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Ozonation Treatment, Edible Coating Carrageenan, and Temperature Variation on The Quality of Fresh-Cut Pineapple During Storage

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ABSTRACT

Fresh-cut pineapples are increasingly popular in Indonesia, but it damage easily due to contamination of pathogenic microorganisms, resulting in a short shelf life. This research aims to examine the effect of applying ozone and edible carrageenan coating on the quality of fresh-cut pineapple stored at low temperatures. The experiment used factorial completely randomized design. The first factor was concentration of carrageenan and the second factor was storage temperature. Based on the lowest TPC (total plate count) value from a preliminary research, the experiment was conducted with soaking time of 60 s. Results showed that weight loss, hardness, and TDS values was respectively 2.24 %; 13.03 °Brix; 11.42 kgf, and tended to increase until the last day of storage. The best results was found at 2.5% carrageenan coating and 5 °C. Results from the organoleptic test, however, found the highest score of 4.41 was collected from 1.5% carrageenan coating and 5 °C. It can be concluded that the combination of soaking in ozonized water for 60 s, immersing the fruit in a 2.5% edible coating carrageenan solution stored at 5 °C can maintain the quality of the fruit and increase the shelf life of fresh-cut pineapple compared to controls that were not given any treatment.

1. INTRODUCTION

Nanas (*Ananas comosus* Merr) is one of the horticultural commodities widely cultivated in Indonesia. Pineapples contain many beneficial nutrients, such as vitamin C (36.65 mg/100 g wb), vitamin A (55 IU/100 g wb), vitamin B3 (0.306 mg/100 g wb), and minerals such as potassium (K) (125-178 mg/100 g wb), calcium (Ca) (13 mg/100 g wb), magnesium (Mg) (12-20 mg/100 g wb), and phosphorus (P) (9-13 mg/100 g wb) (Assumi *et al*., 2021). Besides whole pineapples, sliced or minimally processed pineapples are also available in the market. In this case, fruits need to be peeled, washed, and cut before consumption. Lifestyle changes demand practicality, and consumers are increasingly seeking the health benefits of fresh fruit. This is a market opportunity for fresh-cut pineapples (Darmajana *et al*., 2017). The long processing time and difficulties in peeling the skin and removing the multiple fruit ("eye seeds") is one of the obstacles for consumers when consuming fresh pineapple fruit (Pizato *et al*., 2019). The above mentioned factors cause people to switch their choice to ready-to-eat fresh-cut pineapple (Cordoba & Usme, 2019).

Fresh-cut pineapple available in the market have a short shelf life due to the cutting process, which can increase respiration rate, thus reducing the shelf life to only 1-3 days even at optimal temperatures due to the rapid growth of microorganisms (Adiani *et al*., 2020). So far, there have been several efforts to maintain the quality of pineapple cuts. Physical treatments have been implemented such as UV-C treatment and heat treatment (George *et al*., 2015), ultrasound (Yeoh *et al*., 2017), or high-pressure argon and nitrogen gas treatments (Wu *et al*., 2012). However, some of these physical treatments may cause damage to pineapples, characterized by changes in color, loss of aroma, appearance of odor, loss of vitamin C, softening, and texture changes.

Ozone technology in the food industry has been proven to be more effective in handling spoilage-causing microorganisms compared to chlorine and other disinfectants. Ozone also does not leave chemical residues, and ozone gas easily degrades into oxygen molecules naturally, making it environmentally friendly (Aafia *et al*., 2018). Ozone can be produced using the corona discharge (CD) method, which is widely used in industries. The principle is as follows: a dry gas flow containing oxygen, called a carrier gas, flows through a thin gap separating two metal electrodes; one electrode is covered with a dielectric material. An alternating voltage of several thousand volts is applied between the two electrodes. This voltage generates an electrical discharge filament between the two electrodes (low-intensity band) that separates the gas and produces very strong unstable and ionized gas called "cold plasma." Oxygen molecules (O_2) are broken down in the gas, resulting in the formation of oxygen atoms (O). To stabilize, these atoms attach to other oxygen molecules (O_2) to form ozone (O_3) (Sarron *et al*., 2021).

