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DEVELOPMENT OF OZONE GENERATOR MINI WITH DDBD (DOUBLE DIELECTRIC BARRIER DISCHARGE) TECHNOLOGY AT ATMOSPHERIC AIR PRESSURE

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ABSTRACT

Pesticide residues in fruits and vegetables pose a danger to human health if consumed for a certain period. This requires appropriate technology for household scale and is environmentally friendly. Ozone is a strong oxidizing agent capable of degrading pesticide residues in fruits and vegetables. Ozone is a green chemical compound because it is environmentally friendly and does not produce harmful derivative compounds. A mini ozone generator with DBD technology has been successfully developed. The DDBD reactor is made of Pyrex glass with a length of 11 cm and an outer diameter of 4 cm. The reactor uses electrodes made of copper plates. The outer electrode is 13 cm long and 5 cm wide, while the inner electrode is 10 cm long and 5 cm wide. The mini ozone generator is optimized using high voltage AC pulses whose pulse frequency can be varied from 30 to 60 Hz with 10 Hz intervals. The free air flow rate was varied at 0.2 – 0.8 lpm with an interval of 0.2 lpm. The optimum ozone production of 480 mg/l was obtained at a voltage setting of 2.8 kV, a frequency of 50 Hz, and a flow rate of 0.2 lpm. In this setting, the DDBD reactor consumes 9.32 watts of power. The development of mini ozone generator technology has the potential to be applied on a household scale because of the small reactor size and low power consumption.

Keywords: DDBD; ozone generator; ozone; pulse frequency

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INTRODUCTION

Horticultural commodities, especially fruits and vegetables, have become daily consumption items. Many fruits and vegetables consumed are believed to be healthy and benefit the body. However, fruits and vegetables also have the potential to be harmful due to the presence of pesticide residues [1]. These pesticide residues arise due to the use of pesticides by farmers in the agricultural sector and post-harvest so that their products are protected from pests and look attractive. These pesticide residues can last quite a long time and enter the human food network and accumulation over a certain period can cause health problems [2]. Several researchers have stated in their studies that among horticultural commodities that were found to contain pesticide residues more than the minimum residue threshold were broccoli and chilies. [1]Amilia et al. found that the pesticide residue content in broccoli in West Bandung Regency exceeded the minimum residue threshold of 2.00 parts per million (ppm). In chili, Asgar et al.,[3] also found a pesticide residue content of 2.4 ppm with chili raw materials from farmers in Brebes Regency. Munarso & Broto [4], also found that pesticide residues in cabbage, carrots, and tomatoes from Malang and Cianjur were 7.4 parts per billion (ppb), 10.6 ppb, and 7.9 ppb, respectively.

Washing fruits and vegetables using ozone water is an effective and environmentally friendly way to reduce pesticide residues. Ozone water will oxidize pesticide compounds that are still attached to the surface of vegetables. The chain of pesticide compounds is broken by ozone. Ozone which is unstable and non-selective will bind all the compounds around it into new simpler compounds so that pesticide residues are reduced and meet the allowed minimum residue threshold. Pesticide residues of the profenofos, chlorpyrifos, and malathion groups have been confirmed to decrease by several researchers [3,5,6]. The development of ozone generator technology to maintain food quality has been carried out by PT. Dipo Technology Semarang. The ozone generator technology used is based on a single DBD (Dielectric Barrier Discharge) adapted to high-capacity cold storage. This technology has been proven to be able to maintain the freshness and quality of vegetables in the form of maintaining their nutritional content [7,8]. Alternative ozone production can be produced using DBD and DDBD (Double Dielectric Barrier Discharge) technology. Ozone production is affected by operating voltage, flow rate, input gas, voltage pulse frequency, and reactor configuration. The operating voltage is directly proportional to the ozone generated. The high voltage provides sufficient energy for the dissociation of oxygen molecules and the formation of ozone. While the source of oxygen gas will produce higher ozone production than ordinary air. The greater gas flow rate causes the residence time in the reactor to be short, which results in low ozone production [9,10].

This research is the development of ozone generator technology which is expected to solve the problem of pesticide residues on vegetables and fruit on a household scale. Household ozone generators are usually small in size, low power consumption and portable. The development of this ozone generator uses a small DDBD reactor to obtain a generator that is small, portable and has low power consumption. In this research, the influence of voltage pulse frequency on the working area for ozone production, the influence of air flow rate on ozone concentration, the influence of voltage on the ozone formation process and the analysis of the power consumption required by the DDBD reactor were also studied.

