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Effect of Voltage and Frequency in Pasteurization Pulsed Electric Field (PEF) Continous System of Pineapple (*Ananas comosus* [L.] Merr) Juice

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Abstract. Pineapple which is one of the perishable commodities with high water content about 90.73% in 100 gr of fresh material. Thermal pasteurization has a weakness that can degrade the quality of fruit juice products. In contrast, non thermal processes have expectations which is don't make decreasing quality of the product. One of the non-thermal pasteurization type called Pulsed Electric Field (PEF). Nowadays, PEF system have two type batch and continous, which respectively used in this research is PEF continous system. This study uses research methods group random design (GRD) with two factorial that voltage (20, 30 and 40 kV) and frequency (10, 20, 30 and 40 kHz). Based on these studies it is known that the voltage and frequency is significantly different to the value of Total Plate Count (TPC), and absorbance. However there aren't significantly different with the pH, vitamin C, viscosity, total dissolved solid (TDS), total sugar and color. The treatment based on the microbial test are at a voltage of 40 kV and a frequency of 40 kHz which can reduce bacteria significantly 1.01×10^3 cfu / mL or 0.94 by log cycle with the effectiveness of microbial death by 88.5%. The treatment based on the microbial test are at a voltage of 40 kV and a frequency of 30 kHz which The result indicates that physical and chemical characteristic of pineapple juice become 3.98 of pH, total dissolved solid (TDS) of 6.25 °brix, total sugar of 14.75 % viscosity of 3 cp, vitamin C of 7.6 mg/100ml, absorbance of 0.67, color on the brightness (L^*) value of 24.05, redness (a^*) of 6.35, and yellowish (b^*) of 7.5. This result shows that PEF continuous respectively work system to pasteurize the pineapple juice.

Keywords: Frequency, Fruit Juicy, Pulsed Electric Field (PEF), Pineapple, Voltage

1. Introduction

Horticultural commodities continue to developed, because the commodity has a high economic value howeverless realized variety, quantity, quality. Pineapple (*Ananas comosus* [L.] Merr) as one of the mainstay horticultural commodities in tropical fruit trade especially in Indonesia, the average consumption of pineapple in Indonesia is 6.132.695 tons per year [15]. Pineapple fruit is a perishable commodity with a high water content of 90.73% in 100 grams of material.

One effort that can be done is processing ie in the form of juice, as for the procedure of the process of making fruit juice is process of fresh fruit into fruit juice product by destroying the fruit



into an essence and add additional ingredients to support the taste of the product and then do some treatment for extended shelf life [9]. The extended shelf life of pineapple juice after pasteurization can be done two methods which are thermal and non-thermal. According to [10], pasteurization is a process that has been done in the food processing industry because it is able to inactivate the enzyme and suppress the amount of microbes. Thermal pasteurization has weaknesses, it can damage the texture, taste, color and other physical properties that can reduce the quality of fruit juice products. When compared with the thermal pasteurization process, the non-thermal pasteurization process is able to maintain the quality of food products but in the reduction of the number of microbes causing damage to food needs a further assessment.

In addition to the voltage factor on the Pulsed Electric Field (PEF) pasteurization process there are other factors that influence the final product result that is the distribution of frequency. Frequency contributes to processing time this is because the distribution of the frequency causes a reduction in cell membrane resistance resulting in cell damage to the food product [11]. Therefore, the need for further research on the effect of differences in the frequency of Pulsed Electric Field (PEF) pasteurization process, in addition to being able to get the best product results is also able to minimize processing time. With the result that the research titled is Effect of Voltage and Frequency on Pasteurization of Pulsed Electric Field (PEF) Continuous System on Quality of Pineapple (*Ananas comosus* [L.] Merr) Juice.

2. Material and Methods

The tool used in the research is circuit of Pulsed Electric Field (PEF) continuous system tools, bottles, knives, gloves, aluminum foil, cotton, autoclave, basin, scissors, measuring tube, and paper labels. Tools used for the analysis of pipettes, micropipettes, petri dishes, cotton, brown paper, measuring tubes, measuring cylinders, Laminar Air Flow (LAF), scales, gloves, aluminum foil, test tube, cotton, blue tip, electric stove, and Bionex brand of incubators. The materials used in this research are pineapple fruit was obtained in Blimbing Market, Malang, East Java, 96% alcohol, and aquades. The material used for the analysis is the plate count agar (PCA) merk brand.

