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THE EFFECT OF OZONE EXPOSURE TO EXTEND THE SHELF LIFE OF CARROTS (DAUCUS CAROTA L.) AGAINST VITAMIN C LEVELS AND HARDNESS

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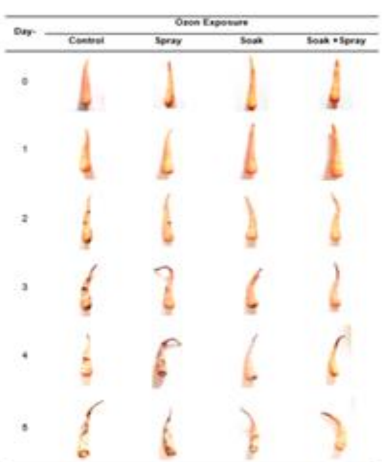
Graphical abstract



Abstract

The handling of post-harvest agricultural products has an impact on agricultural production. The handling should prevent factors that can lead to a decrease in the quality of agricultural products. Ozone exposure is done to find out the most effective shelf life for carrots. The sample consisted of 3 groups: the control group without ozone treatment (T0), the ozone exposure group through air or spray (T1), the ozone exposure group through immersion in water or soak (T2), and the spray and soak combination group (T3). Ozone exposure time is given for 10 minutes in a closed container. Further observed organoleptic changes, pH, hardness, and vitamin C levels contained in carrots after 1–5 days of storage. The research results showed that ozone treatment with various methods resulted in significant differences ($p = 0$) in mass loss, pH, and hardness of carrots. Ozone treatment with spray and soak on days 1–5 resulted in the stability of mass loss, pH, and hardness when compared to other treatment methods. The effect of ozone exposure on carrots by spray and soak can extend shelf life with the smallest percentage decrease based on the results of organoleptic tests, mass loss (58%), hardness (35%), and pH (22%), on the 5th day. So, ozone treatment is able to extend the shelf life of carrots based on their organoleptic and physical parameters.

Keywords: Food security, shelf life of carrots, ozone, organoleptic, pH, hardness, vitamin c

Abstrak

Pengendalian hasil pertanian lepas tuai memberi kesan kepada pengeluaran pertanian. Pengendalian itu harus menghalang faktor yang boleh menyebabkan penurunan kualiti produk pertanian. Pendedahan ozon dilakukan untuk mengetahui jangka hayat yang paling berkesan untuk lobak merah. Sampel terdiri daripada 3 kumpulan: kumpulan kawalan tanpa rawatan ozon (T0), kumpulan pendedahan ozon melalui udara atau semburan (T1), kumpulan pendedahan ozon melalui rendaman dalam air atau rendam (T2), dan kumpulan gabungan semburan dan rendam (T3). Masa pendedahan ozon diberikan selama 10 minit dalam bekas tertutup. Selanjutnya diperhatikan perubahan organoleptik, pH, kekerasan, dan tahap vitamin C yang terkandung dalam lobak merah selepas 1-5 hari penyimpanan. Hasil kajian menunjukkan bahawa rawatan ozon dengan pelbagai kaedah menghasilkan perbezaan yang ketara ($p = 0$) dalam kehilangan jisim, pH, dan kekerasan lobak merah. Rawatan ozon dengan semburan dan rendam pada hari 1–5 menghasilkan kestabilan kehilangan jisim, pH dan kekerasan jika dibandingkan dengan kaedah rawatan lain. Kesan pendedahan ozon pada lobak merah secara semburan dan rendam boleh memanjangkan jangka hayat dengan peratusan penurunan terkecil berdasarkan keputusan ujian organoleptik, kehilangan jisim (58%), kekerasan (35%), dan pH (22%), pada hari ke-5. Jadi, rawatan ozon mampu memanjangkan jangka hayat lobak merah berdasarkan parameter organoleptik dan fizikalnya.

Kata kunci: Keselamatan makanan, jangka hayat lobak merah, ozon, organoleptik, pH, kekerasan, vitamin c

1.0 INTRODUCTION

Geographically, the quality and production of agricultural products are influenced by the handling carried out on post-harvest agricultural products. Improper handling processes will lead to a decrease in the quality of agricultural [1]. The decrease in the quality of agricultural products is due to microorganisms, moisture content, temperature, enzymes, and other factors. Service modalities, especially disease detection instruments, have experienced rapid development, both based on ionizing and non-ionizing radiation. The growth of microbes itself is influenced by intrinsic factors, such as pH, nutrient content, and biological structure; and extrinsic factors, including humidity and temperature. To prevent or minimize these factors, it is necessary to preserve food [2].

