AFSSAAE

Advances in Food Science, Sustainable Agriculture and Agroindustrial Engineering 2022, 5(2), 171-181
ISSN 2622-5921

ORIGINAL RESEARCH Open Access

Physicochemical characteristics of pulsed electrical field–sterilized sugarcane (*Saccharum officinarum* L.) juice with added ginger extract

Arie Febrianto Mulyadi[1*], Sucipto[1], Sumardi Hadi Sumarlan[2], Dina Wahyu Indriani[2] and Rafika Arofatul Lama'ah[1]

[1] Department of Agro-industrial Technology, Faculty of Agricultural Technology, Universitas Brawijaya, Malang, Indonesia
[2] Department of Agricultural Engineering, Faculty of Agricultural Technology, Universitas Brawijaya, Malang, Indonesia

KEYWORDS

Ginger extract
Pulsed electric field
Sugarcane juice
Voltage

ABSTRACT

This study aimed to investigate the effect of the voltage of the pulsed electric field (PEF) and ginger extract concentration on sugar cane juice's physicochemical and organoleptic quality. The experiments were carried out at voltages of 20 kV and 40 kV, and ginger extract concentrations of 2, 4, and 6%. The PEF with 40 kV and 6% ginger extract concentration resulted in the most efficient microbial reduction by 99.54%. Sugarcane juice has a total number of microbes of 3.7×10^3 CFU/ml, antibacterial activity 1.48, pH of 6.26, total solids dissolved of 20.5 °Brix, a viscosity of 4.67 Cp, reducing sugar of 2.17%, brightness of 24.4, redness of 7.17, and yellowness of 8.1. The combination of pulsed electric field and ginger extract addition can preserve the shelf life and maintain sugarcane juice quality. The higher the PEF voltage and ginger extract concentration, the longer the quality of the sugarcane juice can be preserved.

Introduction

The sugarcane production in Indonesia is the world's second highest, at 70.13 tons/ha (Nainggolan, 2003). Some of the problems faced by sugarcane's business and farmers are fluctuations in their profits. This was due to unstable sugar prices and a lack of transparency of the sugar factory in the information of sugarcane yields. Product diversification into sugarcane juice is essential to increase the profits of sugarcane industries and farmers. Usually, sugarcane used for juice used is PS 862 green sugarcane (Sofyan, 2013). PS 862 sugarcane has yellowish-green upright stems, a large diameter and a sugar yield of 9.45±1.51% (Indonesian Sugar Plantation Research Center, 2009).

Sugarcane juice is a refreshing and healthy drink, with a natural energy source containing up to 20% sugar content. This nutritious drink is used for the treatment of heart palpitations, fever, and cough (Thomas, 2007). Sugarcane juice contains a water content of 75-85%, non-reducing sugar (i.e. sucrose) content of 10–21%, reducing sugars (i.e. glucose and fructose) from 0.3 to 3%, organic substances from 0.5 to 1%, and inorganic substances from 0.2 to 0.6% (Siskawardani et al., 2013). Despite its benefits, the sugarcane juice has a short shelf life due to the fermentation by microorganisms. According to Bahar (2005) and Subbannayya et al. (2007), bacteria found in the sugarcane juice including *Escherichia coli*, *Enterobacter* sp., *Proteus mirabilis*, *Proteus vulgaris*, *Klebsiella pneumonia*. *Pseudomonas aeruginosa*, *Staphylococcus aureus*, *Enterobacter spp*, *Citrobacter spp*, *Enterococcus faecalis*, *Acinetobacter spp, and Bacillus subtilis.*

Fresh sugarcane juice gets spoiled soon after extraction due to natural fermentation. Thermal processing methods such as heat pre-treatment (blanching), pasteurization, and ultra-high temperature (UHT). Futhermore, a combination of thermal processing with antioxidant agent can reduce the spoilage and contamination bacteria in sugarcane juice (Özoğlu and Bayındırlı, 2002; Rossi et al., 2003; Mao et al., 2007; Matsui et al., 2007; Jittanit et al., 2011; Karmakar et al., 2011). Thermal pasteurization is often used to extend shelf life nutritional and sensory quality reduction

*Corresponding author
E-mail address: arie_febrianto@ub.ac.id

Received on 28 July 2022, revised on 17 December 2022, accepted on 26 December 2022

(Honig, 2013). Pulsed electric field (PEF) is a non-thermal pasteurization method that inactivates enzymes and microorganisms with a slight effect on the nutritional and sensory of the products (Bi et al., 2013). PEF is one of the emerging techniques to preserve foods, especially liquid ones (such as milk, yogurt, juices, and soups). But, PEF is not suitable for solid foods as itutilizes short electric pulses to destroy the microorganism to preserve the foods. This technology is suitable for pasteurizing heat-sensitive foods (Pal, 2017).

The presence of an antibacterial agent can improve the shelf life of pasteurized food. Ginger extract is one of the natural antibacterial that possess beneficial health and has an attractive taste and aroma. The ginger root contains volatile oils and pungent phenol compounds known as gingerols, sesquiterpenoids, and shogaols (Oboh et al., 2012). Gingerol, a major component of fresh ginger, is unstable and converts to shogaol at high temperatures (Wohlmuth et al., 2005). Gingerol possesses anti-inflammatory, analgesic, antifungal, antibacterial, and antioxidant activities that protect cell/skin against free radicals (Ahmed et al., 2000; Ficker et al., 2003; Masuda et al., 2004; Kim et al., 2005; Park et al., 2008). Secondary metabolites in ginger can inhibit the growth of pathogens, including bacterium of *E. coli, Bacillus subtilis,* and *Staphylococcus aureus,* as well as common spoilage fungi *Neurospora* sp., *Rhizopus* sp., and *Penicillium* sp (Nursal and Juwita, 2006).

