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Research Article

EXPIREMENTAL ANALYSIS OF DIELCTRIC BARRIER DISCHARGE FACTORS ON OZONE PRODUCTION FOR FOOD STORAGE

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ABSTRACT

Ozone, a powerful oxidant, is effective against various kinds of microorganisms on fruits, vegetables, meat grains and their products. The best way to generate ozone was to use dielectric barrier discharge (DBD) at atmospheric pressure. This discharge is a little specific kind because one electrode is covered by a dielectric material, thereby preventing the discharge to move towards electrical breakdown. The aim of this paper has to study and identify the best concentration of ozone generated by DBD which give a better result on increasing on shelf life of food products. Obtained results pointed out that investigated parameters of DBD have significant effect in ozone production and also for preservation of shelf life of food product for around 20 PPM without using cold treatment chamber.

Keywords: Ozone; DBD; Food; Dielectric; PPM.

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1. INTRODUCTION

The growing concern for the protection of the environment from the effects of increasing industrialization, intensive agriculture, and the exploitation of natural resources poses enormous challenges to contemporary science and to the sustainable development of mankind. Most environmental pollutants damage human health and the environment regardless of whether exposures occur in air, water, soil or the food chain [1-6]. Several methods have been developed and used to combat and treat exhaust gases energy efficiently and inexpensively. Indeed, its energy efficiency and its initial and running costs are still in negative situation for the backward nations [7-9].

Therefore, innovative technologies are needed to reduce, convert, decompose or manage environmental pollutants. Non-thermal plasmas (cold plasmas or non-thermodynamic equilibrium plasmas) generated by dielectric barrier discharge are an innovative tool for the reduction of environmental pollutants. This technology offers essential advantages such as high processing efficiency, and improved energy efficiency [10,11].

The device is based on the dielectric barrier discharge. It is capable of producing condition that will enable various chemical reactions to occur [12,13].

The main component produced by the dielectric barrier discharge is ozone (O_3 which is a powerful oxidizer and has much higher disinfection potential than chlorine and other disinfectants. Ozone finds its application mainly in water treatment and air purification [14,15]. Dielectric barrier discharge (DBD) method has proved to be the best method to produce ozone [16,17]. Dried air or oxygen is forced to pass through a 1-2 mm gap.

Indeed, the production of ozone by a dielectric barrier discharge (DBD) depends on several factors. In such application, the list of factors influencing the process includes the level of the applied voltage, the signal frequency and the duration of the dielectric barrier discharge (DBD) application [18]. Thus, it’s necessary to show and study the effect of such as factors on ozone production.

The ozone generated by this kind of discharge was mainly used for several applications in relation of air disinfection such as food preservation in agricultural domain. However, the concentration of ozone generated plays an essential role in the food preservation process. The aim of this paper is to determine experientially the adequate concentration of ozone for a conservation of tomatoes according to the parameters of the dielectric barrier discharge. The results obtained show that a concentration of 20 ppm of ozone is sufficient to prolong and keep an Apple for two weeks without losing either weight or natural qualities and without using a cold room.

2. Materials and Methods

Surface DBD reactors of cylindrical shape were achieved. The dielectric barrier is constituted by a glass tube having a diameter of 50 mm, different length of 50, 100, 200, 300 mm and a thickness of 2 mm. The electrodes are a fine strip of adhesive aluminum such as an internal electrode bonded directly on the outer surface of the glass tube with 2 mm of thickness. The external metal electrode, a stainless-steel mesh was placed inside the glass tube in contact with it (Figure 1). When a high voltage is applied to these electrodes, bluish color plasma is formed on the surface of the tube in contact with the mesh electrode and is distributed homogeneously along the tube (Figure 2).