Some methods are used to extend the shelf life of agricultural products or food, including photonic irradiation methods [3, 4]. Irradiation method using energy from ionizing radiation that converts neutral atoms into positively charged ions with gamma radiation. However, the ionizing light irradiation removes some of the nutrients from food [5]. Non-ionizing light can be used to reduce contaminant bacteria [6,7] and photo biomodulation [8].

To suppress the growth of pathogenic microorganisms in fruits and vegetables given exposure to chlorine. The use of chlorine only eliminates microorganisms on the surface of objects. In addition, chlorine is feared to react with pesticides and form new compounds that are toxic to humans [9]. The ozone method of food preservation has also been used on chili peppers. It is reported that ozone does not damage the nutritional content because, if exposed to sunlight, it evaporates into oxygen [10, 11].

Two types of ozone formation processes are collision processes and light particle absorption processes. In the process of absorption, ozone is formed from ultraviolet (UV) sunlight. The collision process is used in the formation of ozone by the method of release of dielectric stunted plasma. Ozone is a radical oxidant hydroxide that can be used to degrade heavy metal oxides and organic compounds. Therefore, it can kill microorganisms, thus extending the shelf life of food [12]. Based on previous research [3] ozone is able to reduce microbial contaminants and maintain the freshness of vegetable products.

The shelf life of carrots is expected to be longer after ozone exposure. The damage will be characterized by the presence of microorganisms, organoleptic, mass loss, pH, and hardness, as well as the content of vitamin C in carrots [13, 14]. In this study, ozone exposure treatment was studied for 10 minutes with variations in ozone exposure techniques, namely spray, soak, and combination of spray and soak. Furthermore, carrots are stored for 5 days and observed for their organoleptic, mass loss, pH, and hardness, as well as vitamin C levels.

2.0 METHODOLOGY

This research uses Daucus carrota L. obtained from Sumber Brantas Village, Batu City; KI solution 0.15 M, H2SO4 solution, Na_2SO_4 solution; and 1% amolum solution. Water is used as a medium for exposure to ozone in Sumber Brantas Village, Batu City; KI solution 0.15 M, H_2SO_4 solution, Na_2SO_4 solution; and 1% amolum solution. Water is used as a medium for exposure to ozone. Ascorbic acid is the standard (comparator) in the vitamin C level test.

An ozonator with an output of ≤ 400 mg/h was used in this study. Tools for ozone characterization were a set of iodometric tools such as burette tubes, oxygen tubes equipped with flowmeters, Erlenmeyer tubes, and measuring cups. The container is closed for ozone exposure in carrots.

Ozone calibration is using iodometric titration. Pure oxygen is delivered to the ozone generator at a flow rate of 1L/min. KI solution is gassed as much as 20 mL in the Erlenmeyer flask until the KI solution is yellow, this indicates that there has been a reaction of KI and ozone solution. Three drops of amimilum is added [15, 16]. The $Na_2S_2O_3$ solution on the burette acts as a titrant. Ozone concentration can be calculated using Equation 1.

$$O_3 concentration = \frac{mass\ of\ O_3}{volume\ of\ O_3} \qquad (1)$$

$$Mass\ of\ O_3 = \ 24xVtxNt$$

With the value of 24, which is a factor, Vt = volume of $Na_2S_2O_3$ (mL), Nt = normality of $Na_2S_2O_3$ (mg/me), and me = molar equivalent.

Ozone exposure is done to find out the most effective shelf life for carrots. The sample consisted of 3 groups: the control group without ozone treatment (T0), the ozone exposure group through air or spray (T1), the ozone exposure group through immersion in water or soak (T2), and the spray and soak combination group (T3). Each treatment is performed by limiting the exposure time to 10 minutes. Ozone exposure is performed in isolated or closed containers. Then I performed organoleptic observations, mass loss, pH, hardness, and vitamin C every day until the fifth day [11].

