

# Fruit Juice Treatment Using Electromagnetic Pulse Generated Using High Voltage Tesla Transformer to Eliminate Escherichia Coli Bacteria

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**Abstract.** A healthy consumable fruit products demands is highly increase over time. This is mainly due to the need of high-quality food increase as the economic is better and also because of healthy reason. Fresh fruits drink is always requested by costumer, however this is not always available in the market due to some reasons. Thus, processed fruit juice might be a substitution for fresh product. However, during food process, the fruit juice quality might decrease as the juice prone to the pollutant during the process and keeping time. So, it is needed to provide a packing process that able to reduce or even eliminate pollutant during the processing and storing. One of the most dangerous pollutants is pathogenic microorganism such as Escherichia coli. If consumed, Escherichia coli can cause diarrhea which could lead to severe stomach ache. In this paper, discussed food juice treatment by using pulse electric field generated by tesla transformer to disinfect the fruit juice thus eliminate the microorganism. A prototype of the food juice treatment system is built by using a Tesla transformer to produce high voltage thus generate pulse electric field which then will be used to eliminate microorganism.

*Keywords:* Fruit Juice Treatment, Electromagnetic pulse, Tesla transformer, Microorganism

## INTRODUCTION

Public demand of fresh food product, such as processed food of vegetables and fruit increasing along with the economic growth. Fresh fruit and vegetables juice with original aromatic, color, taste and highly nutritious are highly demanded to increase public health. Processed fresh juices also increase human immunity thus might reduce spreading illness in a community.

For freshness and other reason, it is advice to consume the juice as it is produced, however sometimes the juice cannot be consumed directly jus after it is produced thus it is needed to keep the juice for some periods of time before consumed. During the keeping periods, the juice quality might be decreased over time as the bacteria might be developed. The bacteria seeds might come from the fruits or vegetables itself, or added during juice manufacture. Thus, it is needed a food processing method to eliminate or reduce the presence of the bacteria on juice product.

Food processing technology can be divided into two mayor categories based on the applied temperature use in the processing, i.e., thermal processing and non-thermal processing. Processing technology using thermal method such as using microwave, radio frequency, Infrared and sous-vide processing, whilst non-thermal method such as high hydrostatic pressure, irradiation, ultrasound, light pulse and pulsed electric field [1].

Thermal processing method has advantages such as ability to eliminate microorganism with higher probabilities. However, this method tends to ruin the juice taste and aroma, also due to the heating process, the high temperature might reduce the vitamin value on the processed food. While the advantages of the non-thermal method are better

food taste and aroma, and vitamin value on the food remain unaltered. Thus, for juice drink a non-thermal method might be the better method to applied in the processing process.

## **FOODS PROCESSING TECHNOLOGY**

Public demand of processing food and beverages, such as fruits and vegetables juice and milk, increase overtime. This is mainly due to high vitamin content of the fruits and vegetables juice. The juice contains antioxidant such Vitamin C and also contains phenolic and carotin [2,3,4]. For the taste consideration, the juice also must have original colour, aromatic and freshness. If the juice consumed as soon the juice produced, the aforementioned taste might be easy obtained. However, when the juice need times before consumed, its taste might be altered. Thus, it is needed a method to make sure the juice will have colour, aromatic, and freshness as a new product.

Foods processed quality degradation can be happened mainly due to the presence of unwanted microorganism that might be include during the foods processing. So, to maintain the foods quality it is needed to reduce or eliminate microorganism on the processed foods. One of most common practises to eliminate the microorganism is by heating process. However, the heating process tend to alter the aroma and taste of the juice product, and even can reduce the vitamin value of the juice [5].

Due to the problem caused by heating process, many researchers develop the foods processing technology without involving heating treatment. One method developed lately, i.e without heating process, is pulsed electric fields - PEF method [6,7]. The process able to reduce microorganism on the processed foods and increase the length of the keeping time without alter the aroma, taste and nutrient quality of the foods. The PEF technology has 4 processing steps, i.e. pulse generator, treatment process, liquid-handling system, and monitoring system [8].