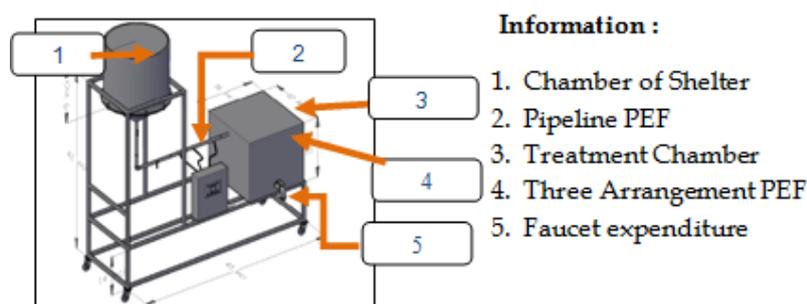


Figure 1. PEF Continuous System Pasteurization Tool Circuit

2.1. Experimental Design

This study uses research methods Group Random Design (GRD) with two factorial that voltage (20 kV, 30 kV and 40 kV) and frequency (10 kHz, 20 kHz, 30 kHz and 40 kHz). Each treatment was repeated 2 times.

2.2. Implementation Research

The process of making pineapple fruit ; first pineapple fruit washed with water then peeled the skin, then pineapple fruit split into four parts. Furthermore, pineapple fruit that has been cleaved then done blanching process. Pineapple fruit is done by blender then filtering and immersion for 1 hour Fruit juice is then added sugar and citric acid, then heated for 10-15 minutes. After the cold the pineapple juice is put into a sterile bottle

Non-thermal process using PEF, place the pineapple juice on the chamber, connect it to the electric current. Set the voltage at the first treatment of 20 kV and frequency of 10 kHz, then press the ON button. Open the output faucet and place it in a sterilized bottle and cover with a sterilized bottle cap to avoid contamination with the environment. Clean the treatment room with 96% alcohol after each research. Repeat for any combination of voltage and frequency of PEF.

2.3. Observation

The test parameters performed are Total Plate Count, absorbance, pH, vitamin C, viscosity, total dissolved solid (TDS), total sugar and colour

2.4. Data Analysis

The data obtained were analyzed using Two-Way ANOVA. If there is a real difference then BNT advanced test and if the interaction of both factors show real difference, then continued with LSD test. *Formatting the title*

3. Result and Discusss

3.1. Material Characteristics of Treatment

Based on the results of pineapple juice analysis before treatment with Pulsed Electric Field (PEF) shown on **Table 1**.

Table 1. Characteristic Value of Pineapple Fruit

Characteristics	Control	Thermal Pasteurization	Literatur	unit
Total Plate Count (TPC)	8,8x10 ³	9,35x10 ²	1. 10 ⁴	Cfu/ml
pH	3,99	4,09	Max 4*	-
TDS	6,75	5	10-11*	⁰ brix
Total Sugar	16,19	17,91	Max 5	%
Viskosity	4,5	5,5	-	Cp
Vitamin C	7,66	3,83	34,77**	Mg/100ml
Absorbance	0,79	0,52	-	abs
Brightness(L*)	23,45	23,20	-	-
Redness (a*)	6,65	6,25	-	-
Yellowish(b*)	7,70	5,95	-	-

Information * SNI 01-3719-1995 **Daniela (2015)

Based on Table 1. At TPC value, research of pineapple juice has lower value than TPC literature, According to [7] the difference of TPC value is caused by the difference of treatment to material and environmental conditions. TPC, pH, color, viscosity, vitamin c, total sugar, TDS and absorbance on control factor and thermal pasteurization have difference caused by thermal pasteurization using heat treatment at the treatment so as to cause undesired reactions. In accordance with the statement of [5], during the process of thermal pasteurisation large amounts of energy are transferred to food. This energy can cause unwanted reactions, such as loss of essential nutrients, discoloration, odor and taste.

3.2 Total Plate Count (TPC)

Total Plate Count (TPC) is the total amount of microbes contained in pineapple juice. The calculation of the amount of contamination will be related to the effectiveness of decreasing the number of microorganisms. The result showed that giving 40 kV (voltage) and 40 kHz (frequency) can reduce total microbial in pineapple juice equal to 1.01×10^3 while giving 20 kV and 10 kHz frequency can only decrease total of pineapple juice nutrient equal to $6,35 \times 10^3$. Based on these results then obtained the amount of microbial contaminants presented in Table 2.

Table 2. Number of Microbial Contaminants

Treatment	Total Plate Count cfu/mL)		Average (cfu/mL)
	I	II	
Control	$9,3 \times 10^3$	$8,4 \times 10^3$	$8,8 \times 10^3$
Thermal Pasteurization	$6,7 \times 10^2$	$1,2 \times 10^2$	$9,35 \times 10^2$
V₁F₁	$5,2 \times 10^3$	$7,4 \times 10^3$	$6,3 \times 10^3$
V₁F₂	$3,8 \times 10^3$	$2,9 \times 10^3$	$3,35 \times 10^3$
V₁F₃	$2,2 \times 10^3$	$2,2 \times 10^3$	$2,2 \times 10^3$
V₁F₄	$1,5 \times 10^3$	$1,1 \times 10^3$	$1,3 \times 10^3$
V₂F₁	$2,2 \times 10^3$	$6,2 \times 10^3$	$4,2 \times 10^3$
V₂F₂	$2,9 \times 10^3$	$2,5 \times 10^3$	$2,7 \times 10^3$
V₂F₃	$1,6 \times 10^3$	$1,1 \times 10^3$	$1,35 \times 10^3$
V₂F₄	$1,3 \times 10^3$	$9,1 \times 10^2$	$1,1 \times 10^3$
V₃F₁	$2,7 \times 10^3$	$2,1 \times 10^3$	$2,4 \times 10^3$
V₃F₂	$2,2 \times 10^3$	$1,7 \times 10^3$	$1,95 \times 10^3$
V₃F₃	$2,4 \times 10^3$	$1,4 \times 10^3$	$1,9 \times 10^3$
V₃F₄	$1,4 \times 10^3$	$6,2 \times 10^2$	$1,01 \times 10^3$