METHOD

Tools and materials

This study uses a pulsed AC high-voltage source produced by PT Dipo Technology which can vary the frequency of the voltage pulse. The voltage pulse frequency is adjusted with the help of the GW INSTEK GDS 1102-U oscilloscope. AC high voltage was measured using a SANWA CD 772 digital multimeter connected to the SEW PD-28 1000x high voltage probe. Electric current was measured using Kyoritsu KEW SNAP 2433 amperage pliers. The gas source uses a Resun LP-20 air pump and the flow rate is regulated using a WIEBROCK flowmeter. The double-barrier reactor (Double Dielectric Barrier Discharge

– DDBD) is made of Pyrex glass with a length of 11 cm and a diameter of 4 cm, copper plates are used as the inner and outer electrode materials with a length of 4.7 and 5 cm, respectively (figure 1). The outer electrode is 13 cm long and 5 cm wide, while the inner electrode is 10 cm long and 5 cm wide. Ozone concentration was measured using the titration method, the material used was Potassium Iodide Analysis (KI) EMSURE and the titrant Sodium Thiosulfate. Titration using a GILSON P-10 micropipette and a HERMA Erlenmeyer.

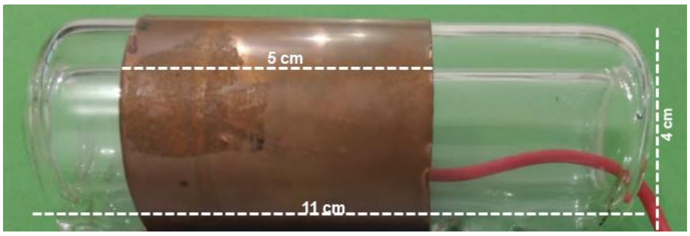


Figure 1. DDBD mini reactor

Research procedure

The research procedure is shown in Figure 2. The input gas source is free to air with variations of 0.2, 0.4, 0.6, and 0.8 liters per minute (lpm). The AC pulse voltage source is set with the pulse frequency with variations of 30, 40, 50, and 60 Hz. The operating voltage is given from 0 to the maximum voltage at 300-volt intervals, and the amperage is recorded. Ozone production comes out of the output hose. The resulting ozone concentration was measured using the titration method with the equation [11]:

$$C_{O_3} = \frac{R \times V_t \times N_t}{V_{gas}} \tag{1}$$

C_{O3} is the concentration of ozone (mg/l), R is the ratio of analytical moles and reactants in stoichiometric equilibrium, V_t is the volume of titrant (l), N_t is the normality of sodium thiosulfate (mol/l) and Vgas is the volume of air (l). The volume of air can be calculated from the product of the flow rate and the time of ozonation into the KI. The titrant volume is the volume needed to titrate the KI solution which is usually brownish-yellow to clear.

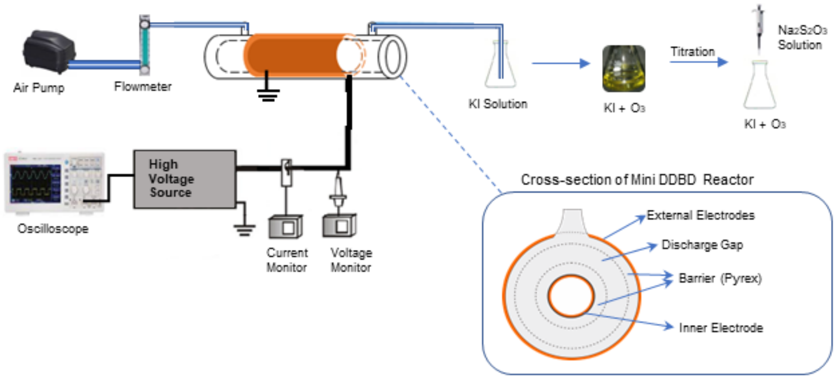
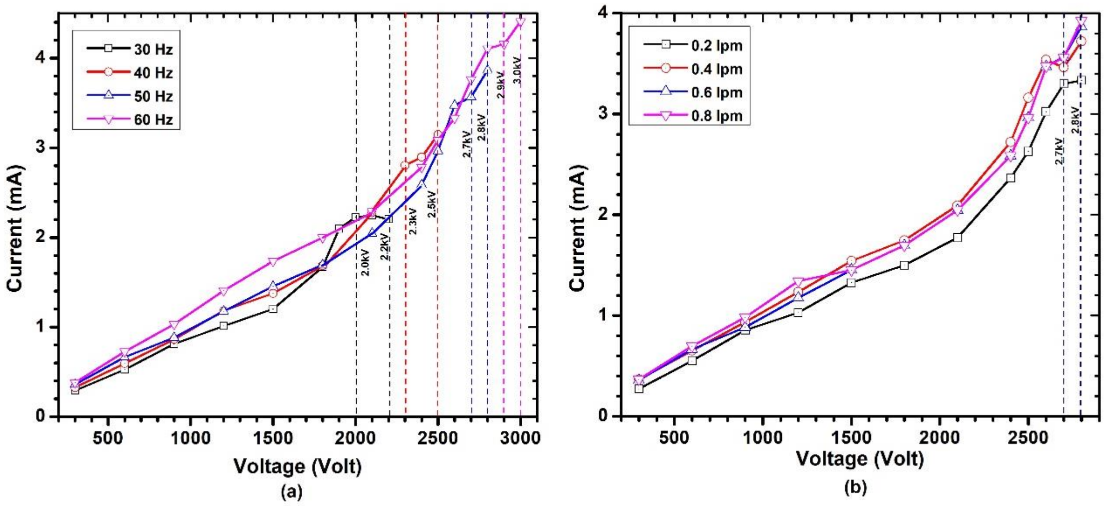