Pulse generator can be generated as laser-pulse laser [9], capacitor-switching proses [10] and radio-frequency pulse generator [11]. Laser pulse generator shows high capability to eliminate microorganism on liquid foods, but relative expensive and quite complicate to applied. Meanwhile capacitor switching and high-frequency pulse generator can be built using lower budget and easier to construct and applied. Their capability to eliminate microorganism not as good as the laser pulse, but quite adequate and shows promising results [1,10,11]. Switching-capacitor pulse generator is built using several capacitor connected in series [10] and high-frequency pulse generator can be built using air-core flyback transformer as the main component to generate high-voltage [11]. Other method to generate high frequency which can be used in food processing is Tesla generator [12].

### **Pulsed Electric Field – PEF to eliminate Microorganism**

Electric field can be generated by varying method as discussed in previous section. In this research discussed the using of Tesla generator to produce high-voltage high-frequency pulse which is able to produce electric field [12]. The electric pulse generated by using Tesla generator or capacitor-switching process has a very short duration, typical at around 1-100  $\mu$ s. This pulse will produce electric field which able to eliminate the microorganism on juice [13].

Electric field can destroy the microorganism membrane structure and cause the microorganism metabolism altered and thus terminate the microorganism [14]. Effectiveness of the PEF method to eliminate the microorganism depend on many factor, such as voltage-level, electric field level, pulse number dan pulse shape [15].

### **TESLA TRANSFORMER TO PRODUCE PULSED ELECTRIC FIELD - PEF**

Electric field pulse can be generated using varying methods, one of the methods and applied in this research is by using Tesla transformer. Tesla transformer able to produce electric field pulse with frequency around several MHz and the voltage level depends on the number turns of the applied transformer. In this research, the input voltage of Tesla transformer is 220 Volts with output several kV. The output of the Tesla transformer is used to generate electric field pulse and applied to the juice which likely to processed.

#### **Tesla transformer**

In this research, a small Tesla transformer is used to generated high frequency voltage. The transformer has air as the core to induct energy from primary into secondary coil. The output at the secondary voltage will has a very high frequency up to several MHz's. The input voltage on the primary coil is 220 volts. The output generated by the secondary coil generated high voltage which able to produce electric discharge thus generate pulsed electric field.

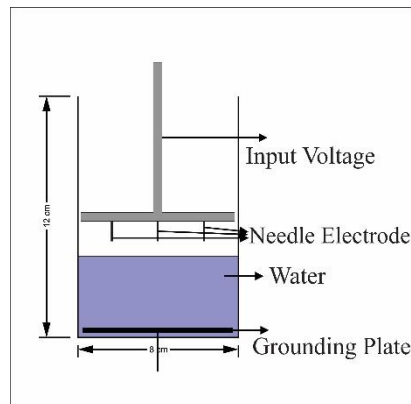
Figure 1 shows the Tesla transformer use in the experiment design. The primary coil use copper wire with diameter of 1 mm and the coil length is 7 mm. The diameter of the Tesla coil is 40 mm. The secondary coil is use copper wire with diameter of 0.25 mm and the its coil height is 90 mm. The diameter of the secondary coil is 26 mm. The triggering switch used in the design is an electronic type which has a very precise switching time.



**FIGURE 1.** Tesla Transformer used in experiment

## Juice Processing Chamber

The pulsed field electric produced by the Tesla transformer is then injected into the juice processing chamber (Figure 2) to treat the juice. The electric discharge above the juice level will produce ozone, ion, UV light, photon and metastable [16]. The discharge caused by the high voltage on the electrode on the juice chamber is also produce short radicals such as hydroxyl-radical (OH), and hydrogen peroxide (H<sub>2</sub>O<sub>2</sub>) which also act as disinfectant agent [16].