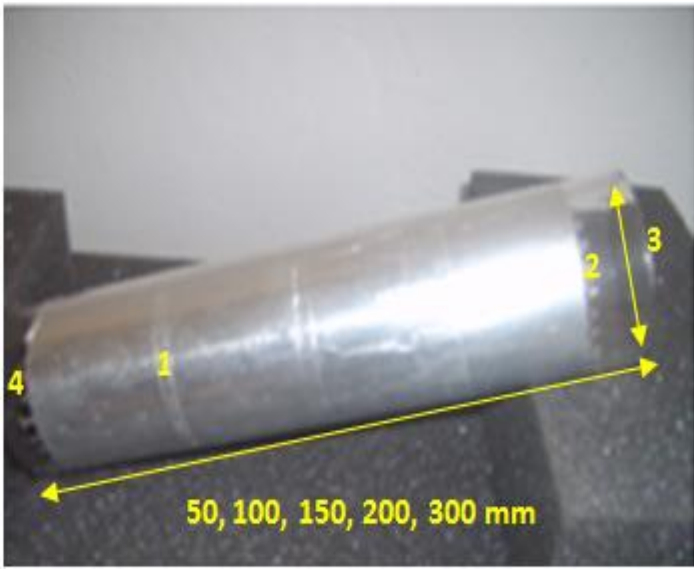

Fig.1. Schematic representation of an ozone generator with surface DBD

1) Internal electrode, 2) external electrode, 3) oxygen input, 4) ozone output

The power supply used comprises two main elements, an AC power supply of 220 V which delivers alternating signals with an adjustable frequency range from 0 to 5.5 kHz, for supply the ozone generator and transformer using to amplify the signal.

The voltage V delivered by the power amplifier applied to the ozone generator is measured using a digital SCOPE, while the current I was measured using a hall effect current sensor

(Pearson electronic). The signals (current and voltage) are stored and transferred to a computer (figure.3).

The ozone concentration produced by the reactor is measured using the Ozone analyzer (Ozone-solution-106H). The ozone level is described in PPM [particles per million].

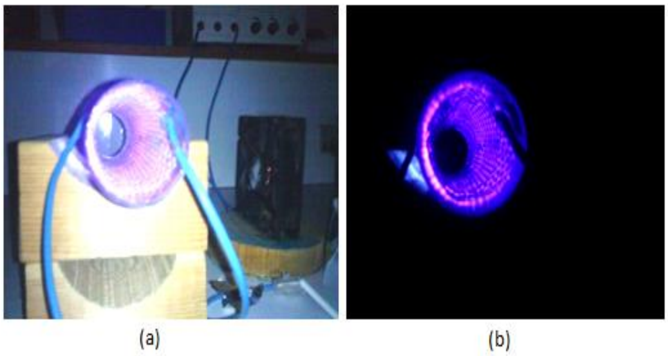

Fig.2. Discharge inside the DBD reactor

a) Day photo b) Night photo

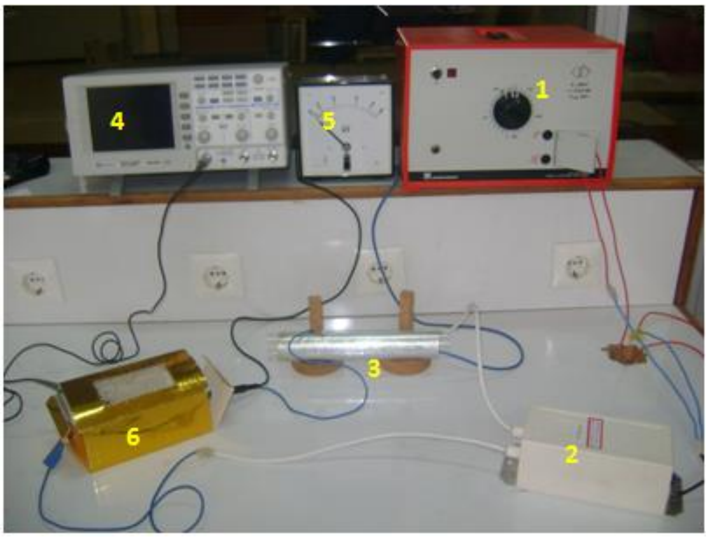

Fig.3. The experimental set-up.

1. AC power supply, 2. Transformer, 3. Ozone generator, 4. Scope, 5. Peak Voltmeter, 6. Hall effect current sensor

3. RESULTS AND DISCUSSION

For all the experiments carried out in this section one factor was varied while the two other factors were kept at constant values.