In a study conducted by Asgar *et al*. (2015), the use of ozone technology with a concentration of 1 ppm can maintain the freshness of chili peppers during storage for up to 14 days at 10 °C. Meanwhile, in a study by Zainuri *et al*. (2018), it was mentioned that the combination of ozone treatment and packaging with polyethylene plastic can maintain the quality and even extend the shelf life of tomatoes for 12 days at room temperature, while fruits without ozone and packaging showed signs of spoilage with microbial growth on the sixth day of storage. In addition to the use of ozone technology, fresh-cut pineapples can also be coated with edible coatings that can help inhibit fungal growth on the fruit, protect against bruising, and improve appearance (Yousuf *et al*., 2018).

Based on research conducted by Novita (2016), an edible coating of carrageenan and glycerol with a concentration of 3% and 2%, respectively, is the best treatment for coating Kristal guava during storage. One of its benefits is reducing weight loss by only 40.87% on the 18th day, while the control reached 52.39%. One of the widely used methods to maintain the quality of fresh-cut pineapples is by storing them at optimal low temperatures. Based on research by Benitez *et al*. (2012), it was reported that on the 2nd and 4th days, the hardness of pineapples stored at 4 °C was superior to those stored at 7 and 13 °C. Therefore, in this study, an effort is made to maintain the quality of fresh-cut pineapples by providing ozone treatment and coating them with carrageenan flour-based edible coating packaged in transparent plastic film and stored at low temperatures.

2. MATERIALS AND METHODS

2.1. Materials and Tools

The research was carried out from November 2021 to March 2022 at the Fresh Handling Laboratory, Organoleptic Laboratory and Microbiology Laboratory, Center for Agricultural Postharvest Research and Development in Cimanggu, Bogor City, West Java Province. The material used in this research is Bogor honey pineapple at maturity level 4 with the characteristic yellow fruit “eyes” reaching 50-75%. Dissolved ozone in water is prepared at a concentration of 1 ppm. Other ingredients include DPD free chlorine reagent, clear plastic mica, plate count agar (PCA) media and carrageenan flour as an edible coating material (IndoGum), 100% food grade glycerol (Naturalpedia), distilled water, and stearic fatty acid (Aloin).

2.2. Fresh-Cut Pineapple Sample Preparation

The pineapple fruit used was purchased from pineapple farmers in Bogor, West Java. Three pineapples were used for each repetition. In preliminary research, 3 repetitions were carried out. Pineapples were selected that have the characteristics of a more open crown, wrinkled stem, flatter eyes, rounder shape, the color of the skin at the base of the fruit begins to turn yellow, and the aroma of the fruit begins to appear. Next, sorting was carried out to select fruit that is not physically damaged. After that, minimal processing was carried out on the fruit by cutting the crown and peeling the pineapple skin manually using a clean stainless steel knife. The "eyes" of the pineapple were removed following the plot, then the fruit was sliced into 9 circles and each slice was cut into 8 pieces, resulting in 72 pieces as experimental material with a thickness of ±3 cm. After that, the fresh-cut pineapple was washed using clean water.

2.3. Dissolved Ozone Preparation

The ozone used in this research was obtained from a Biobase JA-30A ozone generator with an ozone gas flow rate of 30 g/hour. Ozone is produced by the silent discharge method, namely by passing air (20% of which is oxygen) through a narrow gap with an alternating electric voltage (AC) difference of the order of kilo-volts. The purpose of making ozone using the dielectric blocked discharge method is to obtain low concentration ozone between 0.01 ppm to 4.00 ppm (Siahaan & Widayanti, 2020). The way it works is that the ozone generator is connected to a voltage source, then turned on, then the ozone gas flows through a hose which is inserted into a closed container containing distilled water. The generator was turned on for 20 minutes to obtain an ozone concentration of 1 ppm. The ozone concentration produced by the generator was measured using an inScienPro ZE-200 photometer.