Testing with spectrophotometers using wavelengths of 271 nm. The absorption value of the sample is displayed. Data analysis is shown by the absorption of samples to the calibration curve using linear regression, Equation 2.

$$Y = BX + A \qquad (2)$$

Where (Y) represents the value of the absorbance measurement and (X) states the vitamin C levels in the sample.

One Way ANOVA factorial tests are used to analyze quantitative data using Statistical Package for Social Science (SPSS). There are 3 test groups for ozone exposure: air (spray), water (soak), and air + water (spray+ soak) methods, and there is one treatment factor, which is the time of exposure. The percentage reduction formula for various parameters is:

$$\%\,reduction = \frac{(control - treatment)}{control}\ x\ 100\% \qquad (3)$$

3.0 RESULTS AND DISCUSSION

In this study, ozone was produced by dielectric obstructed plasma discharge. That is, by placing a dielectric material in the form of glass between two electrodes with high voltage. Dielectric material serves as a current filament containing energy-energized electrons of 1–10 eV. The voltage is then applied to the electrode. The voltage between the two electrodes is known by the?? , where a indicates time. Then the electric field perpendicular to both electrode plates is known by So that the formula

$$E_r = \frac{V_0 \varepsilon_r}{h + \varepsilon_r (d - h)} \qquad (4)$$

When two gaps filled with oxygen collide, oxygen atoms (O) result from the collision of the electrons. The oxygen atom will pound another oxygen atom and produce ozone. The process occurs due to a voltage that accelerates the motion of electrons from the anode to the cathode. When the voltage between the electrodes is higher, the electric field inside the reactor is also higher. So electrons have higher energy, which results in more ionization. The higher the electron motion, the higher the growth process, which is influenced by the length of time, resulting in higher ozone concentrations [17].

In this study, ozone was used because it is considered safe enough and does not leave chemical residues on food. Ozone also has advantages compared to other preservation methods. The advantage is that ozone will not change or damage the nutritional content of the product, because ozone will evaporate into oxygen when exposed to sunlight [18].

Table 1 shows the results of the statistical analysis of various ozone treatments on carrots. The results showed that ozone treatment with various methods resulted in significant differences (p = 0) in mass loss, pH, and hardness of carrots. Meanwhile, the measurement of vitamin C levels showed no significant difference. Ozone treatment with spray and soak on day 5 resulted in the stability of mass loss, pH, and hardness when compared to other treatment methods. The effect of treatment on vitamin C levels in carrots showed no significant difference (p = 0.57).

Table 1 Statistical analysis of the results of various ozone treatments on carrots

Parameter	Treatment	Reduction Percentage (%)										Statistical analysis
		Day 1		Day 2		day 3		day 4		Day 5		
		Mean	STD	Mean	STD	Mean	STD	Mean	STD	Mean	STD	
Loss Mass	Control	15.43	1.73	36.58	2.01	44.26	3.61	66.69	1.53	76.30	0.58	P = 0.00 Significant different
	spray	15.10	3.06	34.25	2.00	45.74	4.16	52.13	1.00	67.45	1.00	
	soak	14.12	2.89	30.14	1.51	39.11	5.13	53.86	3.61	63.47	2.00	
	Spray + soak	2.35	1.00	22.14	1.02	39.37	3.06	53.41	3.79	58.52	2.52	
pH	Control	14.56	0.47	19.42	0.01	22.05	0.05	22.15	0.08	26.81	0.34	P = 0.00 Significant different
	spray	4.34	0.10	16.02	0.30	20.08	0.06	19.99	0.12	21.84	0.08	
	soak	17.42	0.03	17.47	0.00	21.29	0.06	21.79	0.03	23.86	0.10	
	Spray + soak	7.88	0.30	13.66	0.02	21.13	0.12	22.09	0.06	22.36	0.02	
Hardness	Control	21.83	1.33	35.18	0.54	42.37	2.47	47.71	0.98	55.71	1.76	P = 0.00 Significant different
	spray	6.89	0.47	15.62	0.43	41.32	1.53	52.00	2.84	57.43	1.41	
	soak	14.55	1.48	15.70	0.00	29.15	0.62	41.70	2.26	55.62	1.02	
	Spray + soak	20.02	0.77	20.65	0.00	29.39	0.30	33.10	0.74	35.13	2.78	
Vitamin C	Control	7.35	1.10	7.47	0.00	16.81	2.69	17.45	2.40	33.08	3.21	P = 0.57 No-significant different
	spray	7.84	1.52	8.10	0.01	13.09	1.61	16.21	2.99	34.97	3.00	
	soak	20.59	3.51	28.10	0.33	28.08	1.25	33.71	8.05	41.24	8.03	
	Spray + soak	3.21	0.86	6.84	0.03	16.82	2.69	14.99	1.85	38.13	0.00	

