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The Ozone Generator Design for Carrageenan Sterilization Based on Arduino

Muhammad Zaenal Iksan

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Abstract

Micro, Small and Medium Enterprises (MSMEs) are the pillars of the economy in almost all developing countries, including Indonesia. One of the MSMEs products that the government is pushing to enter the export scale is carrageenan. In food products, carrageenan is widely used to form gels in jelly, jam, syrup, sauce, baby food, dairy products, meat, fish seasoning and so on. To support carrageenan products to compete in the regional and global economy and enter the export scale, the product must be in good condition and quality and comply with the mandatory standards required by the export destination country. Sterilization of materials that is usually done is using heat that has been set at a certain temperature. However, sterilization using this method is not recommended for carrageenan food because heat can damage the carrageenan material itself. Therefore, sterilization must be carried out at room temperature, one of which is ozonation using ozone generator. Ozone generator has been made to sterilize samples of carrageenan based on Arduino. Ozone generator is a device that produces ozone by corona discharge method. This tool has 2 modes of operation namely manual and automatic. Ozone reactors are made with a type of dielectric barrier discharge plasma. The ozone concentration is generated by varying the voltage from (3-28) kV and flow rate variations of 3, 6, and 9 L/min. The ozone reactor used as an ozone generator has a cylindrical skeleton configuration. The inner electrode is made of threaded iron, while the outer electrode is made of aluminum foil reel and the dielectric material used is pyrex. The reactor is given a high voltage AC with frequencies ranging from (1-10) kHz. To determine the ozone concentration produced by the reactor, the resulting ozone is detected and measured using an ozone meter.

Keywords: Ozone generator, Arduino, Carrageenan, Dielectric Barrier Discharge Plasma (DBDP), Ozone meter

1. INTRODUCTION

Micro, Small and Medium Enterprises (MSMEs) are the pillars of the economy in almost all developing countries, including Indonesia. MSMEs need to get support from the government so they don't lose in the flow of trade liberalization, one of which is in the global competition of the ASEAN Economic Community (AEC). When AEC 2015 comes into effect, the economies of the member countries of the Association of South East Asia Nations (ASEAN) will be increasingly integrated through increasingly congested trade traffic.

One of the MSMEs products that the government is pushing to enter the export scale is carrageenan. Carrageenan is a compound extracted from seaweed from the Rhodophyceae

family such as Euchema spinosum and Euchema cottonii which consists of sulfated polyglycan chains with a molecular mass (Mr) of more than 100,000 and is hydrocolloid. In food products, carrageenan is widely used to form gels in jelly, jam, syrup, sauce, baby food, dairy products, meat, fish seasoning and so on.

MSMEs in Indonesia have several obstacles, especially regarding market expansion abroad (exports), one of which is the problem of sterilizing food export ingredients. To support carrageenan products to compete in the regional and global economy and enter the export scale, the product must be in good condition and quality and comply with the mandatory standards required by the export destination country. One of the standards used by many countries regarding the import of food products is that the bacterial content must be less than a certain value. However, carrageenan produced from seaweed processing has a high potential for bacterial content, so it needs to be sterilized before being exported.

Sterilization of materials that is usually done is using heat that has been set at a certain temperature. However, sterilization using this method is not recommended for carrageenan food because heat can damage the carrageenan material itself. Therefore, sterilization must be carried out at room temperature, one of which is ozonation.

Ozonization is an activity to sterilize materials by utilizing ozone particles that have special properties for disinfection (killing germs), detoxification (neutralizing toxic substances) and deodorization (removing bad odors) in water and air. Ozone is a natural gas molecule that is easily soluble in water and non-toxic. Naturally, ozone can be formed through ultraviolet radiation from the sun's rays which can decompose oxygen gas in the free air. The oxygen molecule breaks down into two oxygen atoms, this process is known as photolysis. Naturally, these oxygen atoms collide with oxygen gas molecules around them, forming ozone (O_3). The ozone molecule is unstable and will always try to find a 'target' to be able to release one oxygen atom by oxidation, so that it can turn into a stable oxygen molecule (O_2). Due to its very strong oxidizing properties, ozone is excellent for disinfection (killing germs), detoxification (neutralizing toxic substances) and deodorization (removing bad odors) in water and air.