Thus, figure 4 represent the variation of the DBD reactor efficiency, in terms of ozone generation (ppm), according to the applied voltage (V). This latter was varied from 1 to 12 kV at constant values of f = 300 Hz, L = 150 mm and T = 20 seconds.

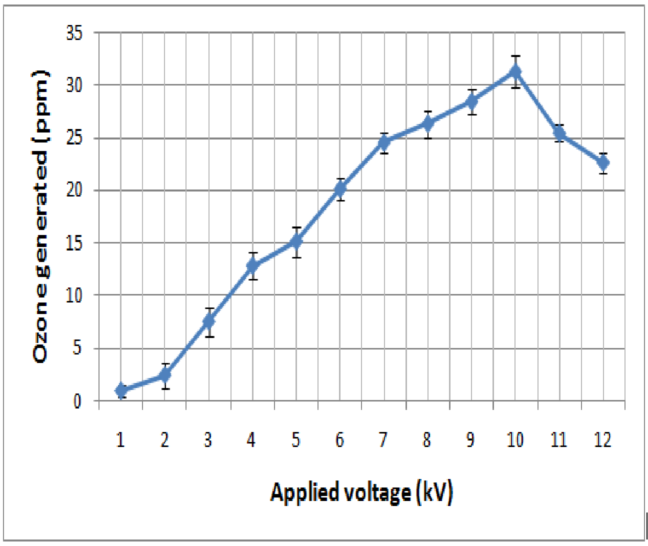

Fig.4. Ozone generation rate according the applied voltage

(f = 300 Hz, L = 150 mm, T = 20 s)

The obtained results show that the surface DBD starts quickly with low tension and the ozone generation rate increases with the applied voltage. Moreover, at a given applied voltage (V= 10 kV), the ozone generation rate reaches a higher value and then decreases (figure.4).

The high voltage applied breaks the oxygen molecule which passes through the DBD discharge zone into two oxygen atoms. These two atoms will subsequently be attached by two new oxygen molecules to form an ozone molecule. This ozone formation process increases with the increase in the applied voltage resulting in the increase of ozone rate generated. The increase in the voltage also generates breakdowns in the DBD reactor which cancels the voltage thus causing the ozone formation process to stop. Then, the optimal value of ozone concentration rate was given by application of 10 kV of applied voltage.

In the same way, in Figure.5, is represented the variation of the ozone generation by DBD reactor (ppm) as function of power supply frequency (f). The power supply frequency was varied from 50 Hz to 1100 Hz for the sinusoidal signal using the function generator for an applied voltage of 5 kV, DBD length of 150 mm and total duration of DBD application of 20 seconds.

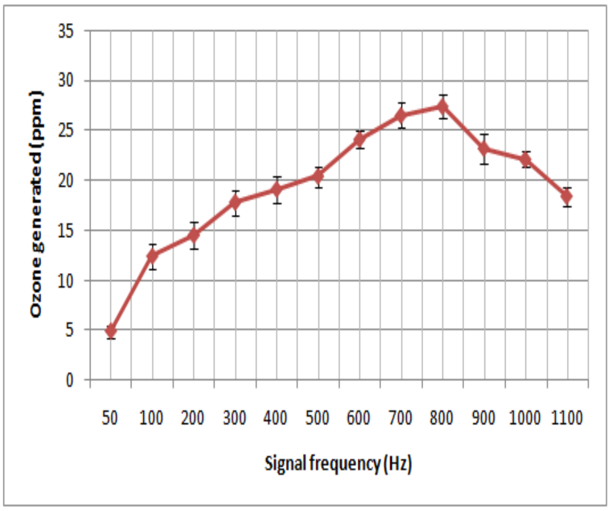

Fig.5. Ozone generation rate according the power frequency signal

(V= 5 kV, L = 150 mm, T = 20 s)

The increase in power supply frequency causes a rapid application of the voltage, which translates into a high speed of the ozone formation process. This effect stops from a certain limit value of the frequency, equal to 800 Hz in our case. Beyond this value, the signal is no longer effective (pulse regime) and the rate of ozone generation decreases (figure.5). Then, the optimal value of ozone concentration rate was given by application of 800 Hz of power frequency signal.