3.3 The Effectiveness of Microbial Deaths

The result of Two Way ANOVA test shows that the voltage and frequency give significant difference, ie sig V (0.032) and sig F (0.001). Then the next test is LSD test indicates that the voltage affecting and frequency, while the interaction between the two factors does not give Influence "no real difference" ($P > 0.05$). When viewed on the value of ANOVA, it can be concluded that the voltage and frequency can reduce the number microbial in pineapple fruit

The smallest microbial death effectiveness is owned by 20 kV and 10 kHz voltage treatment with a percentage of 28.8%. While the greatest microbial effectiveness of 40 kV and 40 kHz voltage treatment with a percentage of 88.5%. An increase in the percentage effectiveness of microbial mortality is shown in **Figure 2**.

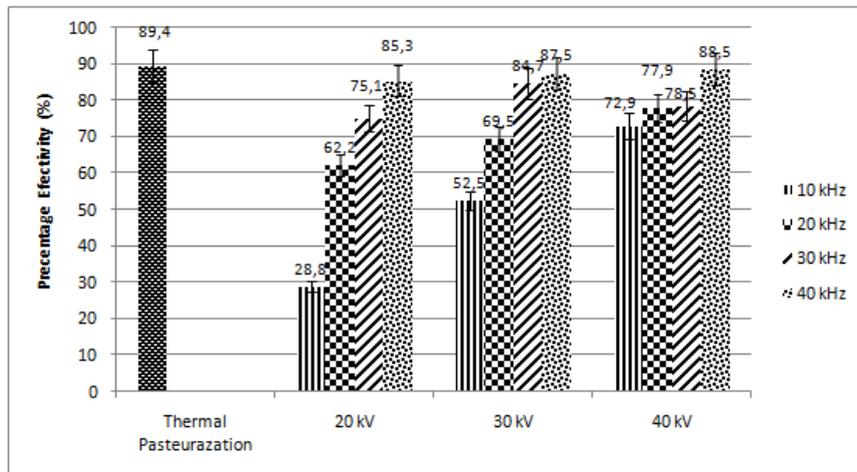


Figure 2. Graph of Percentage Value of Effectiveness of Decreasing the Number of Microorganisms

Giving high voltage shocks causes damage to cell structures such as the destruction of cytoplasmic cell membranes where cell mobilization does not occur resulting in microbial inactivation [8]. According to [12], Frequency on Pulsed Electric Field (PEF) continuous system contributes to the processing time because the giving of the frequency causes the reduction of cell membrane resistance so that the arising of cell damage in food products.

3.4 Decrease in Number of Microbes and Log Cycle

The calculation of the decrease in the number of microbes will be related to Log Cycle microorganisms. The lowest decrease was obtained at 20 kV voltage treatment with frequency of 10 kHz that is equal to 0.14 log cycle. While the highest decrease is in the treatment voltage of 40 kV with a frequency of 40 kHz is equal to 0.94 log cycle. When viewed from the acquisition of the largest D value, pineapple juice with PEF treatment get a D value of less than 90% or 1 log cycle then no need to calculate D value. This is because in the PEF process the lack of treatment time in which the material only passes through the process of giving voltage and high frequency. The value of microbial log cycles or microbial decline is shown in **Figure 3**.

