Corona discharge development and its application to eliminate microorganism in raw milk

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Abstract. Raw cow's milk or fresh milk is a natural food with a complete nutrients which provide many benefits for human health. Raw milk also provides almost ideal media for various microorganisms to grow rapidly that can harm human digestion, or make damages the milk itself. In attempt to investigate an appropriate processing technology as an alternative of thermal pasteurization, we developed non thermal corona discharge to eliminate total number of various microorganisms in milk. The generated corona discharge used 7 pins to plate surface configuration. With a distance 15 mm between the electrodes, the applied voltage of 6.48 kV by a homemade high voltage AC power supply yields in corona discharge that has temperature lower than 30°C after 8 minutes operation. The time dependent effects of the implementation of this discharge to raw milk were carried out at time interval 2, 4 and 8 minutes. It was found that there was three different types of bacteria colony morphology in the microorganism population of raw milk. The microorganism counts were decrease for 2 and 4 min corona treatments. However, when the corona treatment was done in 8 min, the total number of microorganism increased significantly. Although the corona discharge shows the potential benefits in milk decontamination processing at low temperature, more detailed study should be carried out to confirm the suitable in real application including the nutrient composition before and after treatment.

Keywords: Non-thermal plasma, corona discharge, raw milk, microorganism population

1. Introduction

Raw cow's milk or fresh milk is a natural food that is rich in complete nutrients such as protein, fat, minerals, vitamins and bioactive substances which provide many benefits for human health. On the other hand, fresh milk also provides nutrients for various microorganisms that can harm human digestion, or damage the milk itself. With good nutritional content, raw milk might be an ideal media...
for the growth of pathogenic microorganism causing short shelf life of the milk if it is not handled properly [1]. Therefore, an appropriate processing technology is needed so that the shelf life of milk becomes longer [2].

Generally, people treat raw milk by a process called pasteurization. Pasteurization is a prevalent technique to eliminate microorganism population in raw milk. However, it has been observed that pasteurization heat treatment could alter the milk’s chemical composition (proteins, lipids, and carbohydrates) [3]. According to the International Dairy Federation, pasteurization process can be carried out at 63 °C for 30 minutes or 72 °C for 15 seconds as the minimum time-temperature combinations [4] to extend the shelf life of the milk. In Indonesia, the average shelf life of pasteurized milk is around 5 up to 7 days [5]. Another treatment to exterminate the microorganisms contained in raw milk is sterilization. Sterilization is a process to eradicate microorganisms to their spores, which are contained in raw milk. This process is done by heating the raw milk in air tight containers to temperature of 105 to 120 °C, for 10 to 40 minutes with the aim to produce long life milk by destruction of microorganisms [6]. All the processes mentioned above are generally known to be able to effectively eliminate populations of microorganisms in raw milk, however, because they are carried out under thermal conditions it will be accompanied by the decreasing of nutritional content of the milk. Therefore, many researchers are currently conducting many researches in developing non thermal-based alternative technology for processing the raw milk including by using non thermal plasma technology.

Plasma is simply defined as ionized gas and is known as the fourth material phase after the solid, liquid, and gas phases. Gas becomes plasma when the addition of heat or energy causes a large number of atoms to release some or all of the electrons. Plasma technology began to be applied in the industrial, medical, biomedical and agriculture sectors [7]. Corona incandescent discharge plasma is a type of non-thermal plasma and is a source of ions, electrons and free radicals. It has been applied in nitrogen lasers, ionization, ozone making, and is also applied as a sterilization system [8].

In the present study, we developed non thermal corona discharge with 1, 4 and 7 pins-to-surface configuration, powered by a homemade high voltage AC power supply. The developed corona discharge was employed for raw milk decontamination process in which the influence of the corona treatment time was investigated towards the total counts of microorganism colonies. The operating temperature of the corona discharge was intended as lower than 35 °C in order to be suitable for treating thermal sensitive material such as raw milk.