Figure 2. Research scheme

RESULTS AND DISCUSSION

Current characteristics as a function of voltage.

Figure 3 is a graph of the electric current formed as a function of voltage at various pulse frequencies (figure 3a) and different air flow rates (figure 3b). The characteristics of electric current in plasma DBDD technology show that the change in charge per unit time increases with the increase in operational voltage, but the current graph will have a different slope trend in the ozone production area. The voltage will cause an electric field around the electrode, this electric field causes the air molecules to be ionized through the collision mechanism so that there is an accumulation of charge changes per unit time. The current measured in the DDBD reactor is capacitive. The dielectric resistance forms the capacitor and is connected in series with the gas capacitor. Plasma is considered a variable impedance added in parallel with a gas capacitor [12,13].



(a)

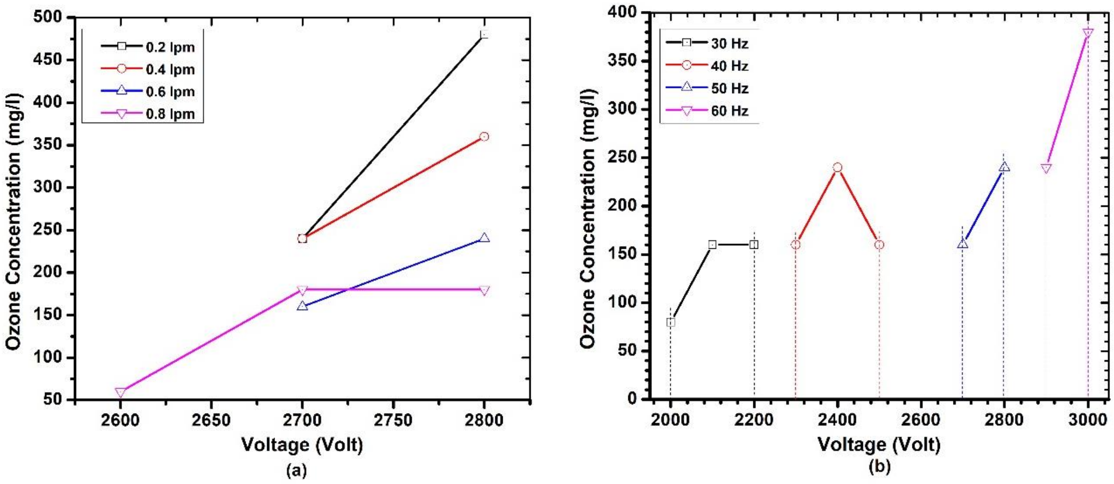
(b)

Figure 3. Graph of current characteristics as a function of voltage: (a) at different frequencies, (b) at different flow rates.

The current characteristics have the same trend at different pulse frequencies and different flow rates. Changes in frequency affect the shift in the ozone production area and the maximum operating voltage. The higher the pulse frequency causes the pulse beats every second to increase so that the maximum output voltage produced also increases. The frequency of 30 Hz has a maximum operating voltage of 2.2 kV, while at frequencies of 40, 50, and 60 Hz, the maximum operating voltage increases to 2.5, 2.8, and 3.0 kV, respectively. Apart from that, adding voltage can result in a greater potential difference, so that the electric field strength generated is also greater. Electric fields accelerate the movement of charged particles and collisions occur between particles which then trigger excitation, deexcitation, ionization and recombination to produce electric charges. Electric charges that move every unit of time form an electric current. This is as obtained by Rahardian et al [14]. The flow characteristics also have the same trend at different flow rates as shown in Figure 3b. At the lowest flow rate of 0.2 lpm, the current graph as a function of voltage looks lower than the other higher flow rates. The low flow rate causes the air molecules to stay longer in the DDBD reactor, thus the supply of air molecules is relatively less.