In 2003, Purwadi et al. research on a dual-channel portable ozone generator could produce an average ozone production of 0.04 mg/sec [1]. Abdi Wirawan Anggawe in 2010 conducted a study to make an ozone generator with a time setting using the AT89S52 microcontroller [2]. Fatlurahman in 2015 conducted a research to create an ozone generator system using ATMega8535 as a timer to support the fish environment [3]. The difference between this research and previous research lies in the type of reactor used to produce ozone, the use of a microcontroller for time control and the purpose of the research. Based on the background that has been described, it can be built and developed an ozone generator for carrageenan sterilization based on Arduino.

1.1. Ozone

Ozone is an unstable molecule but very useful. Ozone is a tri-atomic form of oxygen atoms, compared to normal oxygen molecules composed of 2 oxygen atoms (O_2), ozone consists of 3 oxygen atoms (O_3). Ozone doesn't stay in the tri-atomic form for very long and when it encounters other molecules, it usually splits from O_3 to $O_2 + O_1$ in 20 minutes at atmospheric pressure. O_1 is called a single oxygen atom and this atom is highly reactive to several substances.

1.2 Corona Discharge

Hot spark (corona discharge) is an electrical discharge caused by the ionization of the fluid surrounding a conductor, which occurs when the potential gradient (electrical field strength) exceeds a certain value. Corona is the process by which a current arises from a high potential electrode in a neutral fluid, usually air, by ionizing the fluid to create a plasma around the electrode. The ions that are formed will immediately fill the nearby area with the lower potential difference or recombine to form neutral gas molecules.

1.3 Disinfection

Due to its very strong oxidizing properties, ozone is excellent for disinfection (killing germs), detoxification (neutralizing toxic substances), and deodorization (removing bad odors) in water and air. Through the oxidation process, ozone is also able to kill various kinds of microorganisms such as Escherichia Coli bacteria, Salmonella Enteriditis, Hepatitis A Virus and

various other pathogenic microorganisms. Through the direct oxidation process, ozone will damage the outer walls of microorganism cells (cell lysis) and kill them. Also through the oxidation process by free radicals such as hydrogen peroxide (H_2O_2) and hydroxyl radicals (-OH) which are formed when ozone decomposes in water.