2.4. Preliminary Research

Preliminary research aims to determine the best soaking time for the ozonation process on fresh-cut pineapples. The results of this stage will be used in the main research. The parameters used to determine the best ozone soaking time are based on the results of observing the number of microbes using the Total Plate Count (TPC) test. The fresh-cut pineapples were put into a container containing distilled water using a fruit net to facilitate the slicing process. Ozonation is carried out on each treatment sample, so that the fruit in the net must be completely submerged. After that, the pineapple cuts were soaked with the following treatment: (1) soaking for 60 s, (2) 90 s, (3) 120 s, and 4) without immersion as a control. Then stored at a temperature of ±10 °C for 10 days (Aguayo *et al*., 2014). The microbiological quality of the pineapple was observed to determine the best soaking time. The microbiological quality parameters observed were the total colony count of fungi or the Total Plate Count (TPC) test. The best immersion time will be used in the main research.

2.5. Primary Research and Experimental Design

After knowing the best immersion time using ozone with a concentration of 1 ppm from the results of preliminary research, it was then continued with the main research, namely edible coating treatment, which looked at its effect on cold storage at different temperatures. The main research consists of four important stages, namely the application of ozone gas (ozonation) with the best immersion time according to the results of preliminary research, making the carrageenan edible coating formula, application of the edible coating and storage, and analysis of quality parameters.

The experimental design used in the main research was a factorial Completely Randomized Design (CRD) with 2 treatment factors and three replications. The first factor is the concentration of carrageenan edible coating, namely 2.5% (C1), 1.5% (C2), and control (C3) ((w/v). The second factor is the variation in storage temperature, namely 5 °C (T1), 10 °C (T2), 15 °C (T3). The data obtained were analyzed using two-way Analysis of Variance (ANOVA) with the significance level expressed in $P_{\text{value}} < 0.05$. Then continued with the Duncan Multiple Range Test (DMRT) with a confidence level of 95% ($\alpha = 0.05$) using software SPSS 26.

2.5.1. Application of ozone gas (ozonation)

The application of ozone gas was carried out using the same procedure as in the preliminary research. However, more fruit was used, because it was adjusted to the needs of each test parameter with a thickness of ± 3 cm. In the main research, 3 repetitions were carried out with different time spans. The soaking time used is the best treatment as a result of preliminary research. Ozonation was carried out on each sample, except for the samples used as controls, namely samples that were not given any treatment. After soaking in the ozone solution, the fresh-cut pineapples were placed in a fruit filter, then dried in the air before being coated with an edible coating.

2.5.2. Preparation of the Edible Coating Formula for Carrageenan

The procedure for making 500 ml of edible coating formula is that distilled water (distilled water) is heated with a hot plate to a temperature of 70±1 °C. Then the carrageenan flour (1.5% and 2.5% (w/v)) was dissolved little by little into the distilled water (aquades) while stirring for ±5 minutes until homogeneous. Once homogeneous, glycerol (0.25% (v/v)) was added to increase the elasticity of the layer while continuing to stir. After everything was dissolved, stearic fatty acid (0.25% (w/v)) was added while continuing to stir for ±5 minutes until homogeneous. Stearic acid can reduce the value of the water vapor transmission rate because of its hydrophobic nature which makes it difficult for water vapor to penetrate the sample (Haloho *et al*., 2021).

2.5.3. Edible Coating Application and Storage

To apply edible coating, pineapple cuts were dipped in the edible coating solution for 30 s, then drained and air-dried. After that, it is packaged in PP plastic containers. Storage was carried out at temperatures of 5, 10, and 15 °C. Cut pineapple that was not coated with edible coating was kept as a control. Storage was carried out for 10 days at temperatures of 5, 10, and 15 °C. Next, quality measurements were carried out on pineapples cuts during storage, consisting of measurements of weight loss, hardness, color, total dissolved solids (TDS), and organoleptic.