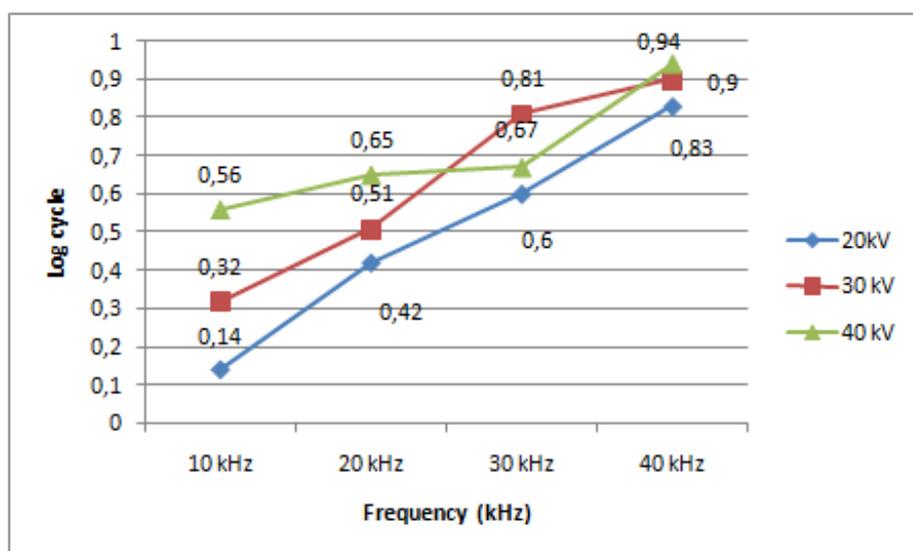


Figure 3. Graph of Relation Frequency and Voltage to Logarithmic Reduction of Microbes

Level of acidity (pH) in pineapple juice that has been subjected to voltage and frequency treatment in the study ranged from 3.96-3.99. The graph of voltage and frequency relationship to pH of pineapple juice is shown in **Figure 4**.

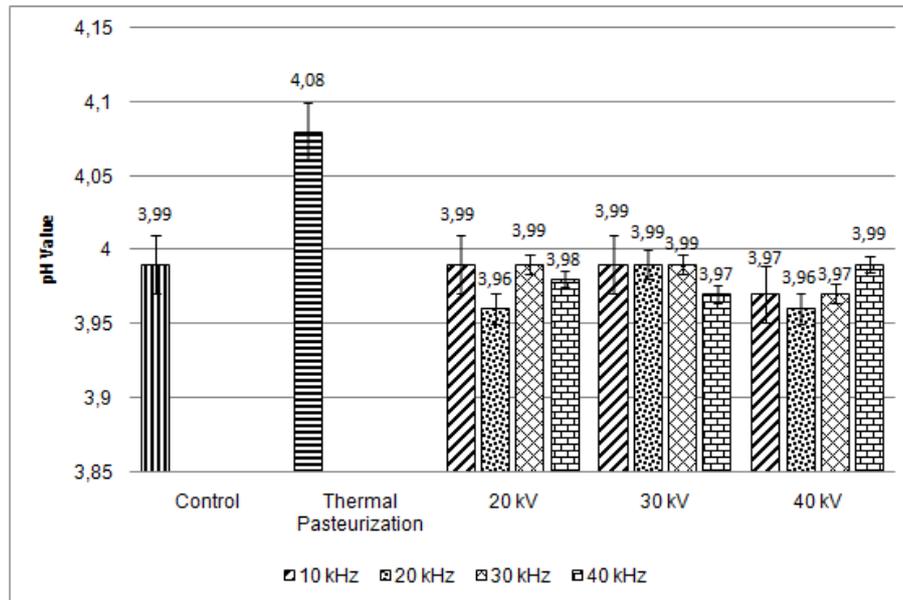


Figure 4. Graph Relation of Voltage (kV) and Frequency (kHz) of Average Value of pH Pineapple Juicy

Based on the result of analysis of Two Way ANOVA fingerprint showed that the voltage, frequency and interaction are not significantly different ($P > 0.05$) to pH in pineapple juice so it is concluded that PEF pasteurization has no effect in pH value of pineapple juicy

In **Figure 4**, the data obtained only range from less than pH 4 which is known that juice usually has a low pH because it is rich in organic acids [10]. Factors of pH damage occur because of high temperatures where high temperatures bring great energy as a result of chemical damage in food [4]

3.5 Total Dissolve Solid (TDS)

Total soluble solids in pineapple research were between brix 6-6.25 °brix the relationship of voltage and frequency to TDS value is shown in **Figure 5**.