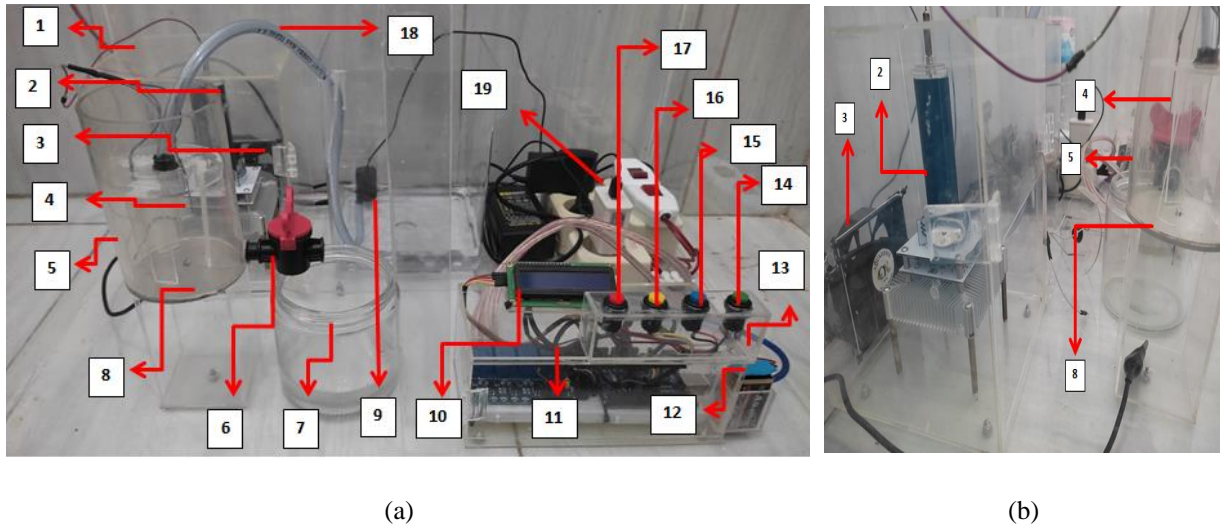


**FIGURE 2.** A circular tube water chamber diagram

## RESULTS

### Design plasma using Tesla Generator

The prototype of the Juice treatment system is shown in Figure 3. The Tesla coil generate high-frequency high-voltage which is inputted to the juice-chamber to treat the juice thus eliminate the microorganism. To control the treatment system an arduino microcontroller is use to control the operation time of the system. The controller adjusts the system to operate from 1 minute to 15 minutes.



**FIGURE 3.** Design of the Juice treatment system using Tesla Transformer to eliminate microorganism (a) front view and (b) side view.

Figure legends.

- |    |                          |       |                      |
|----|--------------------------|-------|----------------------|
| 1. | Juice tank.              | 9.    | Pump.                |
| 2. | <i>Tesla Coil</i> .      | 10.   | LCD.                 |
| 3. | Fans.                    | 11.   | Controller box.      |
| 4. | Metal electrode.         | 12.   | Battery 9V.          |
| 5. | Juice chamber treatment. | 13.   | Battery Switch.      |
| 6. | Faucet.                  | 14-17 | Switch.              |
| 7. | Juice storage.           | 18.   | Pipe.                |
| 8. | Grounding.               | 19.   | Terminal and Switch. |



**FIGURE 4.** Treatment process by applying pulsed field electric above the sample surface.

The juice treatment system is controlled using an Arduino microcontroller. The juice will be pumped to the juice chamber from juice tank. The volume of the juice can be adjusted as the user needs. The default volume of the system

is 100 ml and 200 ml. After the juice in the juice chamber, the controller then turns on the Tesla coil to generate high-frequency high-voltage which is used to eliminate the microorganism that might contain on the juice. The time of the pulse field electric is applied is adjusted from 1 minute to 10 minutes. The operation time is limits to avoid excess heat that might occur on the juice.

Figure 4 shows the typical output of the Tesla transformer which injected to the juice chamber. The output can be seen as a blue glowing as the output voltage is above the corona level of the air surround the metal tip. Note, that the system is tested using water as the sample.

## Future Works

The next works is to test the effectiveness of the system to eliminate microorganism on the juice. Several fruit juice will be tested such as mango juice, melon juice and carrot juice. The treated juice will be tested the microorganism number before and after the treatment. Also, the aroma and freshness of the juice also will be tested.

## CONCLUSION

In this research, a system treatment for fruit juice is design and its prototype is successfully tested. The treatment system using tesla generator to produce high-frequency high-voltage which used to generate pulse electric field which then will be tested its ability to eliminate microorganism on fruit juice.