Ozone production

Ozone production using DBD reactor technology has unique characteristics that are different from DBD technology. This is shown in Figure 4b where the ozone formation area is strongly influenced by the pulse frequency. The pulse frequency can shift the ozone formation region to the right of the voltage variable along with the magnitude of the frequency. The effect of frequency is also seen in the narrow ozone production area, at the lower voltage no ozone has formed, and at the higher voltage, no ozone formation has occurred. This was also confirmed by previous researchers who had ozone production areas in the voltage range of 2.6 to 3.0 kV [15]. The ozone production area with this mini DDBD reactor is located at a voltage of 2.0 – 2.2 kV at a pulse frequency of 30 Hz, a voltage of 2.3 – 2.5 kV at a frequency of 40 Hz, a voltage of 2.7 – 2.8 kV at a frequency of 40 Hz and a voltage of 2.9 – 3.0 kV at a frequency of 60 Hz. The highest ozone production of 480 mg/l was produced using a flow rate of 0.2 lpm and a pulse frequency of 50 Hz (see Figure 4a).



(a)

(b)

Figure 4. Graph of ozone concentration as a function of voltage: (a) at different flow rates, (b) at different frequencies.

Ozone production is also affected by the airflow rate as shown in Figure 5. The ozone concentration has a downward trend with increasing flow rates. A low air flow rate automatically air molecules to have a longer residence time. Air molecules will experience collisions due to the electric field, so they have the potential to form ozone. The mechanism of the collision process of ozone formation occurs at O + O2 + M → O3 + M, as also found by previous researchers [11,15].

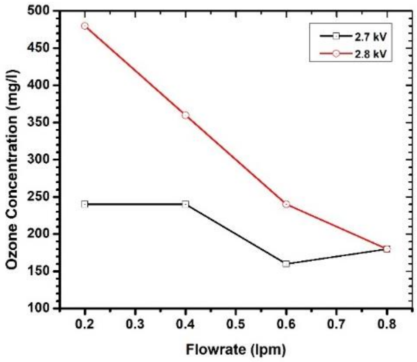


Figure 5. Graph of the effect of airflow rate on ozone production

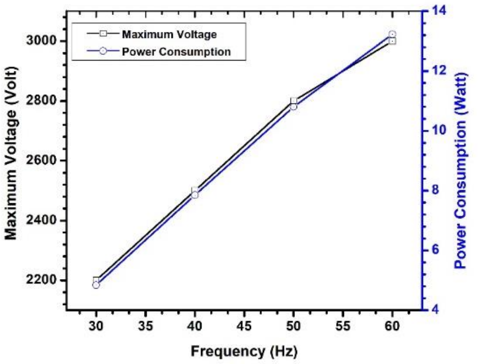


Figure 6. Graph of the effect of pulse frequency on maximum operating voltage and power consumption.

Figure 6 shows a graph of the maximum operating voltage and power consumption as a function of pulse frequency. The power consumption of the DDBD reactor has a similar trend to the maximum operating voltage produced, namely the higher the pulse frequency given, the greater the maximum operating voltage issued, and the power consumed by the reactor also increases. Reactor power consumption is the product of the operating voltage and the generated current. The power required is quite low, namely, a maximum of 13 watts, while to produce ozone with a concentration of 480 mg/l it only consumes 9.24 watts of power, namely at a frequency of 50 Hz and a flow rate of 0.2 lpm.

CONCLUSION

This research has succeeded in characterizing the development of a mini ozone generator using DDBD technology. Ozone production is influenced by pulse frequency, operational voltage, and gas flow rate. This research obtained the lowest ozone production results of 60 mg/l at a voltage of 2.6 kV with a frequency of 50 Hz and a flow rate of 0.8 lpm. At this lowest production, the power consumed by the reactor is 9.04 watts. Optimum ozone production was obtained at 480 mg/l with a power consumption of 9.32 watts. Optimum production was achieved at a voltage of 2.8 kV with a pulse frequency of 50 Hz and a flow rate of 0.2 lpm. The relatively large ozone production with a relatively small reactor and low power consumption shows that DDBD technology has the potential to be applied on a household scale.

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