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Low-heat sterilization system on fruit and vegetable pickling line production in packaging with high-voltage and corona-ozone technique

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Abstract

This research presents a food product sterilization technique using Pulsed Electric Field (PEF) technology to inhibit microbial growth in food products and ozonation with low heat, and low power consumption can reduce the growth of bacteria in the container. This method allows the processing and preservation of food with no loss of nutritional value which preserves the flavor of the product to be more natural, safe for users, and easy to control. The test results of the prototype of a low-heat disinfection system with ozone technique in a high-pressure pulse were found that, at an ozone concentration of 4 ppm and a pressure of 50 KV, a frequency of 10 KHz at 20-35 minutes, the rate of the survival of the germ was significantly reduced: at 20 min sterilization, the growth rate was 270 cfu/ml, at 25 min, the growth rate was 160 cfu/ml. At 30 min sterilization, the growth rate was 47 cfu/ml, and at 35 min sterilization, the growth rate was 4 cfu/ml.

Keywords: Pulsed Electric Field (PEF), ozonation, food product sterilization

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1. Introduction

Currently, most pickled vegetables and fruits still suffer from inconsistent product quality problems, due to the use of microbial fermentation methods mixed with raw materials for fermentation and the risk of food spoilage from product packaging [1]. There are some unwanted bacteria in the food and some contamination of germs in the packaging before and after the raw material is loaded. To solve the problem of deterioration during product distribution to consumers and want to establish standards for fermented food products for safety, according to the Good Manufacturing Practice (GMP) system [2], the researchers suggested the need for sterilization of fermented food products to reduce costs, time, energy, and to increase production. The fermented foods products are as shown in Figure 1.

Since fermented foods are foods that are highly acidic, and with high salinity [3], the containers used must be made of acid- and salt-resistant materials and do not cause harm to consumers in sterilization of fermented foods. The product must be heated. To stop the fermentation process and destroy bacteria that will cause product deterioration, because the product is highly acidic, only heat at the pasteurization level is used by placing containers of pickles in a hot bath of 120 - 140 degrees Fahrenheit. Hot water is filled in a hot tub to a level of one inch above the rim of the containers. The hot water temperature was raised to 180 - 185 degrees Fahrenheit. The bottles then are sterilized for 30 minutes, after that they are immediately removed from the water bath. The heating of pickles before packing is known as hot packs. It kills microorganisms from growing. However, there is another method which is heating after filling by dividing both vegetables and marinade into jars before sterilization.

Currently, food is processed into two main types: 1) Thermal processing, which is an important and traditional process to disinfect and produce safe food. It is still a consumed and used method nowadays. 2) Food processing using low heat or not using heat (non-thermal processing), which is currently being researched for new technologies for food processing and preservation instead of high-temperature methods that destroy some nutritional value and still keep the product to be most natural. An example of new technology that has been applied is Pulsed Electric Field (PEF) technology [4]. Currently, there are many research studies about the use of PEF in the food industry, such as inhibiting microbial growth in food products and ozone (ozonation) using low heat. Low power consumption can reduce the growth of bacteria in the container to be safe for consumers and easy to control [5]. The use of technology to develop food sterilization processes requires knowledge of many fields of science to be applied together in chemistry microorganisms and engineering, in order to be able to implement these methods effectively and to obtain food that is safe for consumers.

2. Materials and Methods

2.1 Pulsed Electric Field (PEF) technique is a technique to remove contaminated microorganisms in liquid food by electrophoresis process (electroporation). When liquid food is stim-

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Figure 1: Fermented foods products.

