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Application of pulsed electric field in pasteurization of orange juice of siam cultivar: study on nutritional, physical, chemical properties, and total microorganism

To cite this article: MJ Wibowo *et al* 2022 *IOP Conf. Ser.: Earth Environ. Sci.* **980** 012007

IOP Conf. Series: Earth and Environmental Science **980** (2022) 012007 doi:10.1088/1755-1315/980/1/012007

Application of pulsed electric field in pasteurization of orange juice of siam cultivar: study on nutritional, physical, chemical properties, and total microorganism

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Abstract. Orange juice, extracted from orange of siam cultivar, was pasteurized using a pulsed electric field (PEF) method. The aim of this research was to analyze the changes on nutritional, physical and chemical properties and total microbes from orange juice after pasteurization. The research was conducted from June until September 2021 located in Jember. The PEF treatment was carried out using treatment time variation for 5 minutes (1 cycle), 10 minutes (2 cycles) and 15 minutes (3 cycles). Several parameters of Vitamin C, density, pH, total soluble and total microbes were observed. The result showed that PEF treatment did not significantly change nutritional, physical and chemical properties and total microbes after pasteurization with PEF in compared with no treatment pasteurization. The best treatment was found in the variation of 10 minutes (2 cycles).

1.Introduction

Food processing is an important step to make food ready for consumption and to improve the quality and shelf life of food products [1]. However, what is often neglected in the food processing process is the degradation of the nutritional content of food ingredients [2]. The damage to the nutritional content of these foodstuffs is generally due to the processing of foodstuffs using a thermal process [3]. One of the newest and not so familiar technologies in Indonesia in the field of food processing without involving a thermal process is to use a Pulsed Electric Field (PEF).

The PEF process is based on the application of short pulses at high voltage to a food material placed between two electrodes. The process is very short ranging from one microsecond to one millisecond with short pulses. HPEF is widely applied to liquid materials, although recently the use of HPEF has expanded to solid materials such as the pretreatment process for essential oil leaves [4]. In addition, PEF technology can be used to increase the yield in fruit juice production, accelerate water transfer during drying operations, as well as increase the extraction of valuable compounds (such as antioxidants, dyes, or flavors) from the interior of the cells [5]. In addition, PEF can also extend the shelf life while maintaining the physical, chemical, and sensory properties of food [6]. The added value is that the purpose of this research is to know the characteristics of Siamese orange juice using the HPEF method.

1.1 Orange Juice

Citrus juice is a drink that is widely consumed compared to other fruit juices because of its taste as well as its health benefits related to the bioactive components contained in orange juice which act as antioxidants such as vitamin C and phenolic compounds. Recent studies have shown that 66% of the antioxidant capacity of orange juice is supported by vitamin C [7].

In the process of making orange juice on an industrial scale, the pasteurization process is generally carried out before being packaged. Pasteurization of orange juice is generally carried out at 80°C for 30 seconds. It aims to kill spoilage microbes, namely mold, and bacteria [8]. High Pulsed Electric Field (HPEF) is one of the electricity-based processing techniques. The application of short electrical pulses at high voltages allows the reduction of thermal processing effects, such as ohmic heating [13], and moderate electric fields. The HPEF method is a microbial inactivation technique without detrimental effects on the attributes of food products so that the nutritional content of food is maintained [9].

The application of PEF for the treatment of food commodities has been widely carried out, from the results of research the PEF method has been known to preserve food products without reducing their nutritional and sensory quality values [10]. Basically, the working principle of this sterilizer with high-voltage electric pulse field technology (High Pulsed Electric Field) is very simple, namely, liquid food media is subjected to an electric pulse field with a certain intensity generated from a voltage generator (coil). Various types of generators can be selected according to their needs, for example, Pearson Coil has been used to generate high voltage by. The Important aspects in HPEF technology are the high-voltage power generation unit, the design of the treatment chamber that is able to suppress the increase in temperature and the design of the electrode that is able to minimize the effects of electrolysis. High field intensity is achieved by storing large amounts of energy in the capacitor bank (a series capacitor) of the DC power supply which is then converted into high-voltage pulses. Energy requirements in PEF are more efficient than thermal pasteurization, especially when using a continuous system.