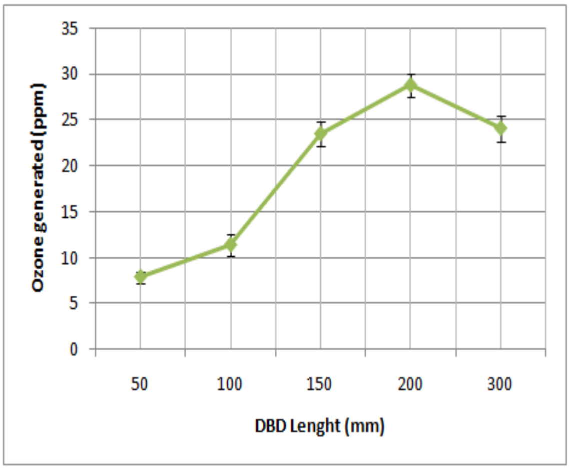

Fig.6. Ozone generation rate according the reactor DBD length

(V= 5 kV, f = 500 Hz, T = 20 s)

Figure .6 is shown the ozone generation rate according the length of reactor DBD reactor (L). In this case, the DBD length was varied from 50 mm to 300 mm at constant values of an applied voltage of 5 kV, power supply frequency of 500 Hz and total duration of DBD application of 20 seconds.

When the DBD length is small the generation of ozone is low, the oxygen that passes through the discharge zone does not have enough time to completely transform into ozone. In addition, the length increases the generation of ozone increases and beyond a certain value of the length of the DBD the rate of ozone generated decreases because the ozone generated is still in the space of the discharge which then facilitates by the effect of the high voltage of its re-transformation into oxygen (figure.6). Then, the optimal value of ozone concentration rate was given by application of 200 mm of DBD lenght.

Figure .7 is shown the ozone generation rate according the total duration of DBD reactor application (T). Indeed, the duration total of DBD application was varied from 10 to 120 seconds at constant values of an applied voltage of 5 kV, power supply frequency of 500 Hz and reactor DBD length of 150 mm.

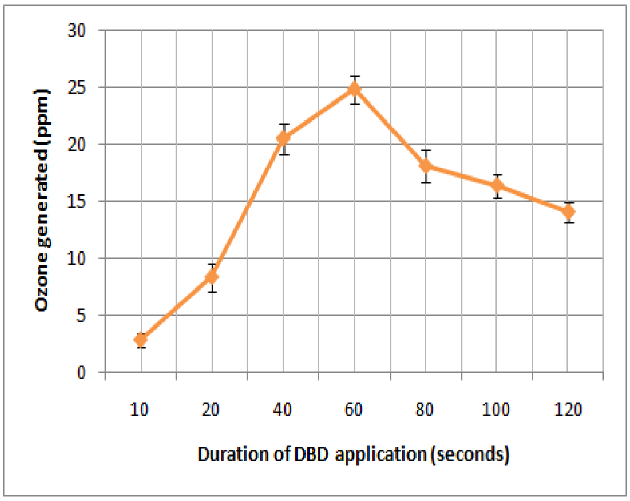

Fig.7. Ozone generation rate according the total duration of DBD reactor application (V= 5 kV, f = 500 Hz, L = 150 mm)

According the figure, the optimal value of ozone concentration rate was given by application of 60 seconds of duration of DBD applications.

4. OZONE APPLICATION ON AGRICULTURAL DOMAIN

Ozone is primarily used for treating air and water, removing bacteria, viruses and unpleasant odors. But it should not exceed a certain amount so as not to lose its effectiveness in eliminating bacteria and viruses. The DBD reactor powered by factors which gives different concentrations of ozone was then used as an ozone generator for disinfection of air in order to compare the effect of ozone on extend the shelf life of food products.

The optimal values of the factors obtained in the previous section are then used for the conservation of food products and compared with the other values of the factors as shown in the table.1.

