Characteristic of DBD plasma for ozone synthesis and its application on disinfection of chilli

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Abstract. The main objectives of this work are to study effect of high voltage power supply on plasma dielectric barrier discharge (DBD) system to amount of ozone concentration and to preliminary study effect of ozone on disinfection of microorganism. The amount of ozone concentration generated by the plasma DBD was determined by the KI standard ASTM method while on-site research work, ozone concentration was measured by the Liverbond test kit. The experimental result showed that ozone concentration was relatively dependent on the voltage supply. The produced ozone concentration was varied between 10 and 100 mg/l of air flow rate relating to voltage supply. The characteristics of plasma discharges was also presented. For feasibility study of disinfection of microorganism on chili by ozonated water bubbling, the results showed that the dissolved ozone with 8 kV can reduce E. coli from 9×10⁵ MPN/100 ml to 1×10⁵ MPN/100 ml in 120 min duration time.

1. Introduction

Due to population growth every year, food and agricultural products must be enough to supply and are also safe for people. It is realized that the world population will be ten billion people in 2050, which is the main reason for producing the food and agricultural product security for them. The big problem is the food quality control even science and technology process can increase agricultural productivities and control food qualities [1-2]. At present, agriculture farming will rely on the use of pesticides and other chemicals to increase agricultural productivity and preventing of pests disturb. The WHO reported the impurities and pesticide residues on agricultural products in many countries around the world [3-4]. Additionally, decontamination of microorganism in food and agricultural products can also be harmful such as Escherichia coli (E. coli). The E. coli is one of the pathogenic bacteria in water and it can threaten people’s health. However, E. coli bacteria can be controlled and destroyed by many methods for examples chlorination, UV radiation, heating etc. The chlorination may induce the secondary hazardous pollutants on water such as trihalomethanes and haloacetic acids whilst use of UV radiation depended on surrounding temperature and relative humidity [5]. To compare to other sterilization techniques [2], the non-equilibrium plasma discharge (temperature of plasma species is different temperature, normally electron temperature is relatively high compared to the ion charges and neutral atoms) is a superior
alternative allowing to reduce these risks and drawbacks, especially on producing of ozone and UV radiation [2,5-7].

Ozone, which consists of three atoms of oxygen, is a good example for an industrial process of plasma dielectric barrier discharge (DBD) application to utilize tools of modern plasma physics [8-9]. The conventional plasma DBD method use for producing ozone is supplied by high voltage power supply such as AC high voltage power supply, high frequency power supply etc. Due to the ozone performance, numerous applications on science and technology researches have been represented on disinfection of some products, potent germicidal properties, high oxidation potential of wastewater and water treatment etc [4,6-7]. Consequently, it decays and oxidizes matter without toxic by-product to environment. However, the ozone needs to be produced onsite because it is easily decomposed, especially on warm weather surrounding conditions (exothermic reaction). Ozone has been proven to be a substance capable of storing agricultural products because it has the capability to destroy toxins from microorganisms and pesticides [1,5,6-7]. However, at the present, it is a few research applying to vegetable, fruit and food product. It can be realized that the pesticide residues and infection of microorganism in agricultural products is an important issue that affects both humans and the environment.

Therefore, the aim of this research is to developed and preliminary studied the ozonation system apply to disinfection of E. coli bacteria on chili.

2. Materials and methods

2.1. Materials

The plasma ozoniser system (PSU-O3#1) in this work consists of 15 kV_{rms} AC high voltage power supply unit, air pump, and ozoniser cell as shown in figures 1(a) and 1(b). The ozone concentration is determined by standard KI method, which is explained. The voltage (V) and current (I) are measured by HP high voltage divider probe model 6015B (Hewlett Packard company, USA) and pulse current probe CT-1 (Tekronix co. Ltd. USA). The V-I signal are detected by HP Digitized Storage Oscilloscope 400 MHz.