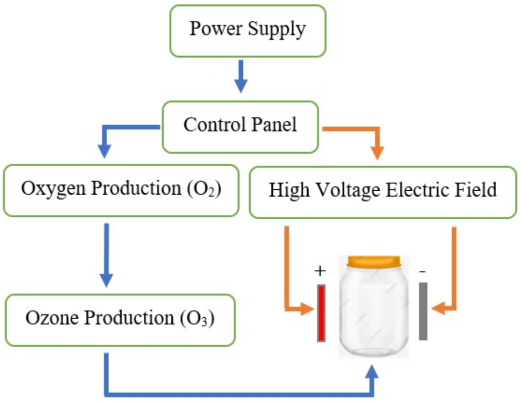

Figure 2: Prototype block diagram.

ulated by high electric field intensity, it produces ion mobility under pulsed electric field conditions at a repetition rate at a certain frequency [6] in a very short period of time, usually 10 - 3 to 10 - 6 sec, resulting in friction on the microbial cell wall, tearing and through pore formation. The extracellular fluid diffuses into the microbial cell around the pore formation [7]. An instantaneous increase in the internal osmotic pressure of the microbial cell occurs in the cell wall, causing the phenomenon of microbial cell proliferation from intracellular pressure until the injecting membrane was broken. That is big leading to permanent microbial cell death, while food cells that are larger than microbial cells are not affected. It is because the cell membrane of food cells has thick walls. So, there was a slight lack of injection, and food cells are able to repair themselves to their original state [8]. It was able to reduce microbial count during non-thermal processing by 4 – 6 log cfu/ml by destroying mold and yeast microorganisms in ready-to-drink juices such as orange juice, apple juice, pineapple juice, tomato juice, and water temperature. The fruit was not more than 40 °C and had a shelf life of more than or equal to 21 days at a storage temperature of not more than 7 °C. The quality, color, taste, and smell were equivalent to that of fresh fruit juice. The shelf life depends on the packaging hygiene and materials, as well as the storage conditions during transportation to the consumers. The sterilization by the pulsed high-voltage electric field is an electric current technique with high electric field intensity, using high-frequency electric field vibrations to destroy the microbial cell membrane. This makes it possible to eliminate bacteria, mold, and yeast that cause spoilage. In addition, because this process takes place at low temperatures, and in a short time,

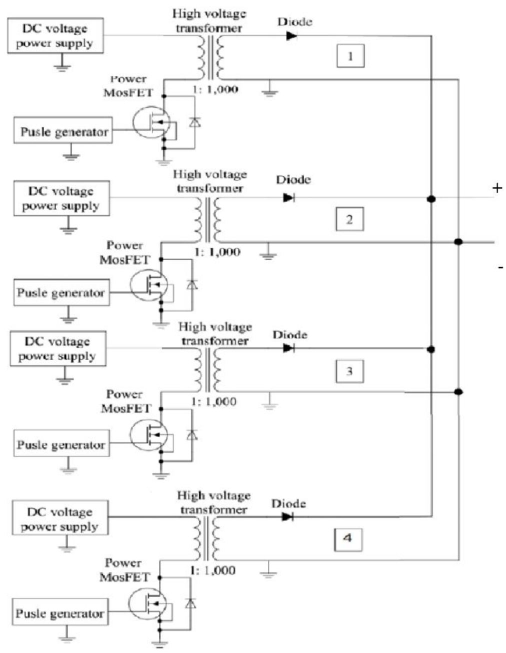

Figure 3: Prototype circuit diagram.

Table 1. The average ozone values in the developed disinfection cabinet and outside atmosphere.

Times (seconds)	Ozone turned on (ppm)	Ozone turned off (ppm)	Ozone output (ppm)
20	0.402	4.209	0.119
40	0.535	3.119	0.073
60	0.729	2.029	0.047
80	1.023	1.973	0.021
100	1.45	1.917	0.005
120	2.28	1.861	0.001
140	3.11	1.295	0
160	3.27	0.729	0
180	3.408	0.163	0
200	4.234	0.123	0
220	4.657	0.083	0
240	4.677	0.043	0
260	4.709	0.031	0
280	4.941	0.019	0
300	4.999	0.007	0

this makes it possible to preserve nutrients, freshness, and flavor without the use of additives and preservatives. The high-voltage drop across the cell membrane [9] can be calculated from the equation (1).

$$V_{cell} = f r_{cell} E_{cell} \tag{1}$$

Where V_{cell} is the maximum voltage across the cell membrane, f is a constant that depends on the shape of the cell, r_{cell} is the outermost radius of the cell membrane and E_{cell} is the value of the electric field stress at the cell membrane.