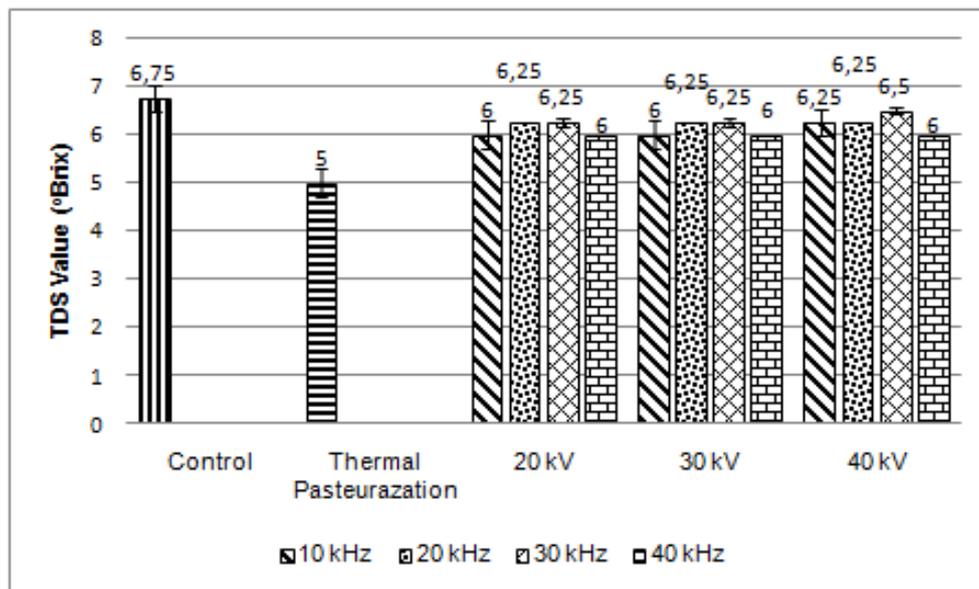


Figure 5. Graph of Voltage Relation (kV) and Frequency (kHz) to mean of TPT (°Brix) Pineapple juice

From Two Way Test ANOVA showed that the voltage, frequency and interaction were not significantly different ($P > 0.05$) so it can be concluded that PEF pasteurization has no effect on the total Dissolve solids (TDS) of pineapple juice. In **Figure 5**, according to the data, it can be concluded that the voltage and frequency of PEF does not have a big effect on the TDS value. According to SNI 01-3719-1995, the value of TPT on the juice is 10-11 °Brix which is very high value when compared to the value obtained that is about 6-6.25 °Brix. According to [13], pineapple juice if left for a day will form a sediment. This precipitate when no homogenization will affect in the total test of dissolved solids.

3.6 Total Sugar

The largest total sugar value was PEF treatment with 20 kV and 10 kHz of 15.49% and the smallest sugar value was PEF treatment with 40 kV and 20 kHz frequency of 14.67. The average graph of total sugar can be seen in **Figure 6**.

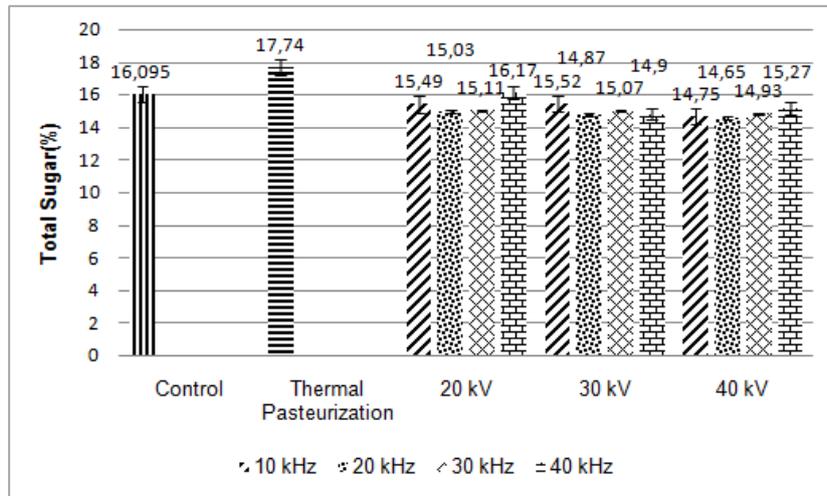


Figure 6. Graph of Voltage Relation (kV) and Frequency (kHz) to mean Total Sugar (%) Pineapple Juicy

Two way ANOVA test showed that the voltage, frequency and interaction are not significantly different ($P > 0.05$) so that PEF pasteurization cannot be concluded that the total value of pineapple juice. In Figure 6 obtained data exceeds the value of SNI 01-3719-1995 is max 5% this is because the total test of sugar made 3 days after the process of making pineapple juice resulting in a change in chemical content during the storage process. According to [6], the longer storage of fruit products will affect the sugar content when the storage is done 5 days and 10 days increased sugar levels when compared with control values, this is due to the polysaccharide split into sugar (sucrose, glucose, Fructose).

Viscosity

The highest viscosity value at 20 kV and 30 kHz is 5 cp and the lowest viscosity value is 2.5 cp of 30 kV and 30 kHz with control value 4.5 cp and thermal pasteurization 5.5 cp. The result of stress and frequency test of viscosity can be seen in **Figure 7**.

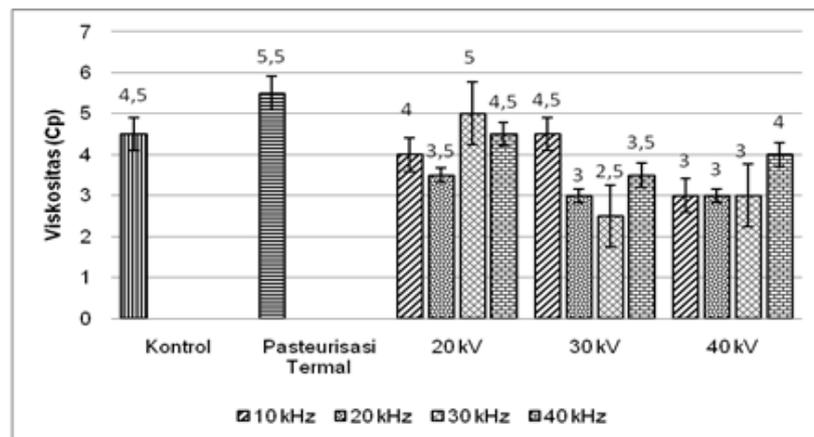


Figure 7. Graph of Voltage Relation (kV) and Frequency (kHz) to Average Viscosity (Cp) of Pineapple Fruit