2. METHODOLOGY

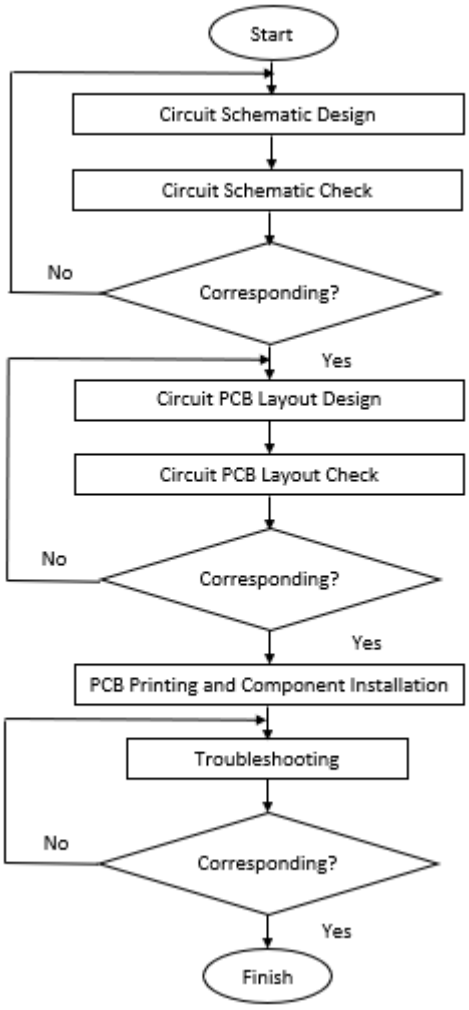
2.1 Hardware Design

Hardware design begins with designing the user interface. The user interface is made so that the user can operate the created ozone generator. The viewer used in this tool is a 16x2 LCD which functions to display menus and time settings automatically. This tool is also equipped with buttons to give commands to move the cursor on the menu and also to adjust the number up and down in setting the time of the tool activation process. In addition, this tool is also equipped with 2 switches, namely POWER 1 which is used to turn on or off the tool and the Arduino microcontroller, and is equipped with a POTENTIOMETER which is used to regulate the rise and fall of high voltage which will result in more or less quantity of ozone produced by the ozone generator.

The box of the tool is made using milky white acrylic material with the thickness of the bottom of the tool is 5 mm and the thickness of the other part is 3 mm. Body box is designed with a size of 400 mm x 300 mm x 150 mm. After designing the box, the box is then printed with laser cutting made of white acrylic with a thickness of 3 mm. Once printed, the box is assembled to install the components.

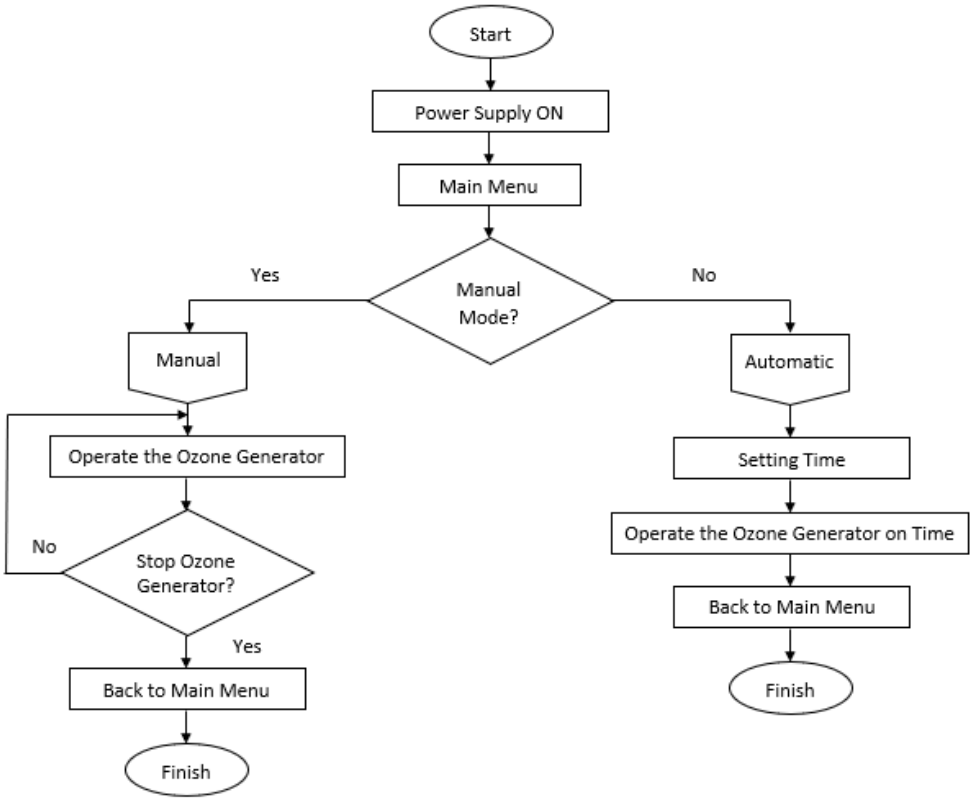
After designing the user interface, the next step is to design the PCB layout. PCB layout design is carried out to make PCBs to meet the needs of electronic systems that will support the needs of the tools made, including power supply circuits, relay circuits, driver circuits and minimum system (minsys).