2.2 Ozone (Ozonation) is an oxidizing agent that destroys many types of microorganisms, including bacteria, yeast, and mold. Protozoa that can cause microbial spoilage and pathogens such as Escherichia coli, Listeria, Vibrio, and Salmonella. High oxidizing ability that interferes with the transfer of charge between the cell wall layers, destroys the cell wall structure of microorganisms and destroys various elements within the cell, resulting in acute damage to microbial cells and eventually death

Table 2. The physical quality analysis of the product before after using the developed continuous low heat sterilization system.

Product	Product			
	Hardness (N)		Firmness (N/mm)	
	Before	After	Before	After
Pickled Cabbage	48.85±4.61	48.85±0.01	146.29±0.41	146.32±0.02
Pickled Ginger 3 Flavors	6,309.21±847.44	6,309.24±0.01	49.03±0.00	49.07±0.02
Pickled Lemon	6.56±2.26	6.58±0.01	418.89±0.63	418.91±0.01

Table 3. The colors quality analysis of the product before after using the developed continuous low heat sterilization system.

Product	Colors					
	L*		a*		b*	
	Before	After	Before	After	Before	After
Pickled Cabbage	37±6.21	37.05±0.02	0.40±1.4	0.40±1.0	23.87±6.11	23.86±0.01
Pickled Ginger 3 Flavors	51.1±6.42	51.40±0.0.20	-0.2±0.42	-0.1±0.05	25.43±1.74	25.45±0.01
Pickled Lemon	36.83±0.73	36.36±0.02	9.03±0.71	9.06±0.01	21.07±0.19	21.06±0.02

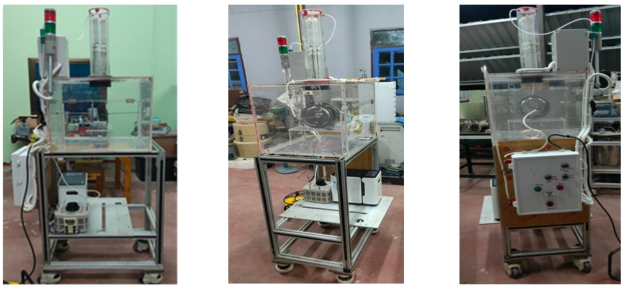

Figure 4: Prototype of a Low-heat sterilization system.

Figure 5: Low-heat sterilization system.

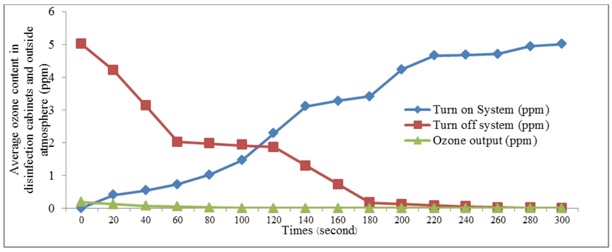

Figure 6: The relationship between time and the amount of ozone in the disinfection cabinet developed and outside atmosphere.

[10]. Currently, ozone is widely used for both disinfection and pollution removal, because ozone uses low production costs. However, there is a limitation. Ozone is harmful to humans if it is exposed to concentrations above 4 ppm continuously. Therefore, there must be a detection and alarm system with a good ventilation system in the area of use. Ozone is also a strong oxidizing agent which can corrode material surfaces. Therefore, it must be used on corrosion-resistant surfaces such as stainless steel. Nowadays, ozone has become one of the most popular methods in water treatment system, because it can remove heavy metals bacteria and odor. Additionally, it is used in the drinking water production process. Moreover, the ozone-treated water can be used for swimming pools, spas, agriculture, livestock farms, and water distribution systems.

2.3 Prototype The researchers created a prototype of a low-heat disinfection system using pulsed electric fields and ozone techniques. Its components are a high-voltage power supply, pulse electric fields ozone gas production section with corona discharge electrical, insulating, and command protection with user interface controls. Sterilization test procedure starts from putting foods in the cabinet, then setting the time for the ozone system to work, and emitting an electromagnetic field to disinfect together for about 30 minutes. This research model is shown in Figure 2, Figure 3, and Figure 4, respectively.

