore the energy lost due to heating process can be eliminate. Using PEF also will resulting in maximizing of energy efficiency comparing to the other pasteurization method [12][21]. With the excellence of PEF method, this technology is start developing to replace thermal pasteurization method, so that can reveal fruit juice product with better quality, safer, fresh and high nutrition..

PEF is the up to date of non thermal sterilizations technology for killing micro organism. This process consist of injecting high voltage pulse 10 – 80 KV/cm for 1 - 100 micro second period into juice which placed in processing chamber. This PEF technology processed food with out increasing temperature during it process so that it can minimized lost of vitamins, taste, aroma and colour from the product [18]. Using high voltage pulse is able to killed various bacterium such as ; *Escherichia coli*, *Staphylococcus aureus*, *streptococcus faecalis* and spora *Bacillus* substilis. The specification of electric generator equipment of capacitor 0.6 uF with current of 47 kv could reduce microbes more than 50% from the original number only in a few seconds and could deactivation of spores up to 99% [3].

With high voltage electric shock could caused surface modification of cells and with observation using electron microscope found that there is a pore at cell skin, while at cells which not inject the electric could not found this pores. Observation using electron microscope for cells condition after applied electric field strength shown that kapang cells has significant differences comparing to one who not injecting the electric field strength, it's shown that high voltage pulse has given effect to physically damage of the cells [11]. Deactivation of micro organism using high voltage pulse has correlation with instability of cells membrane in electro mechanic. The membrane cells is protect microbes from surrounding environmental conditions it's act as semi permeable barrier to control path ways of nutrition into cells, and end product which has correlation with metabolism activities out side of the cells. By effectively maintaining metabolism activities out side of the cells and it's environment the cells membrane will control cells metabolism activities. But if cells of membrane annoyed, the intracellular will take out and cells metabolism activities will lost.

There are two theories regarding to mechanism of microbe deactivation by PEF there are cells membrane damage as the effect of electric strength and effect of electroporation. The electroporation is the phenomenon where some cells damages as the effect of high voltage electric pulse who temporarily broken the lipid and protein layers from cells membrane. Otherwise the plasma content from cells membrane become permeable for small molecular after exposed electric fields. It's causing the cells membrane swelling and broken after than. The main effect as the influence of electric fields given to micro organism cells is for increasing permeability of membrane in this case pressure at the membrane and pores forming [6]. By increasing the electric fields and wave duration it will make the pores will become larger and will create the hole at membrane cells [26]. Cells membrane electroporation process is shown on Fig. 3

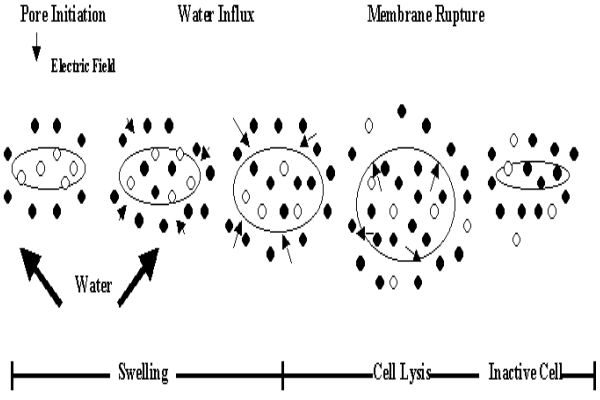


Fig 3. Electroporation Process of cell Membrane

While destroying cells membrane as the effect of electric strength is happen when microbe cells membrane expose to

electric strength than the surface of cells membrane become compression, this compression will create pores at the surface, when electric strength given become higher therefore the pores will become a larger and finally cells membrane broken and deactivation cells membrane happen.[29]. Fig 4 shown cell membrane destroying diagram.

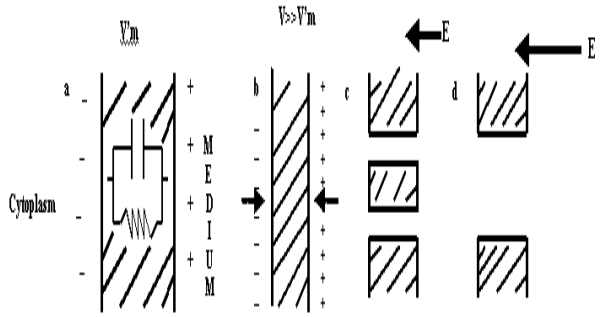


Fig. 4. Diagram of cell membrane damage.