The PCB layout design flow chart is shown in Figure 1.



2.2 Software Design

Software design is done to create a program that will be embedded in Arduino as a digital command that will be processed by Arduino so that when given a command/action, the tool will react according to the program command given. Figure 2 shows a program flow chart where the diagram describes the operating modes of the ozone generator, namely manual mode and automatic mode.



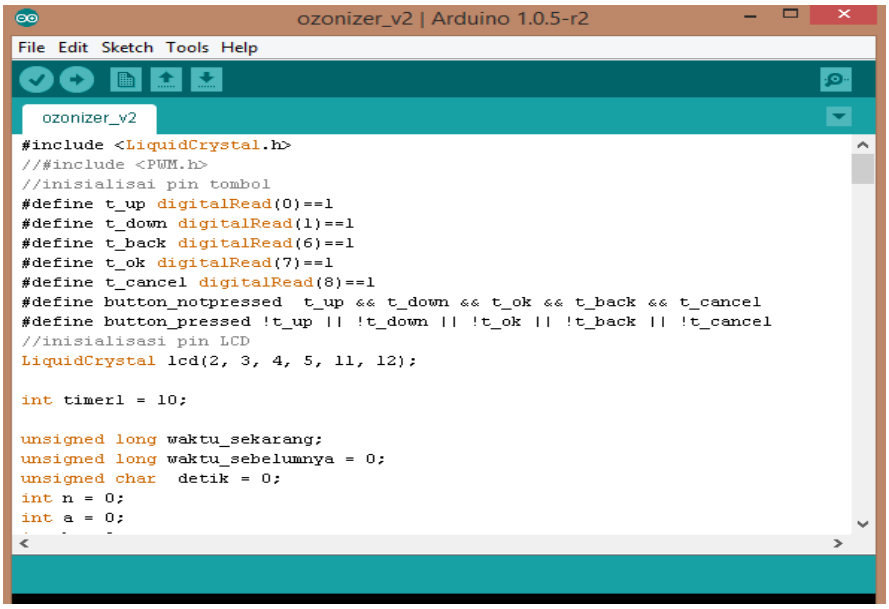
3. RESULTS AND DISCUSSION

3.1 Ozone Generator Design

Ozone generator is made by assembling acrylic that has been cut according to the shape and size into a box shape. At the top of the box, a door handle is attached to open and close the ozone generator box, at the bottom of the box is a rubber stand. The front of the box contains several buttons, LCD, potentiometer and input and output channels as part of the user interface. The back of the box has a female adapter hole as a power input to the device. The ozone generator is equipped with an aquarium pump as an air supply that will be injected into the ozone reactor tube with a constant air flow rate of 3 L/min, 6 L/min and 9 L/min. Besides that, it is also equipped with an air input channel from the outside if you want an air flow rate that can be adjusted and can also be supplied with pure oxygen from oxygen cylinders or air compressors. The appearance of the ozone generator is shown in Figure 3.

3.2 Program Design

Programming is done as a medium of communication between the user and the tool. The program is created using the Arduino IDE application which is then embedded in the Arduino program. Programming is intended for the purpose of setting the time of the ozonization process as well as user communication with the menu display presented on the ozone generator. To realize the program embedded in Arduino, in selecting the menu and giving commands by the user to the tool, it is made in such a way that it is user friendly or can be used easily by the user. The commands to react to the given action have been arranged in such a way that the user can easily operate the ozone generator by simply pressing the button on the front of the device according to the user's wishes. The program creation display is shown in Figure 4.