Two way ANOVA test showed that the voltage, frequency and interaction were not significantly different ($P > 0.05$) so that PEF (non-thermal pasteurization) PEF (non-thermal pasteurization) was not affected in the viscosity value of pineapple juice. Viscosity of pineapple juice after PEF treatment when seen in **Figure 7**. to get a fluctuating value that is a decrease and increase in graphics this can happen because the testing process is too long so that cause the deposition of the pineapple juice. According to [1], the greater the viscosity of the juice make the more concentrated ingredients . This change occurs because the more the amount of water added to the extract the viscosity of the product will be smaller and vice versa, the less water added to the extract the viscosity will be higher.

3.7 Vitamin C

The content of vitamin C in fruit juice experienced significant value, the highest vitamin C value occurred at 20 kV and 10 kHz frequency of 7.73 mg / 100ml and the lowest vitamin C value occurred at 40 kV at 40 kHz frequency of 7.63 mg / 100ml. The relationship of voltage and frequency to the value of vitamin C can be seen in **Figure 8**.

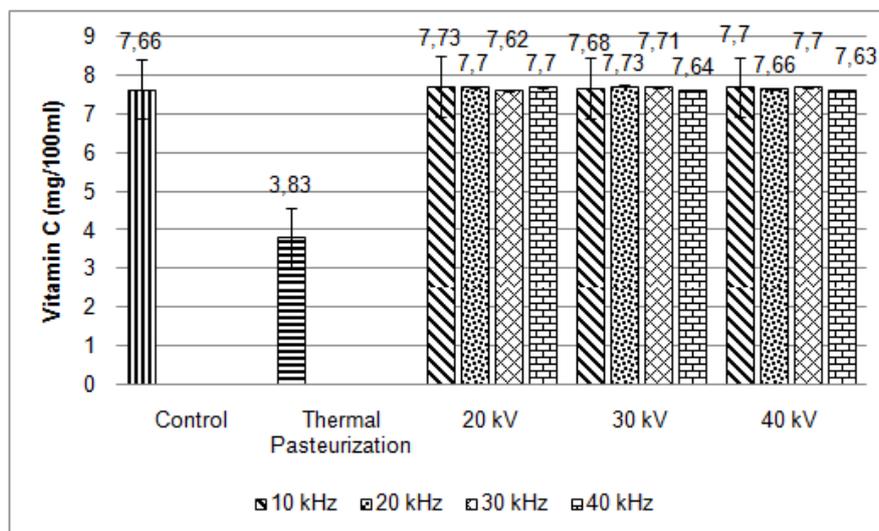


Figure 8. Graph of Voltage Relation (kV) and Frequency (kHz) to the average of Vitamin C of Pineapple Fruit

The Two Way ANOVA test showed that the stress, frequency and interaction were not significantly different ($P > 0.05$) to the value of vitamin C in pineapple juice, so it could mean that non-thermal Pasteurization of PEF (Pulsed Electric Field) does not affect the value of Vitamin C pineapple juice. In Figure 8, vitamin C was obtained with ± 7 mg / 100ml, when compared with the literature [3], stated that the vitamin C content of pineapple fruit was 34.766 mg / 100ml which in vitamin C yield decreased. Value occurs Vitamin C is an easily damaged vitamin, vitamin damage factor is heating, material destruction with blender, cutting material, the presence of metal, pH and light that makes oxidized of vitamin C [8].

3.8 Absorbance

The greatest absorbance value is 0.69 at 20 kV and 40 kHz and the smallest absorbance value is 0.62 at 40 kV and 20 kHz where control value is 0.78 and thermal pasteurization value is 0.51. Following is a graph of the absorbance relationship shown in **Figure 9**.