Based on the potential improvements in shelf life and product quality of ginger extract addition and PEF pasteurization, this study aimed to investigate the effect of voltages and ginger extract concentrations on the physicochemical and organoleptic quality of sugarcane juice.

Research Methods

Equipment and Materials

A PEF, as shown in Figure 1 (voltage: 20-40 kV, developed by the Laboratory of Mechatronics Engineering and Agro-industry, Universitas Brawijaya) was used to pasteurize the sugarcane juices. Fresh PS 862 green sugarcane was obtained from Tulungagung. Red ginger was purchased from a local traditional market. Distilled water with pH 7, ethanol 96 %, *E. coli* culture, PCA (Plate Count Agar) media, and nutrient agar media were also obtained from the local market.

Ginger Extraction

The red ginger rhizome (500 grams) was cleaned, peeled and washed, then sliced with a thickness of 1–2 mm prior to drying at 50 °C for 12 hours. The dried ginger was crushed using a blender and sieved with 60 mesh sieves. The 600 mL ginger mixture (10 % w/w) e was heated and stirred with a hotplate for 120 minutes at a temperature of 40 °C (extraction digestion method) and centrifuged at 4000 rpm (RCF = 4720 g) for 15 minutes. The supernatant was further filtered using a filter cloth to obtain a red ginger extract and concentrated using a rotary evaporator at 55 °C for 30 minutes.

Sugarcane Juice Preparation

The fresh green sugarcane PS-862 (6 kg) was cleaned and peeled. Sugarcane extraction was done by crusher. The extracted sugarcane juice was filtered through one layer filter cloth.

The Application of Pulsed Electrical Field (PEF) on Sugarcane Juice with Ginger Extract Addition

The 140 mLof sugarcane juices with the 2 (J1), 4 (J2), or 6(J3)% ginger extract was pasteurized by PEF (20 (V1) or 40 (V2) kV voltages) with a frequency of 30 kHz, at 31ºC in the chamber. After PEF treatment for 10 s, 140 mL of sugarcane juice was packaged in sterile vials before analysis.

The observation parameters for sugarcane juice treated by PEF include a total number of microbes with Total Plate Count (TPS) Method as described by Fardiaz (1992) using PCA (Plate Count Agar) and Nutrient Agar. pH, total soluble solids, viscosity (Brookfield viscometer), reducing sugar (Japan Customs Analysis Method), color (AOAC, 1995), and the antibacterial activity inhibitory zone (Kirby-Bauer method). The best treatment was selected by using the Multiple Attribute method (Zeleny, 1982).

Experimental Design

The experimental design used was a randomized factorial design using two factors (the voltages of PEF 20 and 40 kV, and ginger extract concentration of 2, 4, and 6%). Control and treatment samples were prepared in triplicate. Control sample used was pure sugarcane juice without any treatment.

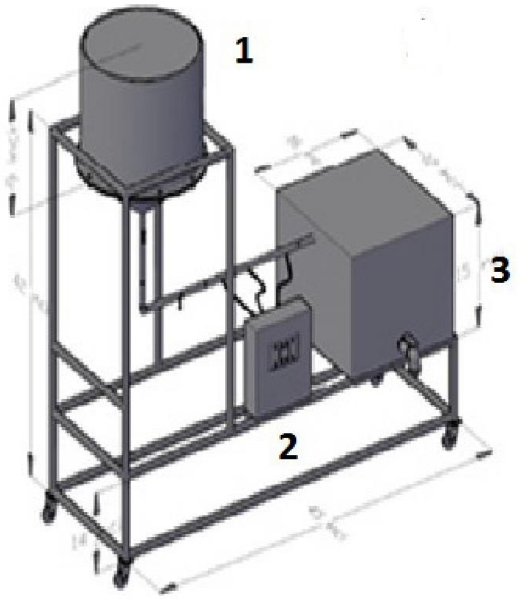

Figure 1. Equipment Series. (1) Input chamber, (2) Electrode series, and (3) Output chamber

The Total Microbial Reduction

The total microbial reduction was calculated using equation below (Sumarlan et al., 2014)::

$$E = \frac{Intial\ microbe\ numbers - final\ microbe\ numbers}{Intial\ microbial\ numbers} \times 100 \quad (1)$$

Where a higher E values indicates better efficacy performance.

Potential Decimal Reduction Time (D)

According to Nisa (2014), the value of decimal reduction time (D) is defined as the time required to reduce or kill the microbes as much as 90% at a constant voltage for the processing of liquid products (juice) with a high-voltage shock technology such as PEF. The D value can be represented on a semi-logarithm graph and depends on the initial microbial numbers (N_o). The final microbial numbers (N) and processing time (t) as shown in the following equations (Ibarz and Barbosa-Cánovas, 2002; Sumarlan et al., 2014):

$$D = -\frac{t}{\log\left(\frac{N}{N_0}\right)} \quad (2)$$

$$Microbial\ reduction = log\left(\frac{N_0}{N}\right) \quad (3)$$

Lethal Rate

The lethal rate is defined as the microorganism death rate per unit of time as a result of high-voltage electrical shock juice. The formula for the lethal rate is (Sumarlan et al., 2014):

$$Slope = \frac{\Delta_y}{\Delta_x} \quad (4)$$

Where y is the number of microbes and x is the treatment period

Results and Discussion

Characteristics of Raw Material

The characteristics of sugarcane are shown in Table 1. Treatment with PEF on sugarcane juice decreased the number of microbes (TPC). It could be due to the use of high voltage results in an electric field that causes the inactivation of organisms (Pal, 2017). In this study, PEF was combined with the addition of the red ginger extract, which serves as a natural antibacterial , thus could further reduced the number of microbes in sugarcane juice. According to Nursal and Juwita (2006), the ginger rhizome contains antimicrobial compounds (such as phenols, flavonoids, terpenoids, and essential oils,) and other classes of bioactive compounds that can inhibit the growth of microbes.