2.2. Methods

2.2.1. Ozonizer system. The high voltage power supply unit was built in the case which produced an AC high voltage output ranging of 0-15 kV_{rms} which oscillated at 50 Hz. This power supply unit consisted of variable transformer (so-called variac), high voltage (HV) step-up transformer of 0-15 kV_{rms}, a dumping resistor for limiting current flow and AC voltmeter. Figure 1 shows circuit diagram of power supply unit. The formation of ozone is an endothermic reaction and the overall exothermic reaction of ozone generation is written as follows:

\[ 3O_2 \rightarrow 2O_3 \text{ (at 1 atm + 284.5 kJ/mol)} \]  

(1)

The \(\Delta H^\circ\) at atmospheric pressure is +284.5 kJ/mol and its redox potential is +2.07 V which is in a group of acute toxicological effect. Since the standard Gibb’s free energy of ozone formation \(\Delta G^\circ\) at 1 atm is +161.3 kJ/mol so ozone molecule can be decomposed easily by heating. That is the reason why ozone synthesis need to be placed on-site.

2.2.2. Determination of ozone concentration. By preparation of 1 % KI Absorbing reagent solution in 0.1 M Phosphate buffer by weighing KH_2PO_4 of 13.61 g, KI of 10.00 g and Anhydrous disodium hydrogen phosphate 14.20 g. Dissolve all chemicals substances in the deionized water, resulting in a volume of 1 liter placing at room temperature for 1 day before use. Prepare standard iodine solution 0.025 M by weighing KI 16.0 g and I_3 1730 g. Dissolve all chemicals substances in the double distilled water, making a volume of 500 ml. Storing the stock solution at room temperature for at least 1 day before use.
Create standard iodine graphs by preparing a standard 0.00125 M iodine solution by a standard 5 ml volume of 0.025 M iodine pipette, resulting in a volume of 100 ml by dissolving in the Absorbing reagent solution, standard 0.00125 M iodine solution pipette, volume 0.2, 0.4, 0.6, 0.8, 1.0 and 1.2 ml dissolved with Absorbing reagent solution until the volume is 25 ml. Take various standard iodine solutions. Measuring the absorbance of values at 352 nm wavelength.

The study of the relationship between the amount of ozone and the electric potential. When the voltage difference is changed to the ozone generator. The amount of ozone will change. Therefore, finding the amount of ozone at various times of each electric potential difference. By passing oxygen to the ozone generator by setting the flow rate of oxygen to 8 litres/minute, giving the voltage of the alternator to 7 kV for 0.5, 1.0, 1.5 and 2.5 minutes respectively, changing the potential difference to 8, 9 and 10 kV respectively.

2.2.3. Disinfection of *E*. coli bacteria. To study disinfection of *E. coli* residues in chilli before and after treatment the experiment is prepared by soaking chili of 1 kg in the ozone dissolved tank by varying duration times of 0, 40, 80, 120 and 160 minutes. The water will be taken and send to Science central laboratory unit of Faculty of Science, PSU for evaluate amount of *E. coli* reduction in each duration period.

3. Results and discussion

The current and voltage signals were measured as shown in figure 1 and these current-voltage waveform results are acquired and illustrated in figure 2. The figure shows the discharge appearance in plasma DBD of O\(_2\) with flow rate of 10 ml/min. The high voltage of 24 kV\(_{pp}\) applied between electrodes and investigated that the high amount of current peak had been incident in a few milliseconds. Amount of these current peaks let oxygen molecules to ionize and form ozone molecules [6-7].

By following the KI methods in section 2.2.2, the ozone concentration can be relative directly determined with KI solution changing to iodine by ratio of 1:1. Figure 3 illustrates the calibration curve of ozone concentration by following the standard KI methods of potassium iodide [6].
Figure 3. Calibration curve of absorbance versus standard potassium iodine (KI) solution for direct proportional evaluation the ozone concentration.

From studying the relationship between the amount of ozone and the electric potential, the graph can be expressed as shown in figure 4. The results show that ozone concentration increase with increase of high voltage supply and discharge time which is corresponding to the previous works [3,6].

Figure 4. Relationship between the amount of ozone and the electric potential.

Figure 5. Amount of E.coli reduction during ozonation time.

From the study disinfection of E.coli by ozonation time at 11 kV_{rms}, the results is shown in figure 5. It states that the reduction of E.coli has been significantly affected by ozone. The amount of E.coli bacteria, these results are corresponding to the previous works [5].
4. Conclusion
The experiment of this research work stated that ozone concentration is dependent upon voltage supply, gas flow rate whilst the amount of ozone concentration can be determined by using standard KI methods. And the percentage of E.coli reduction also depends on duration time of ozonation as well as ozone concentration. Ozone shows high performance for disinfection of microorganism in chili, especially on E. coli.

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