2.5.4. Quality Parameter Analysis

The quality parameters used on fresh-cut pineapple during storage consist of physico-chemical properties which include: weight loss, hardness, color, total plate count (TPC), Total Dissolved Solids (TDS) test and organoleptic test. Organoleptic tests are carried out to determine the level of consumer acceptance of color, aroma, texture and taste.

3. RESULTS AND DISCUSSION

3.1. Total Plate Count (TPC) Test Results

The results of TPC measurements are shown in Figure 1. The fastest microbial growth occurred in pineapple without ozone or control (K) treatment, while the slowest microbial growth occurred in the treatment of soaking the pineapple in ozonized water for 60 seconds (6). According to Kuswati *et al*. (2020), the length of time ozone is exposed to materials affects the half-life of ozone so that its effectiveness in inhibiting or suppressing microbial populations becomes greater. Long exposure to ozone has a big effect in reducing microbial growth on materials. The mechanism of ozone (O3) in destroying microorganisms is through the lysis process, ozone reacts with oxidized cellular components, especially those containing double bonds, sulfhydryl groups and phenolic rings. Therefore, membrane phospholipids, intracellular enzymes, and genomic material are targets of ozone, and these reactions result in cell damage and death of microorganisms (Aafia *et al*., 2018).

In the soaking treatment for 90 and 120 s (9 and 12) there was no significant difference in microbial growth, and it was only slightly faster than soaking for 60 s. This is because the longer the fruit cuts are soaked in ozonized water, the softer the fruit will become so it will spoil more quickly. If the fruit is damaged, microbes can grow more quickly. The research results of Miller *et al*. (2013) also showed the same thing, prolonged exposure to ozone will accelerate fruit damage. Oxidative stress from ozone exposure to fruit accelerates the occurrence of enzymatic reactions that lead to browning of the fruit skin.

Based on Figure 1, it can be seen that the fruit in the control treatment experienced a very significant increase in microbial growth since storage on the fourth day and continued to increase until the tenth day of storage. There was a very significant increase in microbial growth due to the fact that from the start there were more microbes on the control fruit and they did not receive cleaning with ozone treatment. Fruit that is contaminated with microbes from the start will rot more quickly. At H0 (day 0), some pineapples had been treated with ozone, while others were not treated with ozone (as controls), this is what caused the number of microbes at H0 to be different in each sample. According to Alegbeleye *et al*. (2022), gram-positive bacteria, gram-negative bacteria, and fungi are commonly known spoilage agents in fruit and vegetables. In Figure 1, the last day of storage was on the 10th day with the number of control microbes being 7.47 log CFU/ml which was the highest number compared to the number of microbes in the other three treatments, namely 6.26 log CFU/ml in soaking 60 seconds, 6.43 log CFU/ml at 90 s immersion, and 6.68 log CFU/ml at 120 s immersion. Based on these results, it can be seen that ozone treatment can kill and inhibit the growth of microorganisms in fresh-cut pineapples with the best results being soaked for 60 s. Apart from the number of microorganisms on the 10th day of storage, this conclusion is also seen from the growth of microorganisms during the 10th day of storage which shows that the least increase is soaking for 60 s. These results are in accordance with research conducted by Wang *et al*. (2019) used ozone gas on tomatoes, when the ozone concentration was higher and the exposure duration was longer allowing greater microbial destruction, unfortunately bleaching occurred in the tomato epidermis layer. So it is not always linear between ozone concentration, exposure time, and ability to destroy microbes. This can be influenced by the type of material used in the research. The same thing happens when soaking pineapples in ozonized water. Soaking fruit for too long can cause damage to the outer skin layer of the fruit cuts, making it more susceptible to rot.