The main components in the electrical pulse-forming network are: 1) electrical energy generation. A high-voltage electrical energy generation unit capable of providing electrical energy at a specified voltage level up to about 40kV; 2) one or more banks of capacitors, inductors and/or resistors. Capacitors to store electrical energy. Capacitors are connected in parallel to increase the stored electrical energy. Inductors temporarily store magnetic energy thereby delaying the rise in electric current. Resistors are mainly represented by the charge of the process chamber and dissipate electrical energy. 3) one or more switches that transmit electrical energy to the electrodes and foodstuffs. The switches are connected in series and parallel for alternating high voltage and electric current. The pulse length ranges from less than a microsecond to a few milliseconds. 4) one or more process chambers with two electrodes between the food sample being flowed or placed. When the switch is closed, the capacitor discharges the stored energy into the process chamber and an electric pulse flows through the sample of food. The rate at which the voltage increases across the electrodes depends on the closing speed of the switch, the electric wire and the resistivity of the material. Electrical interconnection faults can occur due to using multiple process spaces in series or parallel. 5) Oscilloscope to measure the voltage that passes through the electrodes and displays an image of the shape of an electric pulse. The shape of the pulse depends on the network that forms the electric pulse. Some forms of electric pulses are exponential decay or square wave (both can be monopolar or bipolar), oscillatory pulse or instant reversal pulse, the commonly used pulse forms are exponential decay and square waveform [11].

2. Methods

The first stage is the optimization of the Semboro orange juice pasteurization process (Low Grade) using the HPEF method based on the time factor, duration of exposure with electrical pulses (Pulse Duration) and the voltage range used (Pulse interval).

2.1 Research Procedure

This research is planned until the year 2026, where researchers will divide into basic, applied, development research and finally get orange juice products that are safe for consumption. Researchers have published scientific articles from 2018-2020 related to HPEF technology for pasteurizing cow's milk, and on this basis this technology will be applied to orange juice based on local resources. In the basic research, a prototype of the HPEF method pasteurization device will be built with optimization of the HPEF dose and material contact time. In the following year, non-destructive sterilization technologies with multi-chamber will be developed. At the end of the research roadmap, orange juice products will be obtained that are safe for consumption and the creation of an orange juice agro-industry cluster based on local resources.

2.2 Research Location

This research was conducted at the TEFA Bakery Laboratory and the Food Analysis Laboratory of Politeknik Negeri Jember.

2.3 Tool and Material

The material used is Siamese orange juice obtained from the extraction of Siamese oranges without the addition of other ingredients. Siamese oranges were purchased from the Tanjung-Jember Market. Other materials are 95% alcohol, cotton and sterile bottles. The tools used are a series of PEF tools, high voltage voltmeter, pH meter, petri dish, tds meter, juice extractor, and cool box.

2.4 Research Methodology

The research was carried out from July to September 2021 at TEFA Canning Jember State Polytechnic. The method used is descriptive experimental method. Testing is done by varying the processing time. Processing time is 0, 5, 10, and 15 minutes. The volume of apple cider entered in the treatment chamber is 3 liters. For each processing time with PEF, 3 (three) replicates of samples will be taken which will then be analyzed for changes in nutritional value (vitamin C), chemical properties (pH and total dissolved solids) and the number of microbes (total microbes and coliforms) contained in the PEF will be calculated. Siamese orange juice processed with PEF. The high-voltage pulse generator used in the pasteurization of Siamese oranges with the PEF method consists of several blocks, namely the keypad block, microcontroller, display, flyback converter circuit, high-voltage transformer and chamber. The keypad is used to enter the high voltage setting and the time required for treatment.

The high voltage can be set from 20 kV to 40 kV and the length of treatment can be set in the range of 0 minutes to 15 minutes. The microcontroller serves to display the high voltage and treatment time that is set through the keypad. The flyback converter circuit will receive the output of the microcontroller in the form of square pulses that can be adjusted for the pulse width. The output of the flyback converter in the form of a voltage pulse will count the input voltage of the high-voltage transformer so that the output of the transformer will be in the form of a high-voltage pulse. High-voltage transformers can produce a maximum output of 40 kV. Constant frequency 20 kHz. All PEF components are assembled in a high-voltage generator box made of mica. The high-voltage pulses produced are directly fired into the chamber (the treatment area) which is coated on the outside by electrodes made of copper. The treatment chamber is made of 4 mm thick stainless steel plate which is safe for all food products. The treatment chamber is in the form of a four-legged cylinder with a volume of 1.7 liters equipped with an exhaust valve. To protect the entire pulsed electric field tool, the outside is provided with a barrier made of a clear mica box.