With the high voltage pulse caused pores at cells wall, while at cells which not expose to electric shock this pores are not found. It's based on observation using electron microscope. The high voltage pulse is produced from high voltage pulse generator circuit. [23]. Microbe type at certain medium require certain process parameter such as electric field strength and certain processing time in order to increasing affectivity of microbe activation., so that it's required controlling of strength and processing time at PEF method. Affectivity of micro organism is really depend on process parameter, so that it's required controlling of process parameter for example intensity of electric field strength, processing time, and processing temperature. In order to create inactivation from certain type and concentration of micro organism at certain medium it's also required certain process, for example; size of electric field and processing time.

Electric field strength applied to the PEF processing will determine the microbial inactivation [15]. In the process of apple pasteurization with a very low-field of 0.3 KV/cm, microbe reduction will occur when the number of pulses or processing time given are sufficient. [25]. Increasing voltage and treatment time will increase the number of pulses and electric field strength. Electric field strength is determined as the force per unit charge, the voltage between the electrodes is proportional to the charge that moves between them. So that the electric field in the gap chamber is a function of voltage through the processing chamber and its configuration. Calculation of electric field strength in a cylindrical chamber can be expressed as stated below [18]

$$E_f = \frac{Vo}{r \ln(Rlv / Rhv)} \qquad Rhv \le r \le Rlv \qquad (3)$$

Where Vo is the average voltage of the chamber. In this research, the apple juice is treated with PEF method by providing a high voltage.

Electric field strength generated by high voltage pulse generator circuit depends on how much high voltage pulse given and the size of the chamber. The greater the high voltage given the stronger the electric field generated [18]. According to [16], A given electric field strength of 30kV/cm for apple juice pasteurization with PEF can reduce 99.99% S. Cervisiae contained in apple juice. The higher the electric field strength is used the shorter the processing time can be.

The energy delivered per pulse in units of time until a definite time (t1) can be determined by the equation below [18].

$$E(ti) = \int_0^{t1} W(t)dt \qquad (4)$$

$$W(t) = Vo(t) \times I(t) \qquad (5)$$

Vo (t) and I (t) are the voltage and current as a function of time which flows through the chamber gap, while t1 is the pulse width.

## V. Result and Discuss

Testing and analyzing of this research are carried out in 3 steps, first step is a circuit simulation based on the results of pulse generator circuit design and modeling of high voltage chamber, the second step is testing of the design result that have been made and the third step is testing high voltage pulse generator for pasteurization of apple juice.

### *A. Simulation*

The simulation of the circuit using Multisim 8 software. Input voltage of driver and switching circuit from microcontroller output in this simulation using a signal generator as shown in Figure 5, while the output voltage of driver and switching is shown in Figure 6.

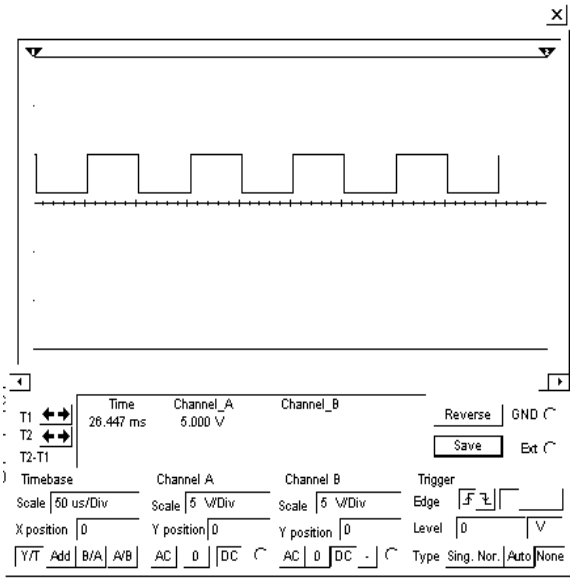


Fig. 5. PWM Output Voltage

Microcontroller output is in the form of square pulses with 50% duty cycle which is the same with a half period of the active pulse. This output producing an output voltage of 5 V while the other half-pulse period producing an output voltage of about 0.5 V. Meanwhile, the output of voltage driver and switching circuit producing the same pulse signal with microcontroller if the pulse produce a voltage pulse of 14.234V in active condition and of 0V in off condition.