Table 1. Ozone concentration rate according of the DBD factors

Factors	***U* *(kV)***	***f* *(Hz)***	***L* *(mm)***	***T* *(s)***	**O_3 concentration rate (ppm)**
Random values	**6**	400	100	20	12.4
Optimal values	**10**	800	200	60	20.8

The laboratory setup used is described in figure 8. The foods to be stocked are put inside a glass enclosure; oxygen concentrator allows the injection of ozone inside the enclosure every day. In the first enclosure, the ozone generator was powered by the optimal values given in the previous section and in the second enclosure the ozone generator was powered by the random values given also in the previous section (figure 8).

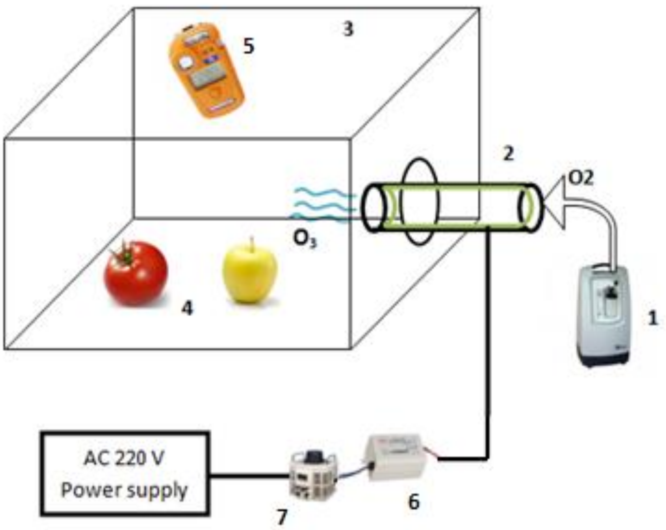

Fig.8. Schematic description of the disinfection process

1. Oxygen concentrator, 2. Ozone generator, 3. Glass enclosure, 4. Food to be processed, 5. Ozone analyzer, 6. Glass enclosure, 7. Auto-transformer

In the third enclosure, the same products and under the same storage conditions as the first are placed this time in an enclosure in the open air and without treatment (figure. 9).

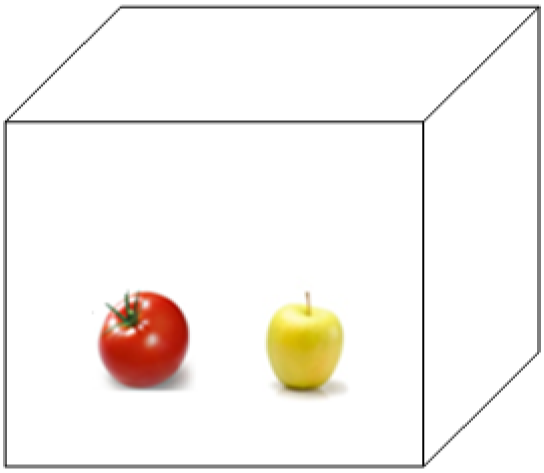

Fig.9. Enclosure without ozone contain the food produts

The results are expressed in terms of visual aspect for the three enclosures (figure.10 and 11).