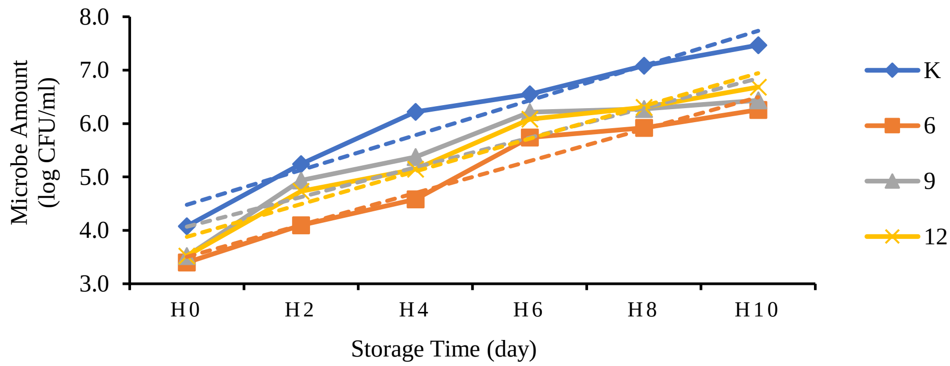

Figure 1. The growth of microbes

According to Ziyaina *et al*. (2021), ozone has bactericidal properties that can kill microorganisms such as viruses, bacteria, fungi and protozoa, which are the causes of foodborne diseases and food spoilage. Ozone can actively destroy bacterial and fungal spores because apart from its bactericidal and viral activity, ozone also has sporicidal, fungicidal and protozoicidal properties (Vitali & Valdenassi 2019). The lysis process in bacteria, namely the cell membrane is the first place to be attacked, then ozone attacks certain glycoproteins, glycolipids, or amino acids, and acts on the sulfhydryl groups of certain enzymes, then the effect of ozone on the cell walls begins to be seen, bacterial cells begin to be damaged after coming into contact with ozone, cell membranes are perforated during this process and ultimately the cells are destroyed or undergo cellular lysis (Rojas-Valencia, 2011).

3.2. Test Results of Several Parameters in Main Research

3.2.1. Weight Loss

During storage of fresh-cut pineapples, there was an increase in weight loss in all treatments, both control fruit and fruit treated with coating. The rate of weight loss varied between each treatment with a tendency to increase from the beginning to the end of storage. The effect of edible coating and storage temperature on the weight loss of pineapple cuts on the 10th day of storage is presented in Table 1. The highest weight loss of pineapple was in the C3T3 treatment (control fruit at a temperature of 15 °C) on the 10th day of observation which reached 7.07%. These results indicate that there is still a respiration process during storage which results in water loss in the fruit, thus affecting weight loss. Weight loss will definitely occur in fruit during storage, but coating treatment can reduce the rate of weight loss that occurs. At low temperature storage, metabolism occurs more slowly which will then reduce the respiration and transpiration rate of the fruit, resulting in less water loss. The lowest pineapple weight loss was on the 10th day of observation, namely in the C1T1 treatment (2.5% carrageenan at a temperature of 5 °C) of 2.24%. Based on the ANOVA test (p<0.05), pineapple stored at a temperature of 5 °C was the best in suppressing weight loss, although statistically it was not significantly different from a temperature of 10 °C, but was significantly different when stored at a temperature of 15 °C.

Based on the ANOVA test (p<0.05) on day 2, it showed that there was a significant difference between the edible coating treatment and the control. Meanwhile, on day 4 there was a significant difference between the 2.5% coating treatment and the control, and there was no significant difference between the 1.5% coating treatment and the control. Until observations on the 10th day, pineapple fruit coated with edible coating with a carrageenan concentration of

2.5% (C1) had the lowest increase in weight loss compared to other treatments at various temperatures. This can be seen from the ANOVA test results which show that the 2.5% coating treatment has the lowest value. In accordance with research by Darmajana *et al*. (2017) on fresh-cut melons stored at 10 °C for 6 days showed that carrageenan was able to inhibit the reduction in weight loss compared to that of control. This happened because fruit without coating would lose water content in the fruit, whereas fruit with a layer coating only loses water from the coating material.