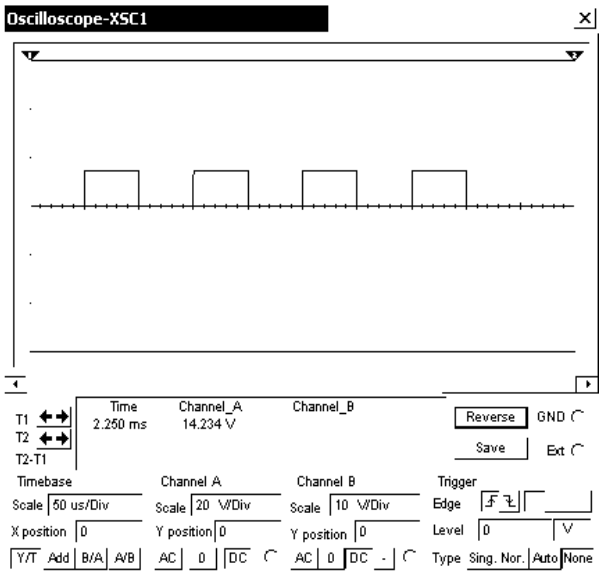


Fig. 6. Output Voltage of Driver Circuit Simulation

The simulation results of high voltage pulse generator with a chamber for the apple juice pasteurization are shown in Figure 7 . The output voltage of high voltage transformer is 21.153 KV as square signal.

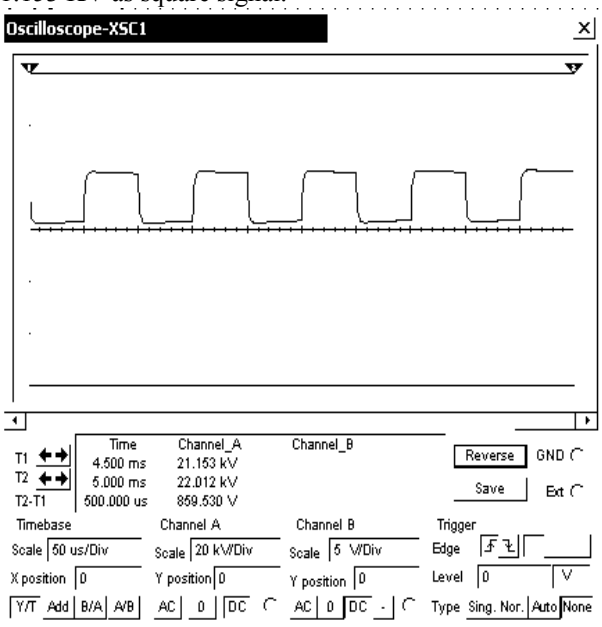


Fig.7 Output Voltage of 20 kV High Voltage Transformer Simulation

HV transformer connected to the modeled chamber as a parallel connection between resistors and capacitors with a value of 0.22 Ω and 0.44 nF respectively. The values of resistor and capacitor are obtained from modeling equation of cylindrical chamber and are the same with the resistance and capacitor measured directly from the chamber containing apple juice. According to direct measurements, the chamber resistance and capacitance values are 0.2 Ω and 0.4 nF respectively.

*B. Design Testing Result.*

Based on high voltage generator testing has results average high voltage of 17 KV and average current 0.48 mA. The duration of processing time does not affect to the average voltage and current because duty cycle and pulse frequency made constant. Testing using HV Probe, digital Multi Metre sanwa and oscilloscope VP-5220A. Figure 8 shown the measurement results of microcontroller output voltage that is connected to the switching circuits and drivers.