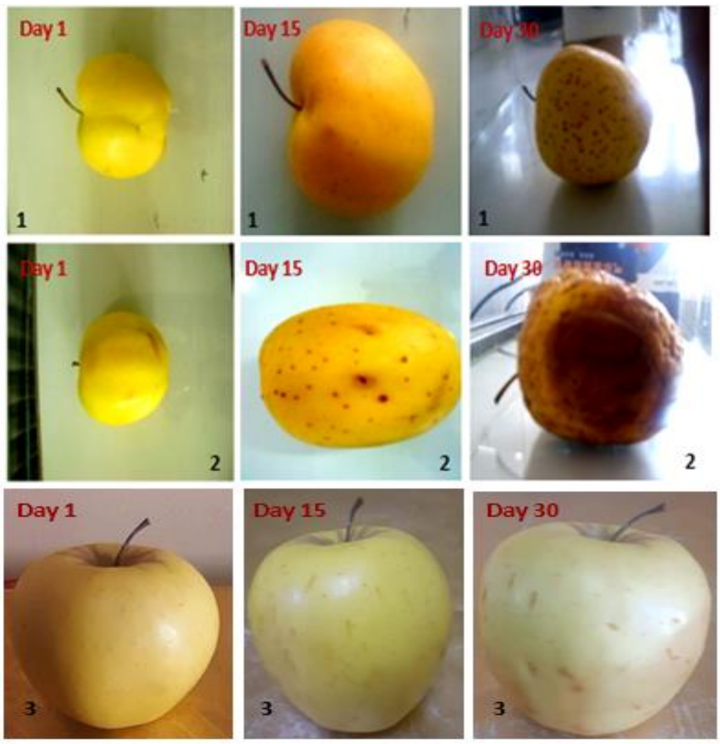

Fig .10. Evolution of visual aspect of the apple

1) DBD powered by random values of factors, 2) Without treatment, 3) DBD powered by optimal values of factors

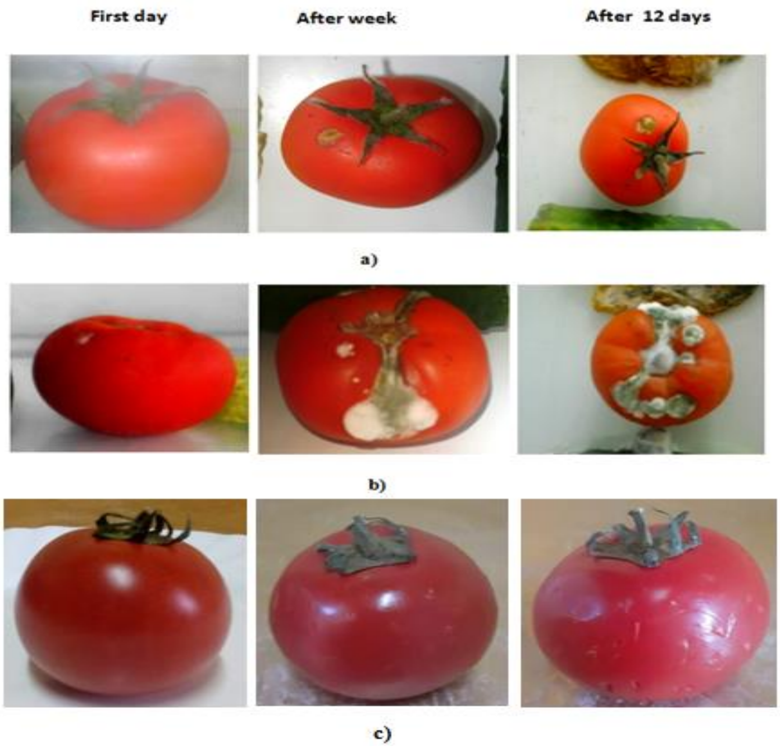

Fig.11. Evolution of visual aspect of the Tomato

a) Control sample random values of factors, b) Without treatment, c) Treated sample optimal values of factors

From the photos, we notice that the products located in the ozone-disinfected enclosure using the ozone reactor DBD powered without optimal values had lost their qualities and their weights after a few days compared to the products located in the ozone-disinfected enclosure using the ozone reactor DBD powered with optimal values. It can be said that the application of ozone as a disinfectant presents an advantageous solution for the preservation of food products in the food industry. This is clearly proven for foods laid without treatment in the open air which quickly lose its qualities because this medium promotes the appearance of microorganisms and bacteria.

The appropriate choice of quantity of ozone also plays its role in food conservation process. From these results; it is clearly seen that for better preservation of food products a concentration of about 20 ppm is sufficient without the use of a cold treatment chamber.

5. CONCLUSION

Ozone can be used safely in the processing, storage and processing of food. This component is used as an antimicrobial agent in gas or water phase. This molecule is the most powerful oxidant and disinfectant to purify the air. It does not produce any undesirable derivative and transforms back into oxygen. However, it has a short life

The dielectric barrier discharge is an easy process to generate the ozone. Indeed this process is multi factorial. So, the study of factors effect on ozone production was an important step before using in food industry.

The results of this work show that 20 ppm of ozone concentration was sufficient for increasing of the shelf life of foods.

Finally, the application of ozone in the food industry seems to be very beneficial. In the future, a combination of ozone with cold storage will be an alternative solution for several sectors.

6. ACKNOWLEDGEMENTS

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