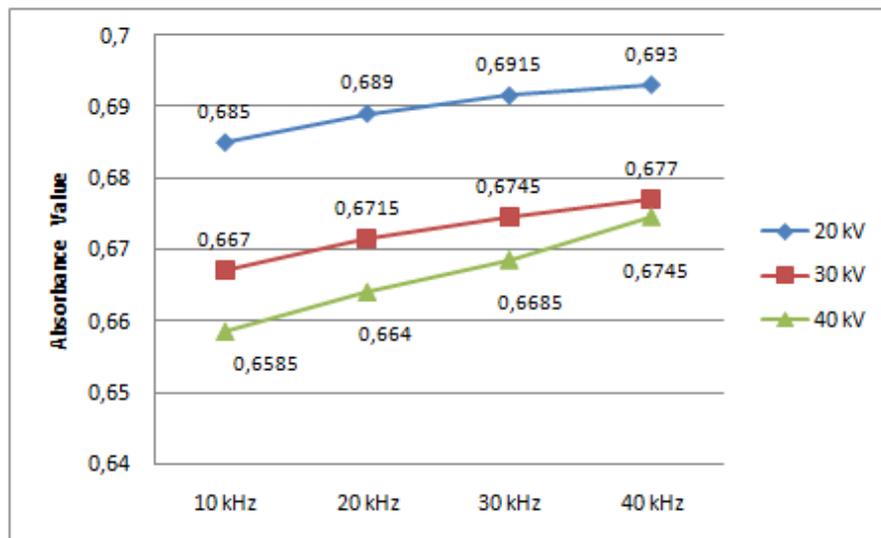


Figure 9. Graph of Voltage Relation (kV) and Frequency (kHz) to the average absorbance of Pineapple Juicy

Two Way ANOVA test result showed that voltage and frequency gave significant difference between sig V (0,000) and sig F (0,002), while the interaction between the two factors did not give "no real difference" ($P > 0,05$) with Sig . 0.346 to the absorbance of pineapple juice so that the voltage and frequency can increase the quantity of substances in the pineapple juice.

When viewed graphic pattern it can be concluded the higher the given frequency then the absorbance value obtained greater and vice versa giving voltage treatment can reduce the absorbance value. According to [11], the lower absorbance range in absorbance values indicates higher absorption of particles and higher absorbance values of lower particle absorption.

3.9 Colour

The measurement of color values is known using a color reader, ie the measurement uses three brightness parameters (L), redness (a^*), and yellowish (b^*). From the results of color testing obtained the color test in the category has a brightness level of bright, faded reddish and yellowish

Two way ANOVA test showed that the voltage, frequency and interaction were not significantly different ($P > 0.05$) so that PEF (non-thermal pasteurization) PEF (non-thermal pasteurization) was not affected in the colour value of pineapple juice.

3.10 Brightness Value (L^*)

The smallest brightness value that is 21.85 is at 20 kV and 20 kHz voltage treatment and the greatest brightness value is applied voltage of 20 kV and 40 kHz equal to 24,35. The relationship of PEF voltage and frequency to the brightness value can be seen in **Figure 10**.

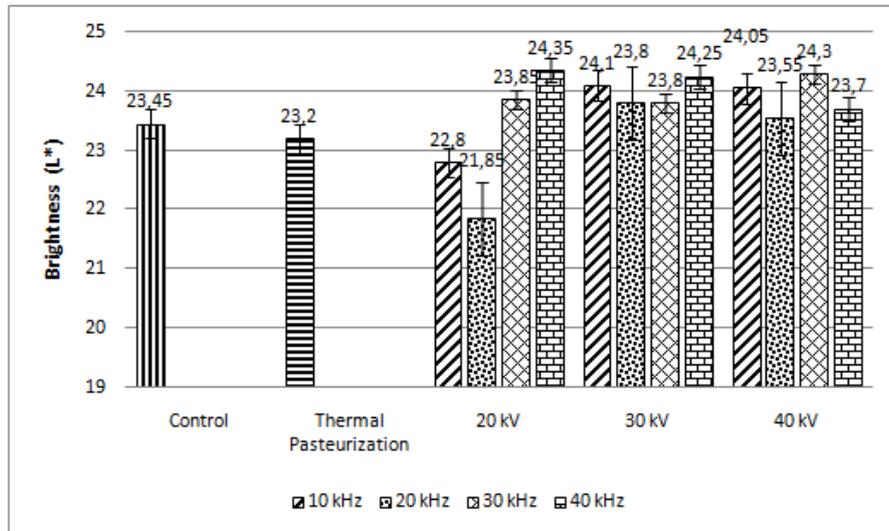


Figure 10. Graph of Voltage Relation (kV) and Frequency (kHz) to Average Brightness (L *) Pineapple Juicy

In Figure 10, there is a fluctuating value based on [2] statement. The increase in brightness occurs due to the variation of the voltage treatment where the particles contained in the product decreases slightly, causing the increase in color and the brightness color change can also be affected by the non-enzymatic browning counter PEF treatment of some enzymes develops thus affecting the brightness level

3.11 Redness Value (a^*)

After the treatment with PEF obtained the largest reddish value at 20 kV at 30 kHz frequency has an average increase of 6.6 and the smallest reddish value at 20 kV at 40 kHz frequency has the smallest average value of 5.8. From the above results it is found that the reddish value is included in the reddish fade category PEF voltage relationship and frequency to the redness value can be seen in **Figure 11.**