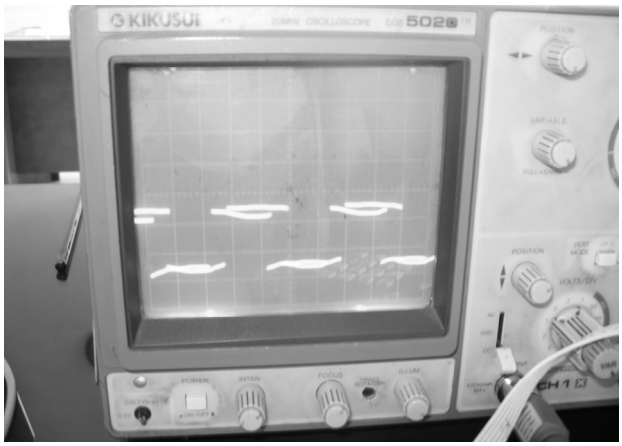


Fig.8. Microcontroller Signal Testing Results

Microcontroller can generate square pulse signal with time function accordance with the processing time. If processing time is set to 10 seconds, microcontroller will generate square pulses for 10 seconds and after 10 seconds microcontroller will be "off"

The operating frequency of microcontroller is 22 kHz and can be adjusted to the operating frequency of HV transformer. The number of pulses produced by this pulse generator circuit in one second is 22,000 pulses. The processing time of this pulse generator circuit can be adjusted accordingly.

*C. Pasteurization of apple juice using PEF*

Examination of apple juice pasteurization is done to evaluate affectivity of high voltage pulse generator, it's connected to the electrode which placed on the chamber. Examination done with varying the processing time. The apple juice pasteurization testing are done in some steps, there are; preparation of apple juice, taking samples, determination total number of microbes and data collection for specific energy produced by high voltage pulse generator.

Examination resulting that total number of microbes from apple juice before pasteurization is $1.7x10^3$ cfu/ml. while the total number of microbes after PEF pasteurization applied in various processing times are as follows; For 10 seconds processing time the total number of microbes was reduced to 200 cfu/ml it's mean that this treatment could reduce microbes content down in 88.23%, while the lowest reduction of microbes content is on 60 seconds treatment time is 110 cfu/ml and it's equivalent to 93'53%. At the other variation processing time the results are; at 20 second treatment number of microbes content is 180 cfu/ml ( reduce 89.41 %), at 30 second treatment time could reduce by 87 %, at 40 second treatment reduce by 91.7 %, 50 second treatment reduce by 92.65 % and at 60 second treatment this process could reduce the lowest number of microbes content down by 93.53 %. Graph bellow shows the total reduction of microbes content versus time variation at Fig. 9.

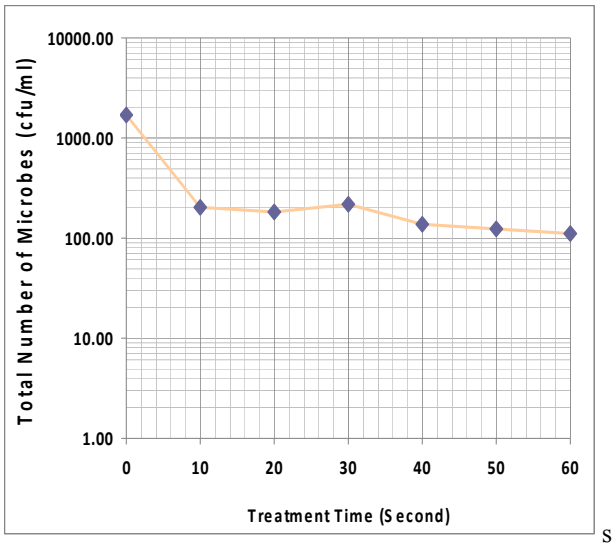


Fig. 9. Graph reduction total number of microbes versus treatment time.

PEF is newest non thermal technology for processing food stuff in liquid phase and semi solid. The process consist of; Applying the short pulse for 1 - 100 micro second of high voltage electric fields 20 – 80 KV/cm into food stuff which placed in between two electrodes at room temperature. [18] Applying high voltage pulse into food stuff it will damage bacterium membrane which will caused these bacterium dead. [5] The possibilities which will be generate from this phenomenon is the happening of unstable metabolism activities and or happening of increasing metabolism from cells body which very quick so that it will bothering the activity and cells physiologies function.