Mass Loss

Figure 1 shows the largest mass loss of carrots with and without exposure to ozone, over time from day 1 to day 5. Exposure to the ozone spray method produces carrots with the highest mass loss value. While the spray-and-soak method has the best influence on the shelf life of carrots with the smallest mass loss compared to other methods,

The results of studies showed that exposure to ozone through the air + water is able to maintain the hardness of the stem, and carrots appear to shrink because the value of mass loss increases every day. This happens because carrots lose water in the evaporation process.

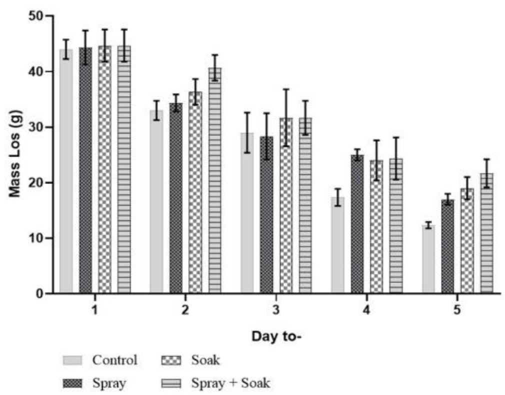


Figure 1 Effect of ozone exposure on mass loss (g)from Day xx to xx

Organoleptic

Figure 2 shows the observation of the effect of ozone exposure on carrot organoleptic. Changes that occur take the longest time compared to carrots exposed to the ozone spray method, the soak method, or carrots that are not exposed to ozone. Ozone exposure in carrots by the soak method still withers the carrots, starting to decay from day 3 to day 5. While carrots are subjected to ozone exposure using the spray method, they decompose starting on day 2.

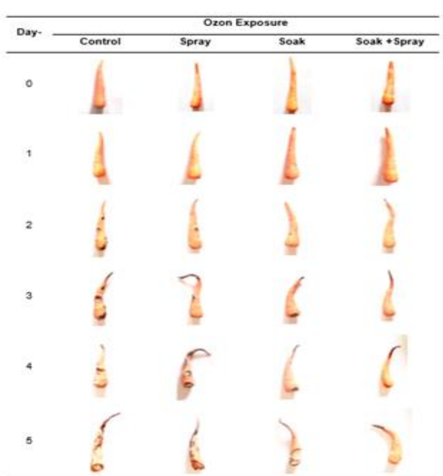


Figure 2 Observation of the effect of ozone exposure on carrot organoleptic

The change in color from orange to pale in organoleptic tests occurred due to changes in carrot carotene. Carotene is easily damaged by acid; this damage causes the color of carrots to turn pale orange. The black discoloration is also caused by microorganisms growing on carrots. These microorganisms can stimulate ethylene hormones. It is this ethylene hormone that can accelerate carrot decay [19].

pH Levels

Figure 3 shows the effect of ozone treatment on the pH of samples. The pH of carrots that were not spread by ozone or control samples decreased at day 2, and over time, it continued to decrease until the fifth day. The carrot group with ozone spray treatment experienced a decrease in pH from day 1 and pH stability on the third to fifth days. The group of carrots treated by immersion and spray treatment with ozone resulted in a stable pH.

Loss of water causes carrot stems to wilt and increase mass loss. During storage, water evaporation occurs in carrots to balance the system temperature in the carrot with the temperature in the outside environment [3]. When compared with other treatments, the immersion and spray treatment of ozone resulted in a good organoleptic stability effect, which was indicated by a stable pH and low mass loss.