The researchers have developed a prototype of a low-heat sterilization system using electric field and ozone techniques for use at the laboratory level. For system structure, the pole base is made of aluminum profile and the cover is made of acrylic with the size of 50x50x100 cm. By inoculating in a petri dish and then using it for testing in the disinfection system, sterilization data were collected according to variables of pulse frequency, time, amount of ozone used in the system, and energy cost per area used for disinfection. A disinfection system for low heat with electric field techniques and ozone in the field based on prototype data from the laboratory was developed. The researchers tested the ozone content used in the disinfection system initially developed with a portable ozone gas detector. The results of the amount of ozone used in the developed disinfection system are shown in Table 1.

3. Results and Discussion

From Table 1, the test for the determination of ozone content used in a disinfection system was initially developed with a portable ozone gas detector. It revealed that when the system is turned on, the system can produce ozone gas in the disinfection cabinet to a concentration of 0.00 ppm. (part per million) to about 5.00 ppm. within 300 seconds, which is a concentration that can eliminate bacteria, or up to 99% of fungi within 2-5

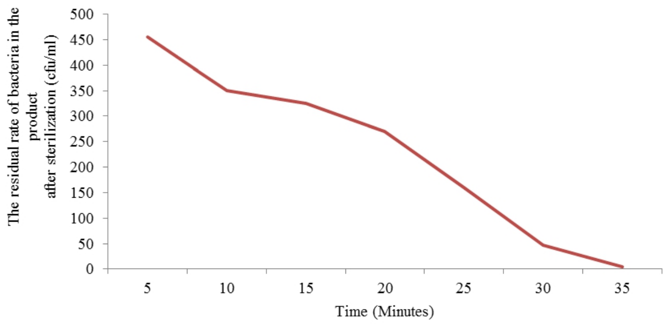

Figure 7: The relationship between time and the amount of ozone in the disinfection cabinet developed and outside atmosphere.

Table 4. Residual rate after using the prototype of a low-heat sterilization system using ozone and high-pressure pulse techniques.

Times (seconds)	The residual rate of bacteria in the product after sterilization (cfu/ml)
5	455
10	350
15	325
20	270
25	160
30	47
35	4

minutes. When the disinfection system is turned off, the system can reduce the ozone concentration in the disinfection cabinet to less than 0.100 ppm. within 180 seconds, by venting the ozone into the outside air with an extractor fan. The ozone concentration in the outside atmosphere is below 0.10 ppm. within 60 seconds, which is a certain level of operator safety. The results are shown in Figure 6. From Table 2 and Table 3, the results of the experiment compare the hardness, firmness, and colors of the sample foods. It showed that before and after using the system, the values are not much different.

When unsterilized samples of pickled lettuce and lemon from the food industry were tested, the growth of all microorganisms was found high at dilution level 101. The researchers, therefore, tested the germs obtained from the two product samples for the sterilization efficiency of a prototype low-heat sterilization system, using ozone in a strong pulse combination technique. The ozone concentration was about 4 ppm and the pressure were about 50 kV and the frequency were about 10 KHz at 5, 10, 15, 20, 25, 30, and 35 min, respectively. The growth rate of the inoculum was high (over 300 colonies/plate) at 20-35 min. As a result, it was found that the survival rate of the inoculum was significantly reduced a growth rate of 270 cfu/ml at a sterilization time of 25 minutes, a growth rate of 160 cfu/ml at a sterilization time of 30 minutes, and a growth rate of 47 cfu/ml at sterilization time of 35 minutes with a growth rate of 4 cfu/ml. The result is shown in Figure 7.

4. Conclusions

Analysis and evaluation of the engineering economics results from the conventional sterilization system to heat sterilization. Each cycle is used to boil an electric pot for producing 100 kilograms of products, using 35 electric units of energy, or about 175 baht, or 1.75 baht per kilogram. The cost of the developed system is about 200,000 baht per batch. Continuous sterilization of pickled vegetables and fruits can be stored in the packaging on the production line for approximately 250 kg per cycle (180 minutes per cycle). In conclusion, the low heat sterilization system with high voltage and corona ozone technique has reduced the cost per cycle because the system does not use high heat energy.

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