Duration of treatment will influence to decreasing the number of microbes where more longer time treatment the dead of microbes also increase. There is anticipated that the biggest number of microbes which living in apple juice has a weakness to high electric shock, so that it will causes a lot number of microbes is dead . while the rest microbes which still life has high impenetrable to electric shock. So that further a number of treatment given it have no significant effect in killing the rest of microbes, Killing spores using the electric source is limited by the electric field strength generated, duration of pulse, the number of pulse applied, and cells size. While injecting high voltage pulse in long time period will have the greater influences in decreasing the number of spores which contain in media [11]

Duration of the treatment, also has an influence to total specific energy input. The calculation of total energy input and power of electric fields is depend on size of current and high voltage which sent into chamber. There are some shape of wave has frequently used for PEF technology. But the mostly used in this application are rectangular shape waves and exponentials. The system which produce exponentials the maximum achievements of energy efficiency is only 38% While some shape of pulse signals with highest efficiency is rectangular pulse which the maximum efficiency could reach 100 % [7].

The maximum efficiency of rectangular pulse is depend on short *rise time* pulse. If we compare between rectangular pulse and exponential pulse, the exponential pulse has a bigger power lost, so that it have lower energy efficiency compare to the system who generate rectangular waves. Other wise the exponential pulse characteristic is really depend on charging and discharging circuit parameter peak tension and energy storing capacity is determining an input every pulse, resistance and inductivity of discharging circuit, influence of rise time wide of pulse While high voltage pulse generator with HV transformer has high efficiency and it is flexible so that much easy in controlling out put voltages. [5]

The calculation input specific energy which required during process using PEF equation used is as follows:

$$W_{PEF} = \frac{U^2 xt}{R_c x V_c} \quad (6)$$

Where U (kV) is a peak tension which given during the PEF process, t (s) is total processing time ( number of pulse multiply by pulse width ) while Rc (Ω) and Vc ($cm^3$) are resistant and volume of chamber. For one process pasteurization, the measurement indicate, chamber resistant Rc is 0.2 Ω and volume of apple juice in camber (vc) is 0.9 liter.

The lowest specific energy input during 10 second processing is 29.19 KJ/l, while the highest specific energy input given into chamber during 60 seconds processing is 175.15 KJ/l, this is indicated that every one liter apple juice which processed using PEF method will required specific energy of 175.15 KJ. More time given into the process, it will result in increasing the input specific energy required, Specific energy input required is derectly proportional with time given to the process, therefore increasing total time processing it will required input of specific energy become greater. Process using PEF method will required input energy more higher if the temperature of process is lower so that it will increase the operating cost [12]

Electric field strength is determine as moment per unit of charge, tension between electrodes are proportional with charge which moved in between. Therefore electric fields between chamber gaps is the function of tension which going through processing chamber and chamber configuration.

Based on the results of measurements from the outside diameter of the chamber deducted by the thickness of both sides of the chamber, will obtain the value of r = 6.2cm, Rhv (high voltage electrodes diameter) is 0.001cm and the Rly (low voltage electrode diameter) is 0.07cm. High voltage generator produce the electric field strength for each chamber area per centimeter is 0.65KV/cm and the energy that is sent to each pulse is 0.000371Joule/pulsa. The energy delivered per pulse is not dependent on processing time, but depending on the width of pulses generated by the circuit.

The strength of electric fields which produced from high voltage pulse generator is depend on high voltage pulse injected and size of the chamber. More higher electric strength given therefore electric fields strength produced will more bigger [18]. Strength of electric fields given to PEF processing will drive inactivation of microbes [15] In apple pasteurization using very low electric fields 0.3KV/cm for example, the decreasing microbes only will occurred when the number of pulse and or duration of processing given is sufficient [25]. Increasing the tension and duration of processing it will increase the number of pulse

and power of electric fields. By the electric fields strength of 30 KV/cm which given into pasteurization of apple juice using PEF method, it could reduce 99.99% *S.Cervisiae* containing in apple juice [16]. More higher electric fields strength used therefore the duration of processing could be eliminate.