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## REFERENCES

1. H. Neetoo and H. Chen, *Alternative Food Processing Technologies*. In Food Processing (eds S. Clark, S. Jung and B. Lamsal), Chapter 7, 2001
2. J. Burns, P. D. Frase, P. M. Bramley, *Identification and quantification of carotenoids, tocopherols and chlorophylls in commonly consumed*, 2003.
3. J. H. John, S. Ziebland, P. Yudkin, L. S. Roe, H.A.W. Neil, “*Effects of fruit and vegetable consumption on plasma antioxidant concentrations and blood pressure: a randomized controlled trial*”. *The Lancet* 359 (9322), 2002, 1969–1974.
4. C. Sanchez-Moreno, L. Plaza, B. de Ancos, M. P. Cano, “*Quantitative bioactive compounds assessment and their relative contribution to the antioxidant capacity of commercial orange juice*”. *Journal of the Science of Food and Agriculture* 83 (5), 2003, 430–439.
5. O. Martin, B. L. Qin, F. J. Chang, G. V. Barbosa-Canovas, B. G. Swanson, “*Inactivation of Escherichia coli in skim milk by high intensity pulsed electric fields*”, *Journal of Food Process Engineering* 20 (4), 1997, 317–336.
6. H. W. Yeom, C. B. Streaker, Q. H. Zhang, D. B. Min, “*Effects of pulsed electric fields on the quality of orange juice and comparison with heat pasteurization*”, *Journal of Agricultural and Food Chemistry* 48 (10), 2000, 4597–4605.
7. D. G. Hoover, “*Minimally processed fruits and vegetables: reducing microbial load by nonthermal physical treatments*”. *Food Technology* 51 (6), 1997, 66–71.
8. S. Min, G. A. Evrendilek, H. Q. Zhang, “*Pulsed electric fields: processing system, microbial and enzyme inhibition, and shelf-life extension of foods*”. *IEEE Transactions on Plasma Science* 35 (1), 2007, 59–73.
9. S. D. Tsen, J. Popovich, M. Hodges, S. E. Haydel, K. T. Tsen, G. Sudlow, E. A. Mueller, P. A. Levin, S. Achilefu S, “*Inactivation of multidrug-resistant bacteria and bacterial spores and generation of high-potency bacterial vaccines using ultrashort pulsed lasers*”, *J Biophotonics*. 2022 Feb;15(2).

10. N. F. Kasri, M. A. M. Piah, Z. Adzis, "Compact High-Voltage Pulse Generator for Pulsed Electric Field Applications: Lab-Scale Development", *Journal of Electrical and Computer Engineering*, vol. 2020, Article ID 6525483, 12 pages, 2020.
11. D. S. Kozak, M. Tonti, P. Cuba, J. Espitia, V. S. Tsepelev, D. Verheyen, S. Akkermans, J. F. M. Van Impe, "Design of a Low-Power Radio Frequency Unit and Its Application for Bacterial Inactivation under Laboratory Conditions", *Appl. Sci.* 2021, 11, 11117.
12. H. H. Sinaga, H. Al Falaq, N. Purwasih and D. Permata, "Water Treatment Using Plasma Generated by High Voltage Tesla Transformer to Eliminate Escherichia Coli Bacteria," 2021 International Conference on Converging Technology in Electrical and Information Engineering (ICCTEIE), 2021, pp. 10-13.
13. T. Ohlsson, N. Bengtsson, *Minimal processing of foods with nonthermal methods*. In: Ohlsson T, Bengtsson N (eds) *Minimal Processing Technologies in the Food Industry*. Cambridge: Woodhead Publishing, 2022, pp. 34–60.
14. G. V. Barbosa-Canovas, M. M. Gongora-Nieto, U. R. Pothakamury, B. G. Swanson, *Preservation of Foods with Pulsed Electric Fields*. San Diego, CA: Academic Press, 1999.
15. H. Vega-Mercado, M. M. Gongora-Nieto, G. V. Barbosa-Canovas, B. G. Swanson, *Nonthermal preservation of liquid foods using pulsed electric fields*. In: Rahman MS (ed) *Handbook of Food Preservation*. New York: Marcel Dekker, 1999, pp. 487–520.
16. D. C. Johnson, J. P. Bzdek, C. R. Fahrenbruck, J. C. Chandler, B. Bisha, L. D. Goodridge and B. M. Hybertson, "An innovative non-thermal plasma reactor to eliminate microorganisms in water" *Desalination and Water Treatment*, 57 (18), 2015, 8097–8108.