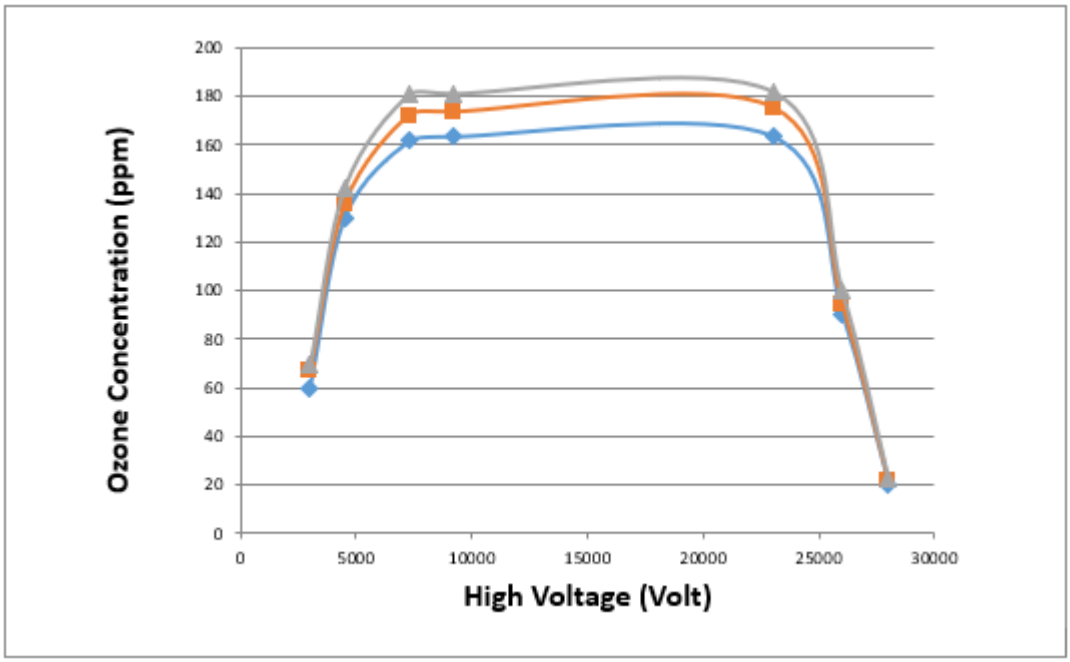


3.3 Ozone Production Concentration Test

To determine the quality of the ozone generator machine that has been made, the parameters related to the ozone generator machine are measured, one of which is a measurement to determine the concentration value of the ozone produced. Table 1 shows the measurement results of the ozone concentration produced when ozonation lasts for 20 seconds. with varying air flow rates.

No.	HV (Volt)	Ozone generated (Air Supply 20 Seconds) (ppm)		
		1 Pump (3 L/min)	2 Pump (6 L/min)	3 Pump (9 L/min)
1.	3000	60	66,7	69,2
2.	4500	130,1	135,8	142,3
3.	7300	161,6	172,2	180,6
4.	9200	163,4	173,4	180,8
5.	23000	163,5	175,2	181,6
6.	26000	90,5	94,2	99,8
7.	28000	20,2	21,4	22,3
8.	1000	7,1	7,3	7,4
9.	1300	4,4	4,5	4,7
10.	1800	3	3,1	3,3

Based on the data presented in Table 1, the next step is to analyze the relationship between the input parameters and the resulting ozone concentration. To find out the relationship of each parameter, a graph is made. Figure 5 is a graph of the relationship between the input parameters and the resulting ozone concentration.



The graph shows the concentration of ozone production, it can be seen that the graphic form of several variations in air flow rate tends to be trapezoidal, this occurs when the high voltage is increased, the air flow rate (O_2) input is also increased, and the time of ozonation is longer, the ozone productivity/The concentration of ozone produced is increasing (high voltage, air supply (O_2), and time is directly proportional to the concentration of ozone produced). However, at some point the ozone productivity will decrease due to the high voltage exceeding the working area of the ozone reactor. The graph shows the highest working voltage that produces the most ozone productivity and is constant at a voltage of 9200 V to 23000 V.