3. Experiment and Result

This study was conducted to determine the characteristics of orange juice with HPEF treatment. Analysis on chemical parameters such as Vitamin c, pH, Dissolved Solids, and Total Microbes were analyzed.

Vitamin C

The vitamin C content of Siamese orange juice before pasteurization is 6.205 mg/100gr. The highest level of vitamin C after pasteurization in the 5-minute treatment was 6.181 mg/100gr and the lowest in the 15-minute treatment was 6.091 mg/100gr. The graph of changes in vitamin C levels against treatment time is shown in Figure 1.

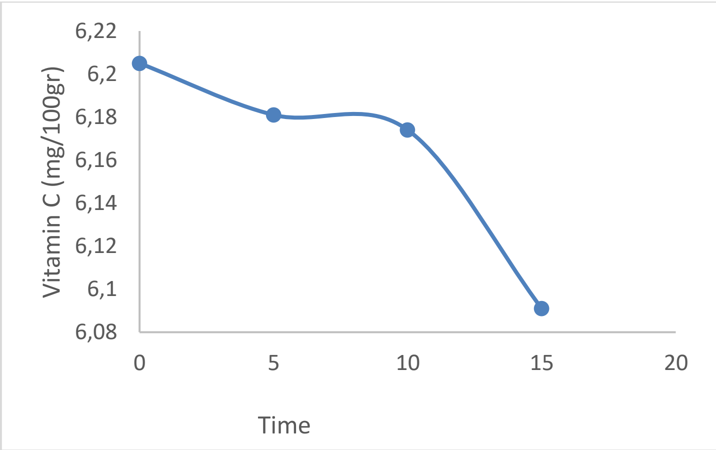

Figure 1. Vitamin C

Figure 1 it can be seen that the non-thermal pasteurization treatment with a high pulsed electric field (HPEF) will cause a decrease in vitamin C levels, but this change tends to be insignificant compared to without HPEF. According to [8] the processing of orange juice using heat will reduce the quality of the citrus juice produced due to oxidation which causes a reduction in the vitamin C content and loses the original taste and aroma of the orange. Meanwhile, when using HPEF technology, Siamese orange juice does not lose vitamin C, the original taste or aroma of the orange juice. This is also in accordance with the opinion [9] that the higher the temperature and the duration of heating, the greater the degradation of vitamin C. Oxidation of vitamin C (ascorbic acid) will convert ascorbic acid into L-dehydroascorbic acid which is chemically very labile and can undergo further changes to Ldiketogulonic acid which has no vitamin C activity anymore.

pH

The pH of Siamese orange juice before pasteurization was 4.64. The highest pH after pasteurization in the treatment for 10 minutes was 4.74 and the lowest in the treatment for 5 and 15 minutes was 4.4. Graph of changes in pH with treatment time is shown in Figure 2.