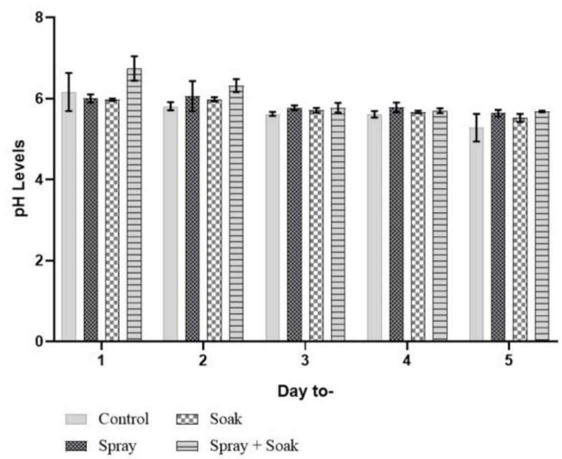


Figure 3 Ozone exposure to pH levels of?

Hardness

Figure 4 shows the effect of ozone exposure on the hardness of carrots. Hardness in carrots that were not exposed to ozone or control samples decreased on the 2nd day, and gradually began to decrease until the 5th day. In the carrot group with the immersion treatment, the hardness decreased as the storage time went on. The hardness of carrots in the ozone spraying group decreased on the third day, but the hardness was lower than the treatment without ozone exposure or the control sample. While the hardness of carrots with spray + soak treatment experienced a long change compared to carrots that were smeared with ozone by spraying, soaking, or not being given ozone (control).

The results showed that exposure to ozone through the water method had a longer shelf life for carrots than the air exposure method. Exposure to ozone in the air can cause cell apoptosis or cell damage. This is because unstable oxygen diffuses into the carrot tissue so that electrons are excited to a higher level. Excited electrons will react with biological systems by transferring protons or electrons and will form anion and cation radicals [15]. Radical ions react with oxygen to produce reactive oxygen. The electron transport reaction produces a superoxide anion. Then the superoxide anion reacts with the biological system and forms a hydroxyl radical. Hydroxyl radicals are the most damaging and diffuse into carrot tissue, resulting in apoptosis or damaged cells [20].

While exposure through water can maintain the shelf life of carrots longer because ozone will oxidize the ions contained in the water so that they decompose. Decomposition occurs when ozone reacts with OH ions and forms hydroxyl radicals. The hydroxyl radical ion will diffuse into the carrot cells and cause the enzymes in the cytoplasm to become inactive. When the enzyme is not active, it will cause the respiration process to be hampered. Respiration produces water. The inhibition process was able to maintain the water content in carrots and the shelf life of carrots.

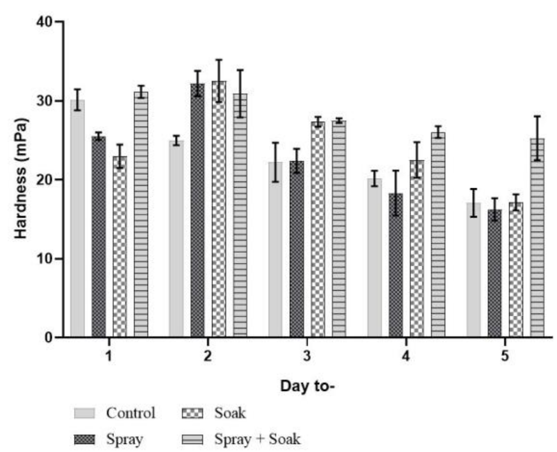


Figure 4 Effect of ozone exposure to the hardness of carrots

Vitamin C

Figure 5 shows vitamin C levels in carrots that were not peeled with ozone or control samples that experienced a fluctuating decrease in vitamin C levels for 5 days of observation. The levels of vitamin C in the carrots that were sprayed decreased on the third day. The levels of vitamin C in carrots that were treated with immersion decreased on the second day, but the levels of vitamin C were lower than the levels of vitamin C in the control sample. Meanwhile, the vitamin C content of carrots treated with soaking and spray changed for a long time compared to carrots that were smeared with ozone with spray, soaked, or not exposed to ozone. However, on day 5, ozone exposure was more effective through spraying.