Table 1. Effect of carrageenan edible coating and storage temperature on weight loss of fresh-cut pineapples during storage

Treatment	Day of storage					
	0	2	4	6	8	10
Carrageenan						
2.5%	0	0.78a	1.7a	2.57a	3.34a	3.71a
1.5%	0	0.86a	1.9ab	2.84a	3.87a	4.31a
Control	0	1.37b	2.5b	3.46a	4.4a	5.35a
Storage Temperature						
5 °C	0	0.56a	1.31a	1.97a	2.57a	3.19a
10 °C	0	0.9a	1.65a	2.66a	3.51a	4.14a
15 °C	0	1.56b	3.15b	4.25b	5.54b	6.05b
Interaction	ns	ns	ns	ns	ns	ns

Note: Numbers followed by different letters in the same column indicate a significant effect (p<0.05) in DMRT (*ns* = not significant)

Aitboulahsen *et al*. (2018) reported the weight loss increased during the storage period of strawberries for 13 days at 4 °C and there was a significant difference (p≤0.05) between those treated with coating (only increased by 3%) and controls (increased up to 24%). Apart from that, in the research of Dwivany *et al*. (2020) stated that carrageenan coating treatment stored at low temperatures can optimally reduce banana water transpiration compared to the control treatment. According to Khaliq *et al*. (2015), edible coating acts as a barrier to water transmission and the transpiration process which is the main cause of increased weight loss. The results of this research indicate that edible carrageenan coating and cold storage are quite capable of reducing the increase in weight loss of pineapple cuts.

3.2.2 Total Dissolved Solids (TDS)

Based on data analysis from the research results, it shows that during 10 days of storage, all treatments, whether given edible coating or not, tended to experience an increase in TDS values. The effect of edible coating and storage temperature on the TDS value of pineapple cuts on the 10th day of storage is presented in Table 2. The lowest TDS value was found in C1T1 fruit (2.5% carrageenan, 5 °C) with an average of 13.03 °Brix, and the highest was the control treatment with average of 13.99 °Brix. This value within the standards of the United Nations (2013), where the acceptance of pineapple fruit by consumers is a minimum of 12 °Brix. This is also in line with the results of research from Treviño-Garza *et al*. (2017) which stated that the TDS content in pineapple cuts treated with edible coating from pullulan plant slime and chitosan experienced a lower increase compared to controls stored for 18 days at 4 °C.

Table 2. Effect of carrageenan edible coating and storage temperature on total soluble solids of fresh-cut pineapples during storage

Treatment	Day of storage					
	0	2	4	6	8	10
Carrageenan						
2.5%	13.2a	13.31a	13.3a	13.26a	13.18a	13.37a
1.5%	13.34a	13.52a	13.5a	13.48a	13.62a	13.7a
Control	13.42a	13.64a	13.57a	13.72a	13.75a	13.85a
Storage Temperature						
5 °C	13.08a	13.11a	13.11a	13.22a	13.2a	13.37a
10 °C	13.12a	13.5ab	13.41ab	13.42a	13.49ab	13.53ab
15 °C	13.76b	13.85b	13.85b	13.82a	13.86b	14.01b
Interaction	ns	ns	ns	ns	ns	ns

Note: Numbers followed by different letters in the same column indicate a significant effect (p<0.05) in DMRT (*ns* = not significant)

Based on the results of ANOVA statistical analysis with a significance level ($p<0.05$), it is known that the edible coating treatment did not have a significant effect on the TDS value, even though the edible coating treatment had a lower TDS value than the control. Moreira *et al*. (2014) stated that the low TDS value is caused by the gas barrier properties of edible coatings against the external environment, namely being able to suppress respiration and transpiration rates which slow down metabolism so that it can delay fruit maturity. In line with research by Pizato *et al*. (2019), in minimally processed pineapples there was an increase in the soluble solids content in fresh-cut pineapples along with the length of storage. The control sample showed the highest increase during 12 days of storage, and the coating treatment with tara gum experienced the lowest increase. This result is caused by the significant water loss experienced by the fruit, causing an increase in TDS concentration.