The pH of sugar cane is 6.26, almost the same as other studies of 6.3. TPT from sugarcane raw materials is 20.4 ^{o}Brix greater than other studies (15.5 ^{o}Brix). Reducing sugar from raw materials was 2.17%, which was slightly lower than other studies (3%)

Table 1. Characteristics of raw sugar cane

Parameters	This study	Literatures
TPC (CFU/mL)	3.7 x 10^3	-
Antibacterial Activity (mm)	1.48	-
pH	6.26	6.3***
TPT (^{o}Brix)	20.50	15.5***
Viscosity (Cp)	4.67	-
Reducing sugars (%)	2.17	3%**
Color		
L* (brightness)	24.40	31.33*
a* (redness)	7.43	8.58*
b* (yellowness)	8.10	6.75*

Source: *(Nisa, 2014), ** (Swaminathan, 1995); *** (Siskawardani, Komar and Hermanto, 2013).

Table 2. The mean total number of microbes, DMRT testing, and the total microbial reduction

Treatment		Means (CFU/mL)	DMRT (5%)	Total microbial reduction (%)
Voltage (kV)	Ginger extract Concentration (%)			
20	2	2.42 x 10^5 d	27737.32	69.87
	4	2.09 x 10^5 c	27657.39	74.01
	6	7.43 x 10^4 b	27417.58	90.76
40	2	9.90 x 10^3a	26937.98	98.77
	4	6.43 x 10^3 a	26378.43	99.2
	6	3.70 x 10^3 a	25179.41	99.54

Note: The mean of a total number of microbes, accompanied by the different notation (letters) indicates significantly different with $p<0.05$.

The Total Microbial Reduction

According to Untara (2011), microbes are the most significant cause of inversion because they account for most of the invertase enzyme present, which is capable of breaking down sucrose into reducing sugars such as glucose and fructose. The total number of microbes before treatment was equal to 8.05 x10^5 CFU/mL and after treatment, ranged from 3.7x10^3 to 2.42x10^5 CFU/mL. Analysis of variance (ANOVA) showed the treatments of voltage variation and ginger extract concentration, as well as their interaction, significantly affected the total number of microbes.

Table 2 shows that the results do not meet the standard of microbial contamination of juice according to Standard Nasional Indonesia SNI-01-3719-1995, of 2 x 10^2 CFU/mL (Standard Nasional Indonesia, 1995). Under the regulations of (Food and Drug Supervisory Agency, 2009), treatment voltage of 40 kV and ginger extract concentration of 2%, 4%, and 6% already meets the maximum limit microbial contamination of fruit juice, that is 1.0x10^4 CFU/mL. Electrical shock exposure using PEF can cause ruptures in cell membranes, trigerring discharge from the cells and resulting in the loss of activity of cell metabolism, thus reducing the growth of the organism (Jeyamkondan et al., 2006). The reduction of microorganism number is linear to the voltage, pulse, and pasteurization time (Barbosa-Cánovas et al., 1999). Thus, it can be illustrated that the higher the voltage and frequency used in the pasteurization process, the more significant reduction of microorganisms. This study found that the higher the voltage, the higher the reduction of the total microbial population

Potential Decimal Reduction Time (D) and Lethal Rates

D value and microbial reduction log value can be seen in Table 3. The timed value in PEF treatment with the largest reduction in microbes (voltage of 40 kV and ginger extract concentration of 6%) was 10 seconds. The initial microbial number was 8.05x10^5 CFU/mL and reduced to 3.7x10^3 CFU/mL for the voltage of 40 kV. Thus, able to reduce microbial growth at 2.34 log cycles.

After PEF treatment, the number of microbes is still considered high. This can be caused by the natural characteristics of sugarcane juice that can easily contaminate with microbes. Therefore, it is necessary to pay attention to sanitary equipment, sterile processing and storage conditions. Bacterial contamination of sugarcane juice may occur at different stages such as by contamination of sugarcane, roller drum crusher, collecting vessels, ice added to the juice, hands of the personnel and the filter. Furthermore, sugarcane attracts flies that may contaminate the juice. Education to the vendors and implementation of the standard hygienic protocol may reduce contamination of sugarcane juice (Subbannayya et al., 2007).

The lethal rate calculation results in each treatment of voltages and ginger extract concentrations are shown in Table 3. Electrical shock treatment at 40 kV and 6% of ginger extract concentrations inactivated microbes up to 80.130 (CFU/mL)/sec. The equation of the model of linear equations is as follows:

$$y - y_t = m \times (x - x_t) \quad (5)$$

Where m is the gradient which is the lethal rate.