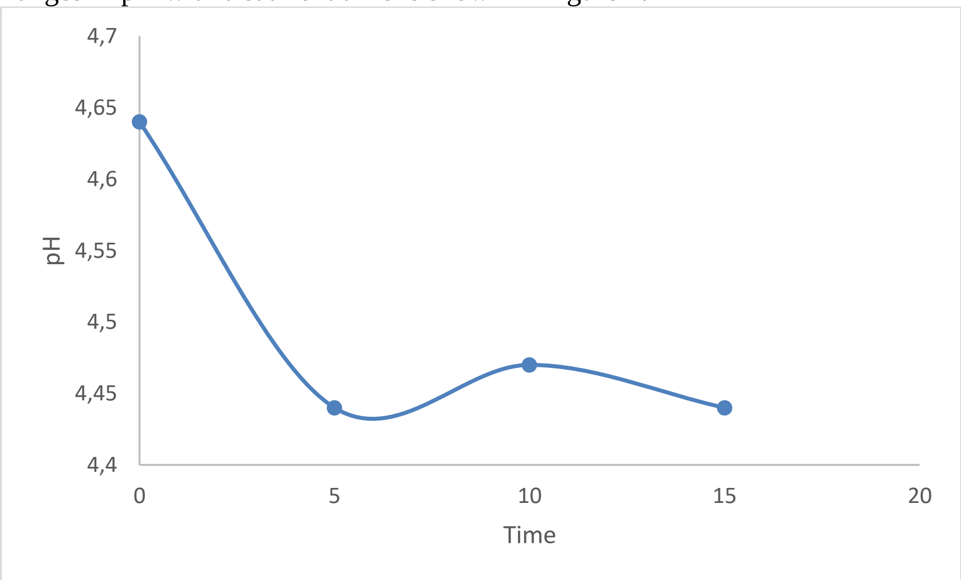

Figure 2. pH Value

In Figure 2 it can be seen that the pH of Siamese orange juice from non-thermal pasteurization using a pulsed electric field tends to decrease the pH of Siamese orange juice but the changes are not significant and are still in the average range with the pH before pasteurization. This is in line with research [10] that the pH of the mixture of orange juice and carrots treated with PEF did not change significantly. [11] also stated that HPEF treatment did not significantly change the pH of milk.

Dissolved Solid

The total soluble solids of Siamese orange juice before pasteurization was 776 ppm. The value of total soluble solids from orange juice after HPEF pasteurization tended not to change, except for the 15 minute treatment of 678 ppm. The graph of the change in total dissolved solids with respect to treatment time is shown in Figure 3.

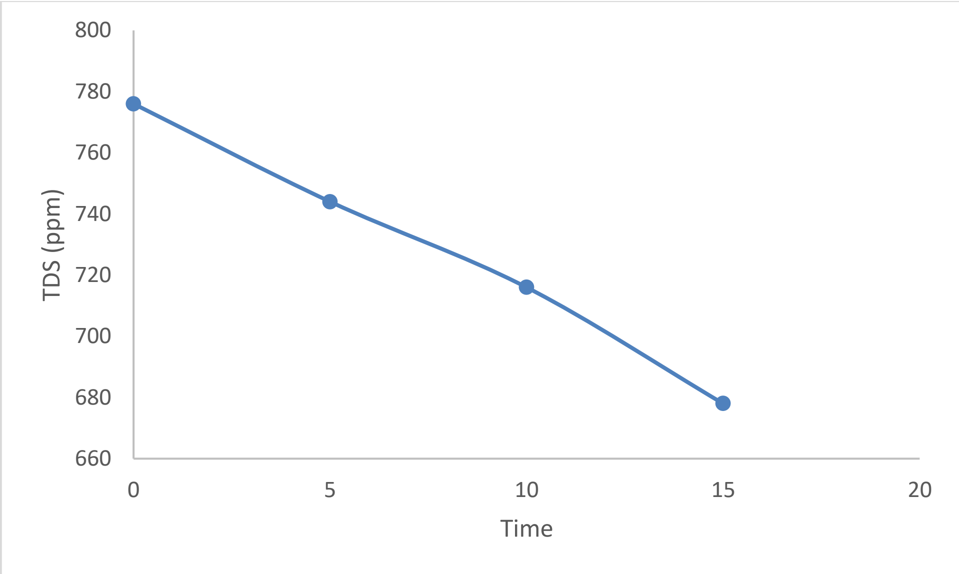

Figure 3. Changes in total dissolved solids with treatment time

The total value of soluble solids is the sum of the total content of all substances, both inorganic and organic, dissolved in food. The components in the fruit consist of water-soluble components, such as glucose, fructose sucrose, and water-soluble protein (pectin). The higher the dissolved solids number, the more cloudy the fruit juice, the more cloudy the drink made will reduce the level of consumer preference for the product [12]. Based on research results, HPEF technology can reduce the value of dissolved solids in a fruit juice. The decrease in the total dissolved solids value is thought to be because the content of the material contained in the Siamese orange juice is not degraded due to processing using HPEF, so that it can reduce the total soluble solids in the Siamese orange juice.

Total microbes

The total microbes of Siamese orange juice before pasteurization were 1.22x104 cfu/ml. The total of these microbes not in accordance with the Indonesian National Standard (SNI) where the maximum total microbes contained in fruit juice drinks is 2x102 cfu/ml. The highest total microbes after pasteurization in the 5 minute treatment was 5.09x103 cfu/ml and the lowest was 3.58x102 cfu/ml in the 15 minute treatment. The graph of the decrease in total microbes with time changes is shown in Figure 4.