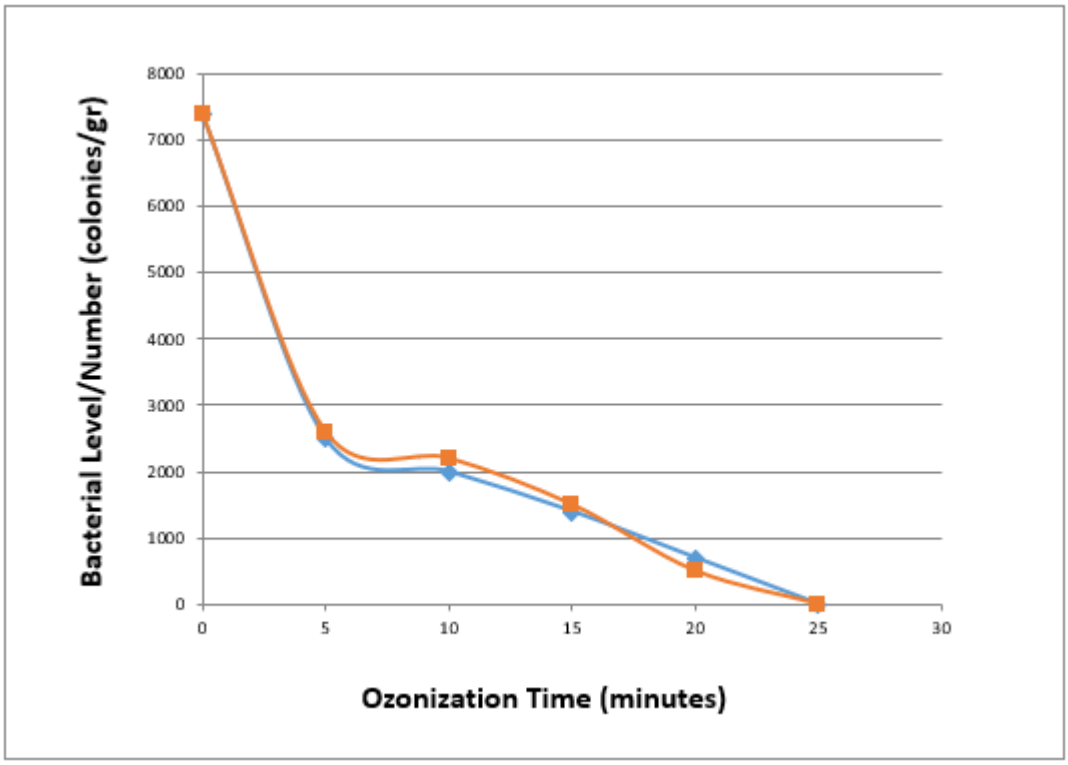
3.4 Bacterial Reduction Test

To determine the quality of the ozone generator that has been made, a test was carried out for the sterilization of samples in the form of carrageenan. The test for decreasing the level of bacteria was carried out to determine the percentage decrease in the level of bacteria in the sample in the form of carrageenan before and after sterilization, and then used for the analysis process of calculating the performance of the tool in order to achieve the target, which can be used for sterilization of carrageenan samples. This test is carried out using the Total Plate Count (TPC) analysis method. Total Plate Number (TPC) is a number that indicates the number of

mesophilic bacteria in every 1 ml or 1 gram of food sample examined. The principle of TPC is to count the growth of aerobic mesophyll bacterial colonies after food samples are planted on a suitable media plate by pouring and then incubating for (24-48) hours at a temperature of (35-37) ^{0}C. The results of measuring the number of bacteria in carrageenan samples before and after ozonation are shown in Table 2.