The graph through the point of (0; 805.00) which is the N_o value from the control treatment was obtained by equation 6:

$$y = 805.000 - 80.130x \quad (6)$$

The use of high voltage on PEF produces an electric field that causes the inactivation of microorganisms. When an electric field is used, the flow of electric current enters the liquid material and is transferred to each solution point due to the presence of molecules in the liquid material (Zhang et al., 1995). The use of PEF with faster pulses and greater electric field strength will affect the intracellular membrane of the nucleus or mitochondria. The faster and stronger the pulse will cause apoptosis (cell death) (Novac et al., 2009). Reina et al. (1998) state that the PEF lethal effect was a function of field strength and treatment time. Higher field strength or longer treatment time resulted in a greater reduction of viable cells.

Antibacterial Activity (Inhibition Zone)

The antibacterial activity was shown by measuring the diameter of the clear zone or inhibition zone in plates of *E. coli* to which sugarcane juices was added with various voltages and ginger extract concentrations. The highest inhibition zone is 1.48 mm by using 6% ginger extract and 40 kV voltage. Analysis of variance (Supplementary Data 1) showed ginger extract concentration significantly affected the size of the inhibitory zone, while the voltage did not affect the inhibition zone. The size of the inhibition zone increased along with the increased red ginger extract concentration added.

The pH Values

Fermentation of sap produces organic acids, causing a decrease in pH (Legaz et al., 2000). Analysis of variance showed that voltage and ginger extract concentration significantly affected pH values of sugarcane juice, as well as the interaction between the two factors. The mean values of pH, along with the results of further DMRT test, can be seen in Table 4.

The control pH was 5.53, after the PEF treatment, the pH value was 6.26. The higher the PEF voltage and ginger extract concentration, the higher (alkaline) the pH value was. The increase in the pH value is presumed due to the antimicrobial in the ginger that can inhibit the action of bacteria in producing acidic conditions (Park et al., 2008). The pH will affect the shelf life because pH will affect the type of microorganisms that will grow. The pH measurement is used as an indicator of sugarcane juice due to the activity of microorganisms, which is characterized by a sour taste, white foam, and slimy (Legaz et al., 2000).

Table 3. D value, microbial reduction log value, and *lethal rates* calculation results

Treatment	**Values TPC (CFU/mL)**	**D(s)**	**Microbial Reduction Log Values (*Log cycle*)**	**Total TPC (CFU/mL)**	***Lethal Rates* (CFU/mL)/sec)**
V1J1	2.42×10^5	19.19	0.52	2.42×10^5	56250
V1J2	2.09×10^5	17.08	0.58	2.09×10^5	59584
V1J3	7.43×10^4	9.66	1.03	7.43×10^4	73067
V2J1	9.9×10^3	5.23	1.91	9.9×10^3	79510
V2J2	6.43×10^3	4.77	2.1	6.43×10^3	79857
V2J3	3.7×10^3	4.28	2.34	3.7×10^3	80130

Table 4. The mean values of pH and results of further DMRT test

Treatments		Mean	DMRT (5%)
Voltage (kV)	Ginger Extract Conc. (%)		
20	2)	6.11[a]	0.0260
	4	6.16[b]	0.0272
	6	6.19[c]	0.0278
40	2	6.23[d]	0.0283
	4	6.25[e]	0.0286
	6	6.26[f]	0.0286

Note: The mean value of pH accompanied by different letter is indicating a significant different between treatments at $p < 0.05$

Total Dissolved Solids (TDS)

Analysis of variance showed ginger extract concentration treatment significantly affected the values of TDS, but it was not significantly affected by the voltage treatment. Overall, TDS tended to decrease. The moisture content in ginger may also affect the value of total dissolved solids. The higher the ginger extract concentration is given to sugarcane juice, TDS would be lower. TDS values are derived from the number of dissolved solids in the ingredients. Ginger contains many dissolved solids, such as organic acids, minerals, proteins, phenols and others.

The concentration treatment of ginger extract showed a significant effect to the value of total dissolved solids, where F_{value} is greater than F_{table} (level 0.05) (Supplementary Data 2), whereas the voltage treatment did not give a significant effect (F_{value} is smaller than F_{table}).

Based on Figure 2, it can be seen that overall TDS tends to decrease. Before the PEF treatment with addition of the ginger extract, the yield of TDS was 22.1°Brix, but after treatment, TPT levels decreased from 20.5 to 21.8°Brix. The higher concentration of ginger extract given to sugarcane juice was parallel to a reduction in the TDS values. The decrease in TDS can be caused by the presence of enzyme effects derived from microbes or that normally already exist in the food. This enzyme enables the occurrence of chemical reactions more quickly depending on the existing enzyme and leads to various changes in the composition of food (Muchtadi, 2010).

Viscosity

The viscosity of sugarcane juice resulting from PEF pasteurization was lower than that of fresh sugarcane juice. Analysis of variance (Supplementary Data 3) showed there were significant differences due to voltage, but ginger extract concentration had no significant effect on viscosity.

The difference in viscosity is presumed due to differences in the amount of the dissolved component. According to Pratama et al. (2012), the higher component of the TDS in a solution may increase the viscosity of the material. The treatment of voltage in PEF causes a decrease in the viscosity value from 7 to 4.33-5.67 Cp. The decrease occurs because of the breakdown of membrane cells due to the stress treatment. This decrease proves that the PEF treatment causes the cell membrane to break, causing the particles in the juice to be suspended. According to Trost (2006), the value of viscosity could increase if the particles (such as fiber, water, and protein complex) present in the juice during processing (bind to pectin. Thus, the viscosity level will increase, wherein pectin tends to be difficult to separate with water. Ginger extract concentration was found to have no significant effect on viscosity.

Reducing Sugar

Reducing sugar results from the hydrolysis of sucrose into inverted sugars, e.g., fructose and glucose. Analysis of variance (Supplementary Data 4) showed that PEF voltage and ginger extract concentration significantly affected reducing sugar, but there was no significant interaction.