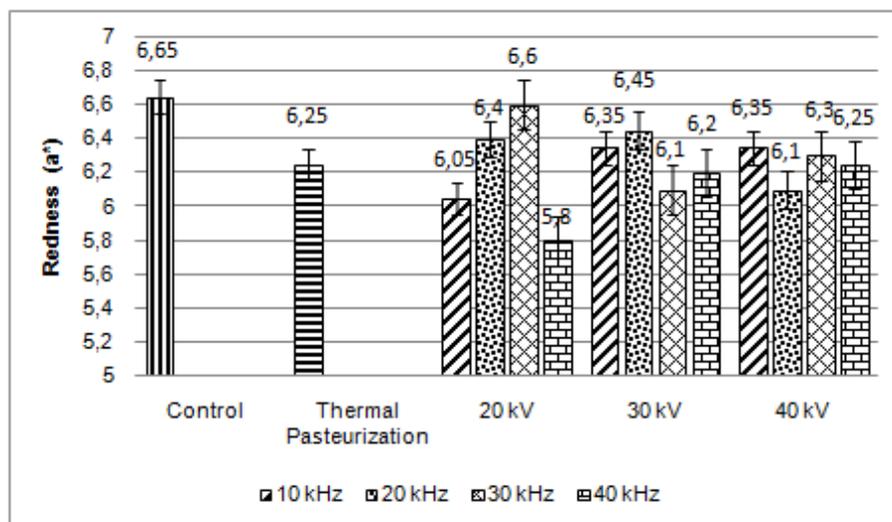


Figure 11. Graph of Voltage Relation (kV) and Frequency (kHz) to mean of Redness (a^*) Pineapple Juicy

Figure 11 shows that the reddish values with different PEF stress treatments have fluctuating values. The existence of fluctuating value in pineapple juice that has been done PEF due to high voltage causes hydrolysis of simple sugars so that the sugar content will go down which in the presence of sugar changes will occur fructose and glucose solubility and form browning process/ browning [4]

3.12 Yellowish Value (b^*)

The value of b^* in pineapple juice treated with PEF has a value of 5.85-7.55. The result of stress and frequency test to yellowish value can be seen in **Figure 12**.

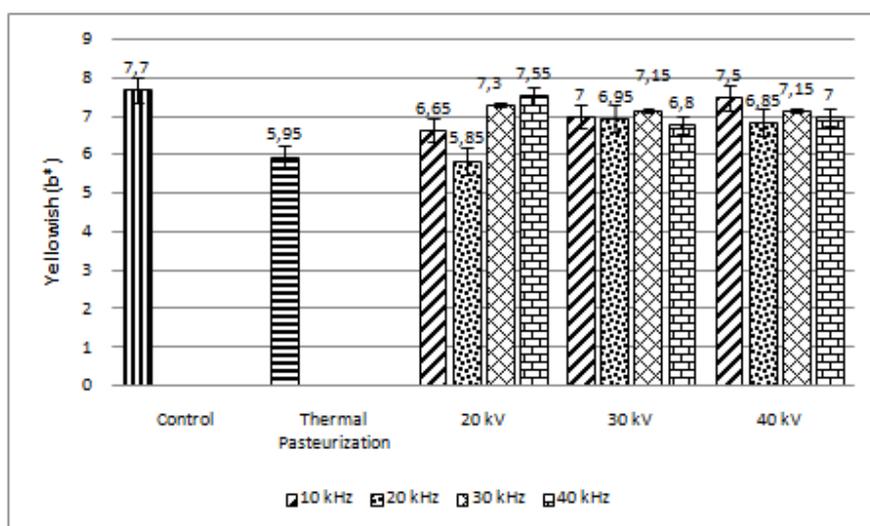


Figure 12. Graph of Voltage Relation (kV) and Frequency (kHz) to mean of Yellowish (a^*) Pineapple Juicy

In **Figure 12**. Shows that According to [2], yellowish values tend to fluctuate. This decline is due to differences in test time from the process of making pineapple juice. There is a decrease in yellowish s due to precipitation so that the yellowish color decreases

CONCLUSION

In the research of pineapple juice with pulsed electric field (PEF) voltage and pulsed electric field (PEF) effect significantly to Total Plate Count (TPC) and absorbance value but no significant effect on total soluble solid, total sugar, viscosity, and color of pineapple juice. The best treatment is a 40 kV (voltage) and 40 kHz (frequency). The best treatment results get TPC is $1,01 \times 10^3$ cfu/mL or 0,94 log cycle with the effectiveness of microbial mortality is 88,5%. The treatment based on the microbial test are at a voltage of 40 kV and a frequency of 30 kHz which Physical and chemical become pH of 3.98, total dissolved solid (TDS) of 6.25 °brix, total sugar of 14,75 % viscosity of 3 Cp, vitamin C of 7.6 mg/100ml, absorbance of 0.67, color on the brightness (L^*) value of 24,05, redness (a^*) of 6.35, and yellowish (b^*) of 7.5.

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