No.	Sample	Analysis Results (colonies/gram)	
		1 gram	2 grams
1	Early carrageenan (not yet ozonized)	7,4 x 10^3	7,4 x 10^3
2	Carrageenan is ozonized 5 minutes	2,5 x 10^3	2,6 x 10^3
3	Carrageenan is ozonized 10 minutes	2,0 x 10^3	2,2 x 10^3
4	Carrageenan is ozonized 15 minutes	1,4 x 10^3	1,5 x 10^3
5	Carrageenan is ozonized 20 minutes	0,7 x 10^3	0,5 x 10^3
6	Carrageenan is ozonized 25 minutes	0 x 10^3	0 x 10^3

Based on the data obtained, then a graph is made to analyze the relationship between the length of time the ozonation process takes the level of bacteria measured in the sample before and after the ozonation process is carried out to determine the decrease in the number of bacteria levels in the sample. Figure 6 is a graph of the relationship between the length of time the ozonation process took to the level of the number of bacteria measured in the samples before and after the ozonation process was carried out.



From Figure 6, we can see that the longer the time of the ozonation process, the lower level of bacteria contained in the carrageenan sample. Starting from before the carrageenan was ozonated, the bacterial content level was 7400 colonies/gram then when carrageenan was ozonated for 5 minutes, the bacterial content dropped to 2500 colonies/gram then when the carrageenan was ozonated for 10 minutes, the bacterial content dropped to 2000 colonies/gram and so on until the process ozonation lasted for 25 minutes the number of bacteria in the sample was depleted and sterile.

The results of these analyzes and calculations, can be used to determine the number of samples that can be sterilized every day, the thing that must be done is by comparing the length of time the ozonation process takes to decrease the number of bacteria. To compare the length of time for the ozonation process to decrease the number of bacteria, by taking one of the data from the data that has been obtained and which will be used to compare the data with a sample weight of 1 gram of carrageenan. Table 3 shows the comparison of the length of time the ozonation process has on the decrease in the number of bacteria.

No.	Ozonization Time (minutes)	Analysis Results (colonies/gram)	
		Bacteria Count	Bacteria Reduction
1	0	7400	0
2	5	2500	4900
3	10	2000	500
4	15	1400	600
5	20	700	700
6	25	0	800

From table 3, we can see that for each additional time of 5 minutes, the level of bacteria decreased from 500, 600, 700 and 800 colonies/gram. In the first 5 minutes, the decrease in the level of bacteria was very drastic, namely as much as 4900 colonies/gram and from the second 5 minutes or the 10^{th} minute the decrease in the level of bacteria began to stabilize, starting with a decrease of 500 colonies/gram and then at the minute to 15 levels of bacteria decreased by 600 colonies/gram, and so on until the 25^{th} minute the level of bacteria decreased by 800 colonies/gram. So for every additional 5 minutes, the decrease in the level of bacteria always increases by 100 colonies/gram and so on until the 25^{th} minute, the level of bacteria contained in the carrageenan sample is 0 colonies/gram or is completely depleted (sterile). From this analysis, it can be concluded that the bacteria in the 1 gram carrageenan sample will be depleted if it is ozonated for 25 minutes using a 1-tube ozone generator reactor. If 1 gram of carrageenan sample takes 25 minutes of ozonation to be sterile, then to find out how much carrageenan sample can be ozonated in one day, the calculation is as follows:

1 day = 8 hours of work

8 hours x 60 minutes = 480 minutes (a day)

480 minutes: 25 minutes = 19.2 grams

So, with the ozone generator that has been made, it is capable of sterilizing carrageenan with a weight of 19.2 grams/day.

4. CONCLUSION

An ozone generator has been successfully made to produce ozone with the Dielectric Barrier Discharge Plasma (DBDP) method which can be used for Carrageenan Sterilization with a capacity of 19.2 grams/day with timer based on Arduino. Parameters that greatly affect the quantity of ozone produced are high voltage (HV), air flow rate (oxygen content in the air that is passed at high voltage), type and construction of ozone reactor tubes.

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