The increase of electric field strength and the total processing time will cause the total specific input energy greater [21]. The greater total specific input energy the greater total microbial reduction. If processing time becomes longer, the specific inputs energy will increase even more. This condition followed by a decrease in the total microbial contained in apple juice as pasteurization result. A specific relationship between specific input energy and the total microbial content is shown in Fig 10.

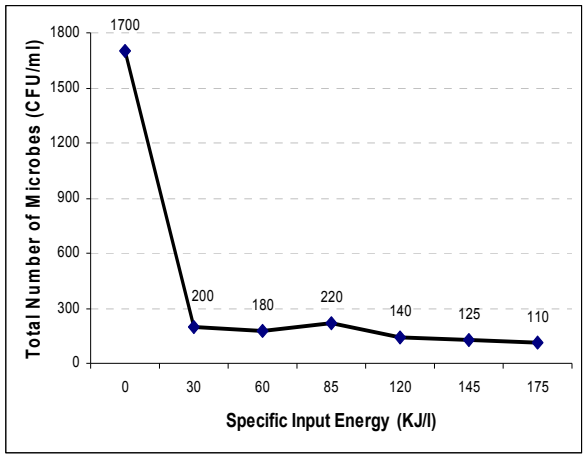


Fig.10. Specific Input Energy Related to Total Number of Microbes

Apple juice without pasteurization does not have specific input energy and the total microbial content is 1700 cfu / ml. At 10 seconds processing time, the specific energy input generated is 30KJ / l with a total content of microbes which dramatically decreases until 200 cfu / ml. The longer processing time will require greater the specific energy and lowest the total microbial content. The longest processing time is 60 second which produces specific input energy of 175 KJ/l with lowest total number of microbes is 110 cfu/ml.

Determination of the best processing time is done base on number microbes decreased and match with the country standard, (SNI) there is 220cfu/ml and minimum of specific energy required. While change in physical behavior , chemistry and nutrition is not used as the parameter in determining the best time of processing due to PEF pasteurization does not change those variables and time of processing does not influence to process. The duration of processing highly influence to the number of microbes and input specific energy. Therefore beside considering the decrease number of microbes there is also put in account regarding to the energy used during the process. By using the Zeleny analysis there can be determine the best time processing and optimum base on correlation between processing time, total number of microbes and input of specific energy. More lower the number of microbes and specific energy used is less therefore this treatment is better. Base on testing result parameters selected there is can be analyze for determining the best three processing time with high voltage pulse requirement of 20 KV. there are 10 seconds, 20 seconds and 40 seconds processing time, while the best time processing from those three parameter is 10 seconds, due to in this time processing, the total number of microbes can decrease down to 200 cfu/ml, and or down 88.23% and specific energy input is only 29.19 KJ/l.

## VI. CONCLUSIONS

In this paper, high voltage pulse generator for PEF has simulated and design. The circuit was applied to the apple juice pasteurization using PEF. Duration of treatment can be set through the microcontroller. While the processing container (chamber) of the cylinders can be modeled with parallel of resistors and capacitors. Strong electric field generated high voltage pulse generator is 0.65 KV / cm. In PEF technology, the processing time is determining microorganism inactivation. The longer processing time, the total content of microorganisms in apple juice will be lower and the specific energy needs will also be greater.

By analyzing the testing data's collected during examination, and base on total number of microbes and input of specific energy requirement, there could be concluded that the best time processing is 10 seconds.

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**Ratna Ika Putri** is a lecturer of electronics Department at Malang State Politechnic, East Java, Indonesia. She received her M.E in Electrical Engineering from Brawijaya University, East Java Indonesia. Her current research interest in control, power electronics and AI technique.

**Ika Noer Syamsiana** is a lecturer of electrical department at Malang State Politechnic, East Java, Indonesia. She received her M.E in Electrical Engineering from Bandung Technology Institute, West Java, Indonesia. Her current research interest in control, and electric drives.

**La Choviya Hawa** is a lecturer of Food Technology department at Brawijaya University, East Java, Indonesia. She received her M.P in Agricultural Engineering from Gajah Mada University, Yogyakarta. Indonesia. Her current research interest in postharvest technology and nonthermal preservation of food.