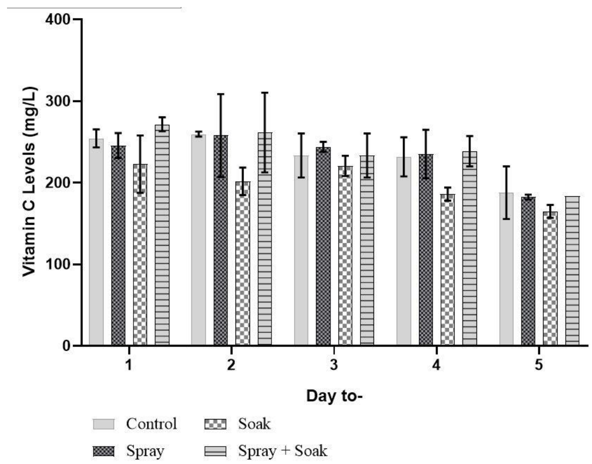


Figure 5 Ozone exposure to vitamin C level (mg/L)

Vitamin C levels in carrots were tested using a UV-Vis spectrophotometer. The UV-Vis spectrophotometer tests vitamin C levels by detecting the sensitivity of the sample solution. Light on a UV-Vis spectrophotometer absorbs the color of the sample solution at a certain wavelength. Vitamin C levels use a wavelength of 271 nm. In this study, the levels of vitamin C produced had different values for each treatment. However, the existence of different results is thought to be due to the influence of inaccuracies in the procedure for obtaining vitamin C sample solutions [21].

4.0 CONCLUSION

The research results showed that ozone treatment with various methods resulted in significant differences ($p = 0$) in mass loss, pH, and hardness of carrots. Ozone treatment with spray and soak on day 5 resulted in the stability of mass loss, pH, and hardness when compared to other treatment methods. The effect of ozone exposure on carrots by soak and spray can extend shelf life based on organoleptic test results, mass loss, hardness, pH, and vitamin C.

References

[1] Haifan, M. 2017. Review Kajian Aplikasi Teknologi Ozon untuk Penanganan Buah, Sayuran dan Hasil Perikanan (Review Study of Ozone Technology Applications for Handling Fruits, Vegetables and Fishery Products). *IPTEK Journal.* 1(1): 15-21.
Doi: Https://Doi.Org/10.31543/Jii.V1i1.99.

[2] Mandal, R., Shi, Y., Singh, A., Yada, R.Y. and Pratap Singh A. 2020. Food Safety and Preservation. *Encyclopedia of Gastroenterology*. 2nd ed. Doi: https://doi.org/10.1016/b978-0-12-801238-3.65904-4.

[3] Astuti, S. D., Drantantiyas, N. D. G., Putra, A. P., Puspita, P. S., Syahrom, A., Suhariningsih. 2019. Photodynamic Effectiveness of Laser Diode Combined with Ozone to Reduce Staphylococcus Aureus Biofilm with Exogenous Chlorophyll of Dracaena Angustifolia Leaves. *Biomedical Photonic*. 8(2): 4-13 Doi: 10.24931/2413–9432–2019–8–2–4–13.

[4] Astuty, S. D., Suhariningsih., Baktir, A., and Astuti, S. D. 2019. The Efficacy of Photodynamic Inactivation of the Diode Laser in Inactivation of the Candida albicans Biofilms with Exogenous Photosensitizer of Papaya Leaf Chlorophyll. *Journal of Lasers in Medical Sciences*. 10(3): 215. Doi: 10(3):215-224. doi:10.15171/jlms.2019.35.

[5] Bramasto, Y., Zanzibar, P. K., and Danu, M. 2016. The Utilization Gamma Rays Radiation to Improve the Viability of Sengon Seed. *Jurnal Hutan Tropis*. 4(1): 14-20.

[6] Setiawatie, E. M., Astuti, S. D., Zaidan, A. H. 2016: An In Vitro Anti-microbial Photodynamic Therapy (aPDT) with Blue LEDs to Activate Chlorophylls of Alfalfa Medicago sativa L on Aggregatibacter Actinomycetemcomitans. *Journal of International Dental and Medical Research*. 9(2): 111-117

[7] Sunarko, S. A., Ekasari, W., and Astuti, S. D. 2017. Antimicrobial Effect of Pleomeleangustifolia Pheophytin a Activation with Diode Laser to Streptococcus Mutans. *Journal of Physics: Conference Series*. 853: 012039. Doi: 10.1088/1742-6596/853/1/012039.