In the current study, fresh-cut pineapple having the lowest increase in weight loss was fruit with 2.5% coating treatment (C1), which caused a lower increase in TDS value compared to the control (C3) which had the highest increase in weight loss resulting in an increase in TDS value, which was more significant in the control treatment. Research on fresh-cut pineapple by Prakash *et al*. (2020) also found a significant increase in TDS in control samples in 12 days of storage, at a temperature of 4 °C, while all edible coating treatments tended to remain the same during storage. Storage temperature has a significant effect on the TDS value of pineapple cuts. Pineapples stored at a temperature of 5 °C experienced the lowest increase in TDS values, followed by a temperature of 10oC and a temperature of 15 °C. Insignificant changes in TDS values are expected to occur because pineapple is a non-climacteric fruit and its sugar content does not cause TDS values to change during storage.

Table 3. Effect of carrageenan edible coating and storage temperature on hardness fresh-cut pineapples during storage

Treatment	Day of storage					
	0	2	4	6	8	10
Carrageenan						
2.5%	11.33	11.51	11.48	11.66a	11.94a	12.17a
1.5%	11.50	11.55	11.69	11.96ab	12.18ab	12.45a
Control	11.94	12.06	12.03	12.61b	12.68b	13.24b
Storage Temperature						
5 °C	11.11a	11.12a	11.16a	11.45a	11.6a	11.9a
10 °C	11.67ab	11.76ab	11.57a	12.1ab	12.36b	12.57b
15 °C	11.99b	12.24b	12.47b	12.68b	12.84b	13.38c
Interaction	ns	ns	ns	ns	ns	ns

Note: Numbers followed by different letters in the same column indicate a significant effect ($p<0.05$) in DMRT (*ns* = not significant)

3.2.3. Hardness

The effect of edible coating and storage temperature on the hardness of fresh-cut pineapple on the 10th day of storage is presented in Table 3. The hardness value of fresh-cut pineapple ranges from 10.82 (lowest day 0) – 14.22 (highest day 10) kgf shows that the texture of pineapple is soft. Control fruit at each storage temperature had the greatest hardness value compared to the two coating treatments. This means that the control fruit has lower hardness statistics than the treatment statistics using edible coating. This is related to the working principle of the penetrometer, namely the penetration of the needle into the material tissue with a certain pressure for a certain time (Weliana *et al*., 2014). If the number shown by the tool is greater, it means that the penetrometer needle is deeper into the fruit, and it can be concluded that the fruit is getting softer. From the results of ANOVA statistical analysis with a significance level ($p<0.05$) in Table 3, it shows that edible coating has a real effect on the hardness of pineapple fruit during storage on days 6, 8 and 10. Meanwhile, storage temperature shows a real effect on hardness since first day of storage. This is in line with research by Moreira *et al*. (2015), where the edible coating treatment had a significant effect ($p<0.05$) on the hardness of freh-cut apples stored at a temperature of 4±1 °C, and was significantly different compared to the control.

3.2.4 Organoleptic

The organoleptic test results in Table 4 show that the edible coating treatment and storage temperature increased the panelist preferences for all parameters, with the highest level of liking for the pineapple color parameter, namely 4.75

in the C2T1 treatment (1.5% carrageenan at a temperature of 5 °C). The effect of edible coating and storage temperature on the organoleptic test results of fresh-cut pineapple fruit is presented in Table 8. The highest score of panelist preferences for taste, texture, aroma and color was the C2T1 treatment (1.5% carrageenan at 5 °C) with consecutive scores, namely 4.39; 4.07; 4.43; 4.75 and a total preference score of 4.41. These results are in accordance with research conducted by Dwivany *et al*. (2020) used Cavendish bananas, namely treatment with 1.5% carrageenan edible coating combined with storage at low temperature (20 °C) is the best treatment to delay ripening and optimally preserve the fruit, both in terms of taste and also the physical quality of the banana. This treatment maintained a shelf life six days longer than the control. These results are in line with research by Dea *et al*. (2010) who showed that fresh-cut mango slices had a longer shelf life when stored at 5 °C compared to 12 °C because there were significant changes in appearance and aroma at higher temperatures compared to lower temperatures.