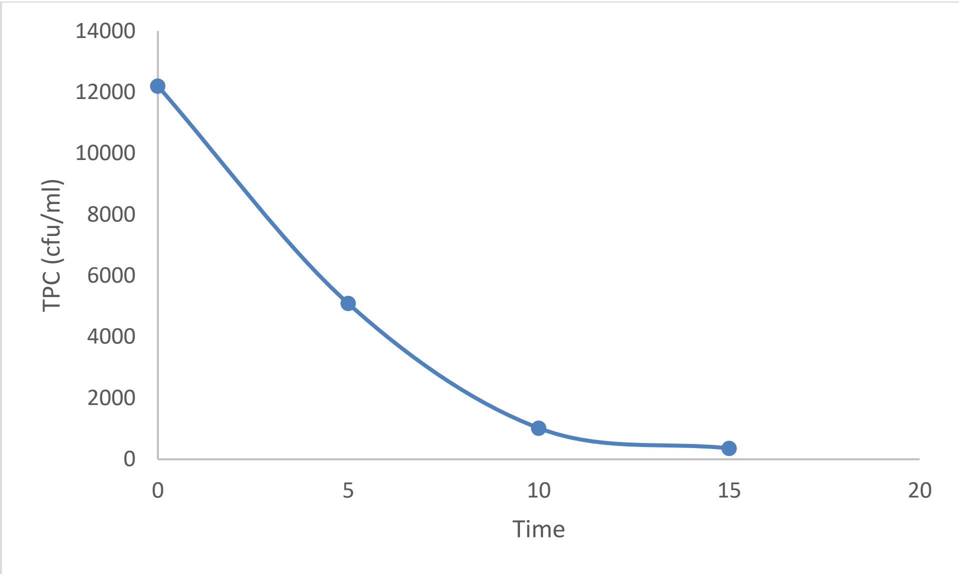

Figure 4. Decrease in total microbes with treatment time

The results of the analysis showed the presence of coliforms in the fresh Siamese orange juice. At the time after pasteurization, coliforms were still found in the treatment time up to 10 minutes, but at 15 minutes there were no coliforms. This is in accordance with the Indonesian National Standard (SNI) where the maximum permissible coliform limit is 20 APM/ml. No coliforms were found in the PEF pasteurized orange juice because the pH condition of the apple cider was quite acidic which ranged from 4.44-4.64. Under acidic conditions, coliforms are not able to live properly.

PEF is the latest non-thermal technology for liquid and semi-solid food processing systems. The process involves administering short pulses of 1 s to 100 s of a high voltage electric field between 20–80 kV/cm to a food material placed between two electrodes at room temperature [13]. Giving high-voltage pulses to food will damage the bacterial membrane causing the bacteria to die [14]. The possibility that arises from this phenomenon is the occurrence of abnormal metabolic activity or an increase in cell body metabolism that is too sharp so that it interferes with the work and physiological functions of cells. Electric shock with high voltage causes physical damage to cells. Microbial death due to high-voltage electric shock is thought to be influenced by damage to other cell structures, such as damage to the cell's cytoplasmic membrane. Although naturally the cytoplasmic membrane can be synthesized again but with high voltage, the damage in the form of holes in the outer membrane of the cell cannot be repaired, thus allowing the entry and exit of macromolecular compounds from the cell and cause death [15]. The length of treatment also affects the amount of microbial decline, where the longer the treatment time the microbial mortality is also getting bigger. It is suspected that the largest total microbes contained in orange juice have a high susceptibility to electric current, causing a high mortality rate [16]. Meanwhile, the remaining total living microbes were thought to have high resistance to electric shocks, so that the number of subsequent electric shock treatments was not so large in killing the remaining total microbes [17]. According to [18], spore death by electrocution treatment was limited by the strength of the electric field generated, the duration of the shock, the number of shocks applied and the cell size. Meanwhile, according to [19], electricity with high voltage for a long time has a greater effect in reducing the number of spores contained in the media.

4. Conclusion

The PEF treatment was carried out using treatment time variation for 0-15 minutes. Several parameters of Vitamin C, density, pH, total soluble and total microbes were observed. The result showed that PEF treatment did not significantly change nutritional, physical and chemical properties and total microbes after pasteurization with PEF in compared with no treatment pasteurization.

IOP Conf. Series: Earth and Environmental Science **980** (2022) 012007 doi:10.1088/1755-1315/980/1/012007

Acknowledgments
Our thank goes to Politeknik Negeri Jember, who has helped support for this research.

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