The higher the PEF voltage and ginger extract concentration, the lower levels of reducing sugars produced. Low levels of reducing sugars indicate delays in the process of sucrose inversion. The predominant contaminant microorganisms - initially present to invert sugars - that degrade sugars are acid-producing microorganisms that use inverted sugar substrates for growth through fermentation reactions (Mulyadi and Yuni, 2014; Susinggih et al., 2014).

According to Nursal et al. (2006), bioactive compounds in ginger inhibits microbial growth by bacterial cell membrane disruption. Inhibited microbial activity may increase pH and decrease reducing sugars.

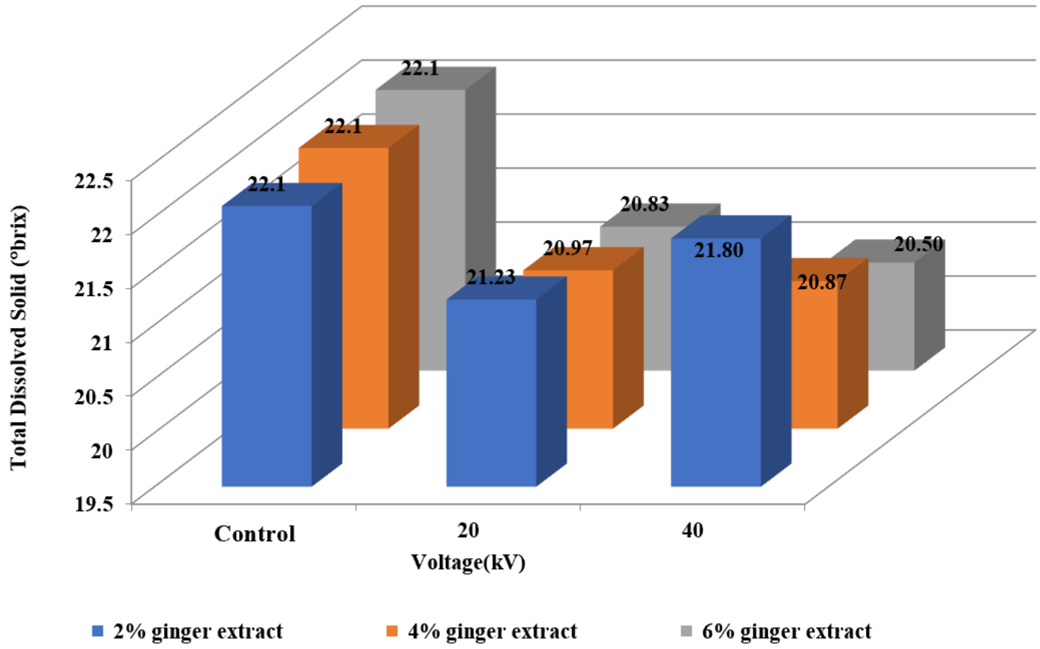

Figure 2. Total dissolved solids of sugar cane juices at different PEF voltages and ginger concentration

Color

The color is one of the criteria for determining consumer acceptance, so it will affect the product's value. The L* parameter expresses the degree of darkness to brightness ranging from 0–100. Analysis of variance showed that the treatments of voltage and the ginger extract concentration significantly affected the value of sugarcane juice color brightness. However, there was no interaction between the two treatments. The higher concentration of ginger extract and the PEF voltage, the brighter the color. Analysis of variance also showed that the treatments of PEF voltage and ginger extract concentrations did not significantly affect the value of the redness of sugarcane juice. The redness of sugarcane juice tended to decrease with the increasing concentrations of ginger extract added. Treatment of ginger extract concentrations significantly affects the value of the yellowness. The value of yellowness in sugarcane juice tended to increase with increased concentrations of ginger extract.

The result of variance analysis (ANOVA) (Supplementary Data 5) showed that the PEF voltage and concentration of ginger extract had a significant effect (α=0.05) on the brightness (L*) of sugarcane juice, but no interaction between the two treatments. The average brightness (L) effect of PEF voltages can be seen in Table 5.

Table 5 shows that the brightness did not influence by PEF voltage. The results indicates that sugarcane with 6% ginger extract possesses the highest brightness, significantly different from those in 2% and 4% concentrations. The brightness of sugarcane juice resulted from PEF pasteurization with various voltages and ginger concentration was ranging from 22.03 to 24.5.

The higher the concentration of ginger extract and the PEF voltages, the brighter the color of the sugarcane juice. The lower the concentration of ginger extract, the darker the color obtained. This was because the sugarcane juice contains a high sugar content which causes the color to darken. Consequently, the concentration of 2% ginger extract has a low brightness.

The redness of sugarcane juice tended to decrease with the concentration of ginger extract (Supplementary Data 6). However, this decrease did not significantly affect the PEF voltage treatment or the ginger extract concentration. The redness of sugarcane juice after treatment ranged from 7.03 to 7.43, with the redness of raw sugarcane juices was 7.2.

Table 5 shows that the highest yellowness was found in the ginger extract concentration of 6%. This result was significantly different from the yellowness in the ginger extract concentration of 2% and 4%. The PEF voltage treatment did not show a significant difference in the yellowness value (the F_{value} was smaller than the F_{table}).