2. Experimental

2.1. Corona Discharge Development

Non-thermal corona plasma discharge development was performed by using stainless pins embedded in the board, start from using 1 pin up to 7 pins. The configuration of using 7 pins can be seen at the Figure 1. The utilization of multiple pins was intended to widen the covering area of the corona. Those pins were connected each other and was used as a positive electrode. Thin aluminum (65×65 mm) was connected to the ground. A homemade high voltage AC power supply was employed to generate the corona in between those electrodes. The distance between the pin and aluminum surface and applied voltage were adjusted to get the optimum glow light of the corona discharge.

2.2. Exploring Corona for Raw Milk Processing

The schematic diagram in applying the developed corona discharge for raw milk processing is exhibited in Figure 2. Raw milk was obtained from a local farm in Bogor, Indonesia. Samples of 3 ml of raw milk were placed on the aluminum surface before corona irradiation. Corona discharge was used to treat the raw milk by various treatment times to understand its influence to eliminate the microorganisms in milk. After getting corona irradiation, 0.1 ml treated milk sample was taken to a serial dilution up to 10^6 in order to calculate the number of microorganism colonies. The total number of microorganism population was monitored by total plate count (TPC) method using the pour-plate
techniques. The plates were then incubated at 37 °C for 48 hours. The microorganism colonies were count and the yields were expressed in CFU/ml.

![Figure 1](image1.png)  
**Figure 1.** Configuration of pins on the board

![Figure 2](image2.png)  
**Figure 2.** Schematic diagram corona discharge for raw milk processing.

3. Result and Discussion

3.1 Non-thermal Corona Discharge Development

The corona discharge can be defined as an electrical discharge caused by the ionization of air surrounding between two electrodes powered by high voltage. In many applications, usually corona discharge is generated by using pin to plate surface configuration. In this study we tried to make a corona discharge with 1 pin, 4 pin and 7 pin configurations that connected to the positive pole of the power supply and aluminum plate surface that connected to the negative pole. The image of all configurations to generate violet blue corona discharge can be seen in Figure 3. From the measurement results of applied voltage by using oscilloscope, it was found that the increasing number of pins installed on the board results in a decrease in applied voltage. Each measured applied voltage for the use of 1 pin, 4 pin and 7 pin is 8.56 kV, 8.20 kV and 6.48 kV. Observation towards the temperature of the corona discharge shows that the corona from all configuration were still lower than temperature of 30°C, as captured from thermal imaging camera FLIR-TG 165. Considering the wider covered area, we therefore were using the corona discharge with 7 pins arrangement for the application in raw milk processing. The voltage waveform of this 7 pins corona discharge is shown in Figure 4.

![Figure 3](image3.png)  
**Figure 3.** Corona discharge with (a) 1 pin, voltage: 8.56 kV; (b) 4 pins, voltage: 8.20 kV; and (c) 7 pins configuration, voltage: 6.48 kV
3.2 Exploring Corona Discharge for Milk Processing

In this present study the developed non thermal corona discharge was applied to eliminate microorganism population contained in raw milk. The influence of plasma corona treatment time on number of microorganism colonies, measured in CFU/ml is depicted in Figure 5. The representative picture of the microorganism colonies of the non-treated and corona treated in various time after incubation can be seen in Figure 6. From that figure, plasma corona treatment only gave a slightly decrease to the number of microorganism colonies in raw milk both for 2 min and 4 min treatments. This result is unexpected because some findings from other research study say that a 3 minutes corona treatment was enough to make the population of bacteria to decrease by 54% [9].