[8] Suhariningsih., Winarni, D., Husen, S. A., Khaleyla, F., Putra, A. F., and Astuti, S. D. 2020; The Effect of Electric Field, Magnetic Field, and Infrared Ray Combination to Reduce HOMA-IR Index and GLUT 4 in Diabetic Model of Mus musculus. *Lasers in Medical Science*. 35: 1315-1321. Doi: https://doi.org/10.1007/s10103-019-02916-z.

[9] Karaca, H., and Velioglu, Y. S. 2007: Ozone Applications in Fruit and Vegetable Processing. *Food Reviews International*. 23(1): 91-106. Doi: https://doi.org/10.1080/87559120600998221.

[10] Karaca, H., and Velioglu, Y. S. 2020. Effects of Ozone and Chlorine Washes and Subsequent Cold Storage on Microbiological Quality and Shelf Life of Fresh Parsley Leaves. *Lwt*. 109421. Doi: https://doi.org/10.1016/j.lwt.2020.109421.

[11] Saraslifah, N. M., and Arianto, F. 2016: Pengaruh Ozon yang Dibangkitkan Melalui Reaktor Plasma Berpenghalang Dielektrik Elektroda Silinder Spiral Terhadap Pengawetan Cabai. *Youngster Physics Journal*. 5(4): 319-326.

[12] Syafarudin, A. 2013. Produksi Ozon dengan Bahan Baku Oksigen Menggunakan Alat Ozon Generator. *Jurnal Teknik Kimia*. 19(2): 1-9.

[13] Gibney, M. J., Lanham-New, S. A., Cassidy, A., and Vorster, H. H. 2009. *Introduction to Human Nutrition*. 2nd Edition. USA: Wiley Blackwell.

[14] Han, Y. J., Gharibeshghi, A., Mewis, I., Förster, N., Beck, W., and Ulrichs, C. 2020. Plant Responses to Ozone: Effects of Different Ozone Exposure Durations on Plant Growth and Biochemical Quality of Brassica campestris L. ssp. chinensis. *Scientia Horticulturae*. 262(August). Doi: https://doi.org/10.1016/j.scienta.2019.108921.

[15] Astuti, S. D., Wibowo, A., Abdurachman, Triyana, K. 2017. Antimicrobial Photodynamic Effects of Polychromatic Light Activated by Magnetic Fields to Bacterial Viability. *Journal of International Dental and Medical Research*. 10(1): 111-117.

[16] Puspita, P. S., Astuti, S. D., Nasution, A. M. T., Pradhana, A. A. S., and Mawaddah, A. 2020. Photodynamic Therapy with Ozone Aids to Staphylococcus Aureus Biofilm Reduction. *The Indian Veterinary Journal*. 97(02): 24-26.

[17] Ikehata, K., and Li, Y. 2018: Ozone-based Processes. Advanced Oxidation Processes for Wastewater Treatment. *Emerging Green Chemical Technology*. 115-134. Doi: https://doi.org/10.1016/B978-0-12-810499-6.00005-X.

[18] Astuti, S. D., Arifianto, D., Drantantiyas, N. D. G., Aulia, M. T. N., and Abdurachman. 2017. Efficacy of CNC-diode Laser Combine with Chlorophylls to Eliminate Staphylococcus Aureus Biofilm. *Publishing in International Seminar Sensors, Instrumentation, Measurement, and Metrology (ISSIMM), IEEE Xplore 5 January 2017, INSPEC Accession Number*: 16563895, Doi: 10.1109/ISSIMM.2016.7803722.

[19] Hu, H., Zhao, S., Li, P., and Shen, W. 2018. Hydrogen Gas Prolongs the Shelf Life of kiwifruit by Decreasing Ethylene Biosynthesis. *Postharvest Biology and Technology*. 135(May 2017): 123-130. Doi: https://doi.org/10.1016/j.postharvbio.2017.09.008.

[20] Glowacz, M., Colgan, R., Rees, D. 2015. The Use of Ozone to Extend the Shelf-life and Maintain Quality of Fresh Produce. *Journal of the Science of Food and Agriculture*. 95(4): 662-671. Doi: https://doi.org/10.1002/jsfa.6776.

[21] Suhartati, T. 2017. Dasar-dasar Spektrofotometer UV-Vis dan Spektrofotometer Massa untuk Penentuan Struktur Senyawa Organik. Bandar Lampung: Anugrah Utama Raharja.