Table 5. The brightness and yellowness of sugarcane juices at different PEF voltages and ginger concentration

Voltage (kV)	Average of the color brightness	LSD (5%)
20	22.87[a]	0.6472
40	23.38[a]	
Ginger extract concentration (%)	**Average of the color brightness**	**LSD (5%)**
2	22.33[a]	0.6472
4	22.58[a]	
6	24.45[b]	
Ginger extract concentration (%)	**Average of yellowness**	**LSD (5%)**
2	7.27[a]	
4	7.47[a]	0.5966
6	8.00[b]	

Note: Average of color brightness and yellowness value accompanied by same letters indicates no significant difference (α = 0.05), each data were obtained from three measurements.

Table 6. Comparison of optimum treatment with control treatment based on microbes and physicochemical parameters

Parameters	Optimum Treatment (V2J3)	Control	Standar Nasional Indonesia *	BPOM**
TPC (CFU/ mL)	$3.7x10^3$	$8.05x10^5$	$2 x10^2$	$1x10^4$
Antibacterial Activity (mm)	1.48	-	-	-
pH	6.26	5.53	4-7	
TDS (°Brix)	20.5	21.1	-	-
Viscosity (Cp)	4.67	7	-	-
Reducing sugars (%)	2.47	3.42	-	-
Color				
Brightness (L)	24.4	22.9	-	-
Redness (a*)	7.17	7.2	-	-
Yelloness(b*)	8.1	7.4	-	-

Note: *(Standar Nasional Indonesia, 1995); ** (Food and Drug Supervisory Agency, 2009).

The Best Treatment

Assessment of the best treatment included microbial and physicochemical parameters. Combination treatments of 40 kV voltage and 6% ginger extract concentration had the lowest effectiveness index value. Both are based on microbial and physicochemical parameters and based on organoleptic parameters. Thus, it was chosen as the best treatment. A comparison of the best and control treatments based on microbial and physicochemical and organoleptic parameters is shown in Table 6.

Conclusion

Treatment with PEF voltages and ginger extract concentration influenced the decreasing microbial population. Applying PEF for sugarcane juice at 40 kV voltage and 6% ginger extract concentrations addition was the best treatment in reducing the microbial population by 99.54% or by 2.34 log cycles. The characteristics of the sugarcane juice produced from the best treatment were the total microbes of $3.7x10^3$ CFU/mL with the antibacterial activity of 1.48 mm. pH of 6.26. TDS of 20.5°Brix, viscosity of 4.67 Cp, reducing sugars of 2.17%, the brightness of 24.4, redness of 7.17, and yellowness of 8.1, respectively.

Declarations

Conflict of interests The authors declare no competing interests.

References

Ahmed, R. S., Seth, V., Pasha, S. T., and Banerjee, B. D. (2000) 'Influence of dietary ginger (*Zingiber officinales* Rosc) on oxidative stress induced by malathion in rats', *Food and Chemical Toxicology*, 38 (5), pp. 443–450

AOAC (1995) *Official Methods of Analysis*. 16th edn. Washington: Association of Official Analytical Chemists.

Bahar, E. (2005) 'Uji bakteriologis terhadap minuman segar air tebu yang beredar di Pasar Raya Padang (Bacteriological testing of fresh sugar cane juice circulating in Padang Raya supermarket)', *Majalah Kedokteran Andalas*, 29, pp. 1–9. [In Indonesian]

Barbosa-Cánovas, GV., Pothakamury, UR., Gongora-Nieto, M.M., and Swanson, B.G. (1999) *Preservation of foods with pulsed electric fields*. San Diego: Academic Press.

Bi, X., Liu, F., Rao, L., Li, J., Liu, B., Liao, X., and Wu, J. (2013) 'Effects of electric field strength and pulse rise time on physicochemical and sensory properties of apple juice by pulsed electric field', *Innovative Food Science & Emerging Technologies*, 17, pp. 85–92

Fardiaz, S. (1992) *Mikrobiologi pangan* (Food microbes). Bogor: Institut Pertanian Bogor [In Indonesian]

Ficker, C., Smith, M. L., Akpagana, K., Gbeassor, M., Zhang, J., Durst, T., Assabgui, R., and Arnason, J. T. (2003) 'Bioassay-guided isolation and identi?cation of antifungal compounds from ginger', *Phytotherapy Research*, 17 (8), pp. 897–902

Food and Drug Supervisory Agency (2009) *Pedoman kriteria cemaran pada pangan siap saji dan pangan industri rumah tangga* (Guidelines for contamination criteria in ready-to-eat food and home industry food). Jakarta: Directorate of Food Product Standardization [In Indonesian]

Harijani, N., Ernawati, E., and Suwarno, S. (2011) 'Pemanfataan sari rimpang jahe (*Zingiber officinale*) sebagai antibakterial alami pada susu pasteurisasi berdasarkan penurunan jumlah bakteri Escherichia coli (Utilization of ginger rhizome extract (*Zingiber officinale*) as a natural antibacterial in pasteurized milk based on the decrease in the number of *Escherichia coli* bacteri)', *Jurnal Veterinaria*, 4 (3), pp. 193–196 [In Indonesian]

Honig, P. (2013) *Principles of sugar technology*. New York: Elsevier Publishing Company.

Ibarz, A., & Barbosa-Cánovas, G. V. (2002). Unit operations in food engineering. CRC press.