Table 4. Effect of carrageenan edible coating and storage temperature on hedonic score of fresh-cut pineapples during storage

Treatment	Quality Parameter			
	Taste	Texture	Aroma	Color
Carrageenan				
2.5%	3.20a	3.26a	3.19a	3.76a
1.5%	3.77b	3.82b	3.65b	3.87a
Control	3.86b	3.85b	3.48ab	3.55a
Storage Temperature				
5 °C	4.06b	3.9b	4.16c	4.35c
10 °C	3.89b	3.8b	3.4b	3.71b
15 °C	2.88a	3.24a	2.77a	3.12a
Interaction	ns	ns	ns	ns

Note: Numbers followed by different letters in the same column indicate a significant effect ($p<0.05$) in DMRT (*ns* = not significant)

Based on the results of ANOVA statistical analysis with a significance level ($p<0.05$), there is a real influence between edible coating treatments but there is no significant difference in color parameters. However, even though the 2.5% carrageenan concentration has a thicker edible coating layer than 1.5% carrageenan, the overall results are not better than the thinner layer. This result was caused by the fact that at a carrageenan concentration of 2.5%, the edible coating layer was too thick so that it greatly inhibited the exchange of oxygen in the fruit, or even did not experience respiration at all, this is what gave rise to anaerobic respiration in the fruit. Anaerobic respiration can cause the cells in the fruit to renovate internally which can result in the rotting process occurring more quickly than normal. But on the other hand, if the concentration of edible coating is too low, the effect will be minimal or even have no effect at all (Aini *et al*., 2019). Meanwhile, storage temperature has a significant effect on all parameters, storage at 5 °C is better in maintaining pineapple quality parameters compared to temperatures of 10 °C and 15 °C.

The observation data on the weight loss, hardness, TDS parameters at the 10th day of storage and average organoleptic test results are shown in Table 5.

Table 5. Effect of carrageenan edible coating and storage temperature on hardness of fresh-cut pineapples during storage

Treatment	Weight Loss (%)	Hardness (kgf)	TDS (°Brix)	Organoleptic Test			
				Taste	Texture	Aroma	Color
C1T1	2.24	11.42	13.03	3.43	3.36	3.75	4.21
C2T1	2.87	11.91	13.21	4.39	4.07	4.43	4.75
C3T1	4.25	12.38	13.31	4.36	4.05	4.29	4.07
C1T2	3.53	12.27	13.14	3.68	3.54	3.29	4.04
C2T2	4.15	12.33	13.43	3.93	3.96	3.71	3.82
C3T2	4.73	13.11	13.67	4.07	3.89	3.18	3.29
C1T3	5.17	12.83	13.64	2.50	2.89	2.54	3.05
C2T3	5.92	13.09	13.95	3.00	3.43	2.82	3.04
C3T3	7.07	14.22	13.99	3.14	3.39	2.96	3.29

4. CONCLUSION

The best results from ozone treatment on fresh-cut pineapple fruit were immersion for 60 seconds, immersion in ozone water for 60 seconds had the lowest microbial growth until the 10th day of storage, with a total microbial value of 6.26 log cfu/ml. Then, based on the ANOVA statistical test ($p<0.05$) followed by the DMRT, there was a real effect of the carrageenan edible coating treatment on the weight loss and hardness parameters, but there was no significant difference in the TDS value. Meanwhile, storage temperature has a significant effect on all parameters. Until the end of storage, the 2.5% coating treatment at 5 °C had the lowest weight loss, hardness and TDS values, namely 2.24% respectively; 11.42 kgf; 13.03 °Brix. Meanwhile, control fruit had the highest value. Based on organoleptic tests, the best results were obtained from a combination of 1.5% carrageenan treatment at a temperature of 5 °C with a favorability score of 4.41. It can be concluded that the combination of soaking in ozonized water for 60 s, soaking the fruit in a 2.5% carrageenan edible coating solution stored at 5 °C can maintain the quality of the fruit and increase the shelf life of fresh-cut pineapple fruit compared to controls that were not given any treatment.

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