Differences in system and plasma corona parameters might be the ones of the reasons. In additional, the use of 7 pins which causes a decrease in applied voltage compared to the use of 1 pin can also be another cause. It is known that a decrease in applied voltage will result in lower degree of ionization, thus produce fewer reactive species during contacted with milk surface. Hence, the efficiency of the corona discharge in eliminating microorganisms in milk turned to decrease. Even more surprising is when the corona treatment time was increased to 8 minutes, instead of further reducing the microorganisms population, the result makes the microorganisms population increased significantly.
Figure 6. Microorganism population in raw milk treated with corona in various times: (a) 0 (untreated), (b) 2 minutes, (c) 4 minutes, and (d) 8 minutes

In this experiment, we found three different types of bacteria colony morphology in the microorganism population of raw milk (Figure 6). Colony morphology includes color, opacity, shape, smooth and elevation. First bacteria colony (refer as C1) was milky-white color, circle, opaque, smooth, and convex. Second bacteria (refer as C2) colony was yellow, circle, opaque, smooth, and convex. While, the third colony (refer as C3) was a small colony with milky-white color, round shape, opaque, and smooth. Our observation showed a reduction of colony number of C1 and C2 after plasma treatment, irrespective to various time. Contaminant bacteria in raw milk are divided into pathogenic (i.e., *Escherichia coli*, *Staphylococcus aureus*, and *Salmonella* sp.) and spoilage bacteria (i.e., *Bacillus* sp., and *Micrococcus* sp.) [10]. Therefore, more detail investigation on the effect of non-thermal corona plasma in various raw’s milk contaminant bacteria species will be required. Each bacteria species may show different sensitivity due to their physiological properties.

4. Conclusion
In this study, we developed corona discharge with multiple pins (7 pins) to plate surface configuration, powered by a homemade high voltage AC power supply. With the applied voltage of 6.48 kV at a distance 15 mm between the electrodes violet blue light of corona discharge can be generated and the temperature of the discharge was found lower than 30°C after 8 minutes operation. Application of the developed corona discharge for raw milk decontamination processing was carried out in various treatment time. The raw milk was found to mainly consist of three types of microorganism colonies. It was found that the microorganism colonies were decreased after 2 min and 4 min corona treatment. However, corona treatment for 8 min results in increasing the colonies significantly. More investigations should be conducted to clarify this preliminary finding in order to understand the impact of the corona towards each of the three types of bacteria in raw milk and also on the nutrient composition of the milk.

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References
[1] Eniza Saleh 2004 Dasar pengolahan susu dan hasil ikutan ternak *USU Digital Library* 1-31.
[2] Muchamad Saiful Rizal, Enny Sumaryati, Suprihana 2016 The effect of time and temperature sterilization on the cow milk chocolate flavour *Jurnal Ilmu-ilmu Pertanian “Agrika”* 10 20-30.
[3] İbilge Saldamlı, Eren Numanoğlu, Ali Topçu 2006 Proteolysis and storage stability of UHT
milk produced in Turkey *International Dairy Journal* 16 633-638.

[4] Harley Juffs, Hilton Deeth 2007 Scientific Evaluation of Pasteurisation for Pathogen Pasteurisation for Pathogen Products, New Zealand: Food Standards Australia New Zealand.

[5] Novita Dewi Kristanti 2017 The effect of pasteurization milk storage to quality Microbe Thermoduric and chemical properties *Jurnal Ilmu dan Teknologi Hasil Ternak* 12 1-7.

[6] Tri Yuni Hendrawati, Suratmin Utomo 2017 Optimasi suhu dan waktu sterilisasi pada kualitas susu segar di kabupaten Boyolali *Jurnal Teknologi* 9 97-101.

[7] Tuhu Agung R., Hanry Sutan Winata 2011 Pengolahan air limbah industri tahu dengan menggunakan teknologi plasma *Jurnal Ilmu Teknik Lingkungan* 2 19-28.

[8] Muhammad Nur 2011 Fisika Plasma dan Aplikasinya, Semarang: Badan Penerbit Universitas Diponegoro Semarang.

[9] C. Gurol, F.Y. Ekinci, N. Aslan, M. Korachi 2012 Low Temperature Plasma for decontamination of E. coli in milk. *International Journal of Food Microbiology* 157, 1-5.

[10] Suwito W. 2010 Bakteri yang sering mencemari susu: Deteksi, patogenesis, epidemiologi, dan cara pengendaliannya *Jurnal Litbang Pertanian* 29(3) 96-100.