Indonesian Sugar Plantation Research Center (2009) *Deskripsi tebu varietas Ps 862* [Description of sugarcane varieties PS 862] [online]. Available at https://id.scribd.com/doc/27523271/Deskripsi-Tebu-Varietas-Ps-862 (Accessed: 10 February 2019) [In Indonesian]

Jeyamkondan, S., Jayas, D. S., and Holley, R. A. (2006) *Pasteurization of foods by pulsed electric fields at high voltages*. Canada: Department of Biosystem Engineering and Food Science Department, Manitoba University [In Indonesian]

Jittanit, W., Wiriyaputtipong, S., Charoenpornworanam, H., and Songsermpong, S. (2011) 'Effects of varieties, heat pretreatment and UHT conditions on the sugarcane juice quality', *Chiang Mai Journal of Science*, 38 (1), pp. 116–125

Karmakar, R., Ghosh, A. K., and Gangopadhyay, H., (2011) 'Effect of pretreatments on physico-chemical characteristics of sugarcane juice', *Sugar Technology*, 13, pp. 47–50

Kayalvizhi, V., Pushpa, A. J. S., Sangeetha, G., and Antony, U. (2016) 'Effect of pulsed electric field (PEF) treatment on sugarcane juice', *Journal of Food Science and Technology*, 53 (3), pp. 1371–1379

Kim, E. -C., Min, J. -K., Kim, T. -Y., Lee, S. -J., Yang, H. -O., Han, S., Kim, Y. -M. and Kwon, Y. -G. (2005) '[6]-Gingerol, a pungent ingredient of ginger, inhibits angiogenesis in vitro and in vivo', *Biochemical and Biophysical Research Communications*, 335 (2), pp. 300–308

Legaz, M. E., de Armas, R., Barriguete, E., and Vicente, C. (2000) 'Binding of soluble glycoproteins from sugarcane juice to cells of *Acetobacter diazotrophicus*', *International Microbiology: The Official Journal of the Spanish Society for Microbiology*, 3 (3), pp. 177–182

Mao, L. C., Xu, Y. Q., and Que, F. (2007) 'Maintaining the quality of sugarcane juice with blanching and ascorbic acid', *Food Chemistry*, 104 (2), pp. 740–745

Masuda, Y., Kikuzaki, H., Hisamoto, M., and Nakatani, N. (2004) 'Antioxidant properties of gingerol related compounds from ginger', *BioFactors*, 21 (1–4), pp. 293–296

Matsui, K. N., Granado, L. M., de Oliveira, P. V., and Tadini, C. C. (2007) 'Peroxidase and polyphenol oxidase thermal inactivation by microwaves in green coconut water simulated solutions', *LWT - Food Science and Technology*, 40 (5), pp. 852–859

Muchtadi, T.R. (2010) *Teknologi proses pengolahan pangan* (Food processing technology). Bandung: Alfabeta [In Indonesian]

Mulyadi, A. F. and Yuni, H. (2014) 'Studi proses pengolahan pasta mangga podang urang (*Mangifera Indica L.*): Kajian konsentrasi dekstrin dan metode pengawetan termal (Study of mango podang urang pasta processing process (*Mangifera indica* L.): Study of dextrine concentration and thermal preservation method)'. Undergraduate thesis. Universitas Brawijaya, Malang [In Indonesian]

Nainggolan, K. (2003) 'Kebijakan gula nasional dan persaingan global' (National sugar policy and global competition)', *Artikel Agrimedia*, 10, pp. 52–65 [In Indonesian]

Nisa, F. F. (2014) 'Pengaruh lama dan suhu pemasakan terhadap kualitas sirup tebu hijau (Effect of cooking time and temperature on the quality of green sugarcane syrup)'. Undergraduate thesis. Universitas Brawijaya, Malang [In Indonesian]

Novac, B. M., Sarkar, P., Smith, I. R., Whittow, W., and Greenwood, C. (2009) 'An innovative and non-invasive technology for PEF food processing', *IEEE Pulsed Power Conference, 2009*, pp. 737–741

Nubhakty, O. (2010) 'Pasteurisasi non thermal teknologi pulsed electric fields (PEF) untuk inaktifasi *Staphylococcus aureus* pada sari buah tomat (Pulsed electric fields (PEF) non-thermal pasteurization for the inactivation of *Staphylococcus aureus* in tomato juice)'. Undergraduate Thesis. Universitas Brawijaya, Malang [In Indonesian]

Nurhidajah, N. (2010) 'Aktivitas antibakteri minuman fungsional sari tempe kedelai hitam dengan penambahan ekstrak jahe' (Study of antibacterial activity functional drinks of black soybean tempe with addition ginger extract)', *Jurnal Pangan dan Gizi*, 1 (2), pp. 11–19 [In Indonesian]

Nursal, S. W., and Juwita, W. S. (2006) 'Bioaktifitas ekstrak jahe (*Zingiber officinale* Roxb.) dalam menghambat pertumbuhan koloni bakteri *Escherichia coli* dan *Bacillus subtilis* (The bioactivity of ginger extract (*Zingiber officinale* Roxb.) In inhibiting the growth of *Eschericia coli* and *Bacillus subtilis* colonies)', *Jurnal Biogenesis*, 2 (2), pp. 64–66 [In Indonesian]

Oboh, G., Akinyemi, A. J., and Ademiluyi, A. O. (2012) 'Antioxidant and inhibitory effect of red ginger (*Zingiber officinale* var. Rubra) and white ginger (*Zingiber officinale* Roscoe) on Fe^{2+} induced lipid peroxidation in rat brain in vitro', *Experimental and Toxicologic Pathology*, 64 (1–2), pp. 31–36

Özoğlu, H., and Bayındırlı, A. (2002) 'Inhibition of enzymic browning in cloudy apple juice with selected antibrowning agents', *Food Control*, 13 (4–5), pp. 213–221

Pal, M. (2017) 'Pulsed electric field processing: an emerging technology for food preservation', *Journal of Experimental Food Chemistry*, 3 (2), pp 1-2

Panjaitan, E. N., Saragih, A., and Purba, D. (2012) 'Gel formulation from red ginger rhizome extract (*Zingiber officinale* Roscoe)', *Journal of Pharmaceutics and Pharmacology*, 1, pp. 9–20

Park, M., Bae, J., and Lee, D. S. (2008) 'Antibacterial activity of [10]-gingerol and [12]-gingerol isolated from ginger rhizome against periodontal bacteria', *Phytotherapy research: PTR*, 22 (11), pp. 1446–1449

Pratama, S. B., Wijana, S., and Mulyadi, A. F. (2012) 'Studi pembuatan sirup tamarillo (kajian perbandingan buah dan konsentrasi gula)' [Study of tamarillo syrup making (Study of fruit comparison and sugar concentration), *Industria: Jurnal Teknologi dan Manajemen Agroindustri*, 1 (3), pp. 181–194 [In Indonesian]

Reina, L. D., Jin, Z. T., Zhang, Q. H., and Yousef, A. E. (1998) 'Inactivation of *Listeria monocytogenes* in milk by pulsed electric field', *Journal of Food Protection*, 61 (9), pp. 1203–1206

Rossi, M., Giussani, E., Morelli, R., Lo Scalzo, R., Nani, R. C., and Torreggiani, D. (2003) 'Effect of fruit blanching on phenolics and radical scavenging activity of highbush blueberry juice', *Food Research International*, 36 (9–10), pp. 999–1005

Siskawardani, D. D., Komar, N., and Hermanto, M. B. (2013) 'Pengaruh konsentrasi Na-CMC (Natrium– Carboxymethyle Cellulose) dan lama sentrifugasi terhadap sifat fisik kimia minuman asam sari tebu (*Saccharum officinarum* L.)' (Effect of concentration of NaCMC (Sodium Carboxymethyle Cellulose) and length of centrifugation on the chemical physical properties of sugarcane juice (AST) (*Saccharum officinarum* L)), *Jurnal Bioproses Komoditas Tropis*, 1 (1), pp. 54–61 [In Indonesian]

Sofyan, A.R. (2013) 'Kajian analisa kelayakan pengembangan usaha dengan melakukan diversifikasi produk olahan tebu di CV. Kurnia Agung (Study of feasibility analysis of business development with product diversification of processed sugarcane at CV Kurnia Agung)'. Undergraduate Thesis. Universitas Brawijaya, Malang [In Indonesian]

Standar Nasional Indonesia (1995) *Fruit juice*. Jakarta: Dewan Standarisasi Nasional (DSN). [In Indonesian]

Subbannayya, K., Bhat, G. K., Shetty, S., and Junu, V. G. (2007) 'How safe is sugarcane juice?', *Indian journal of medical microbiology*, 25 (1), pp. 73–74

Sumarlan, S. H., Liani, R. D. A., Yulianingsih, R. and Indriani, D. W. (2014) 'Pengaruh Tegangan dan Frekuensi Terhadap Karakteristik dan Penurunan Jumlah Mikroorganisme Sari Buah Belimbing (*Averrhoa carambola L*) menggunakan pulsed electric field (PEF) (Voltage and frequecy effect to characteristic and amount of microorganism of starfruit extract (*Averrhoa carambola* L) using Pulsed Electric Field (PEF))', *Jurnal Teknologi Pertanian*, 15 (1), pp. 47–58 [In Indonesian]

Susinggih, W., Mulyadi, A. F. and Theresia, D. T. S. (2014) 'Pembuatan permen jelly dari buah nanas (*Ananas comosus L*.) subgrade: Kajian konsentrasi karagenan dan gelatin (Making jelly candy from subgrade pineapple (*Ananas comosus* L.): Study of carrageenan and gelatin concentrations)'. Undergraduate thesis. Universitas Brawijaya, Malang [In Indonesian]

Swaminathan, MS. (1995) *Food science, chemistry and experimental foods*. Bangalore: Bangalore Print & Publishing Company.

Thomas, ANS. (2007) *Tanaman obat tradisional* (Traditional medicinal plants). Yogyakarta: Kanisius. [In Indonesian]

Trost, E.G. (2006) *Protein beverages - A healthy alternative* [online]. Available at http://www.ameft.de (Accessed: 20 February 2015).

Untara, B. (2011) 'Pengaruh acid (buffer sucrose dan aktivitas enzim invertase selama penyimpanan tebu pasca panen buffer sucrose carboxyl benzene (kajian lama sucrose) sucrose) terhadap jumlah mikroorganisme penunda (Effect of carboxyl benzene and monounsaturated fatty acid (sucrose buffer) on the number of microorganisms and activity of the invertase enzyme during post-harvest sugarcane storage (Study of delay time and sucrose buffer concentration)'. Undergraduate Thesis. Universitas Brawijaya, Malang [In Indonesian]

Wohlmuth, H., Leach, D. N., Smith, M. K., and Myers, S. P. (2005) 'Gingerol content of diploid and tetraploid clones of ginger (*Zingiber officinale* Roscoe)', *Journal of Agricultural and Food Chemistry*, 53 (14), pp. 5772–5778 [In Indonesian]

Zeleny, M. (1982) *Multiple criteria decision making*. New York: McGraw-Hill.

Zhang, Q., Barbosa-Cánovas, G. V., and Swanson, B, G. (1995) 'Engineering aspects of pulsed electric field pasteurization', *Journal of Food Engineering*, 25 (2), pp. 261–281