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The Use of Chitosan Coating to Maintain the Quality of Cherry Tomatoes (*Lycopersicum esculentum* var. *cerasiforme*)

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ABSTRACT

Cherry tomatoes are prone to deteriorate during storage. Proper post-harvest technology is needed to maintain the quality of cherry tomatoes. This research aims to examine the effect of chitosan coating and storage temperature on the quality of cherry tomatoes and determine the optimal treatment. Cherry tomatoes of the Fortesta variety were used for experiment. Cherry tomatoes were dipped in chitosan solution with concentrations of 1% and 2%, and control. Each group of cherry tomatoes was then stored at temperatures of 15°C and 25°C. The research was arranged under a factorial completely randomized design with three replications. Measurement was performed on respiration rate, weight loss, firmness, total soluble solids, and organoleptic tests (freshness, color, and aroma) of cherry tomatoes. The results showed that chitosan coating affects the respiration rate, weight loss, firmness, total soluble solids, and organoleptic tests. Storage temperature affects respiration rate, weight loss, firmness, total soluble solids, and organoleptic tests. Chitosan coating of 2% concentration and storage temperature of 15°C were the best treatments that were able to suppress respiration rate, weight loss, firmness, total soluble solids, and were still accepted by panelists on the 21st day of storage. In contrast, the control only lasted until the 12th day of storage.

1. INTRODUCTION

Cherry tomatoes (*Lycopersicum esculentum* var. *cerasiforme*) are one of the types of tomatoes that are quite popular with the Indonesian people. Cherry tomatoes are one of the agricultural commodities that provide great benefits to the body because they contain high levels of vitamin A, vitamin B, vitamin C, carbohydrates, fat, and protein (Manalu & Rahmawati, 2019). Cherry tomatoes have an economic advantage over other tomatoes because the selling price is high and relatively stable. Cherry tomatoes are more commonly found in modern markets than in traditional markets.

Cherry tomatoes are horticultural products that are easily damaged, degraded, and have a relatively short shelf life if not stored with special treatment. Postharvest damage to tomato fruit caused by improper handling is estimated at 20% to 50% of the harvest cherry tomatoes are classified as perishable fruit because of the large water content reaching 94% of its total weight (Rudito, 2005). In addition, cherry tomatoes are a climatic fruit, so the ripening process continues even though the fruit has been picked. The rapid decline in quality is caused by transpiration and respiration activities. According to (Wulandari & Ambarwati, 2022), the presence of oxygen, carbon dioxide, and water vapor has an impact on the respiration process that affects the physiological condition of the fruit. The high selling price of cherry tomatoes, their perishable nature, and easy quality decline encourage the need for innovation in the postharvest handling process of the fruit.

A postharvest method that can be used to maintain fruit quality so that it is still in good condition is fruit coating. Edible coating is a thin layer applied by dipping the fruit into a coating solution made from consumable materials and can function as a barrier to mass transfer such as oxygen, water vapor, and carbon dioxide to maintain product quality and shelf life (Cipta *et al*., 2021). Chitosan was chosen as a coating material because it has odorless, tasteless, flexible, and transparent characteristics (Mudyantini *et al*., 2018). The ability of chitosan as a coating layer can increase shelf life, reduce respiration rates, able to form a good film so that it can inhibit the damage and ripening of fruits and vegetables (Jianglian, 2013). Da Silva *et al*. (2024) reported that passion fruit coated with chitosan and beeswax exhibited a reduction in respiration rate, a slower ripening process by approximately 3 days, and a significant decrease in weight loss. The composite coating of chitosan can be applied as an effective strategy to improve postharvest fruit quality of guava, cherry tomatoes, sugar-apple fruit,

Another postharvest method that can be used is storage temperature control. This method is one of the important factors in maintaining fruit quality to keep it fresh during storage. Decreasing storage temperature is an effective treatment to reduce the rate of respiration, therefore cooling is considered an economical way to store fruit in the long term (Mudyantini *et al*., 2018). The combination of cold temperature treatment and chitosan coating is expected to maintain the quality of cherry tomatoes, rather than just one treatment. This study is expected to obtain the best effect and formulation of chitosan coating treatment and storage temperature to maintain the quality of cherry tomatoes during storage.

2. MATERIALS AND METHODS

2.1. Materials and Equipment

The material used was cherry tomatoes of Fortesta variety that obtained from Lima Sukses Utama Farm, Cipayung Datar Village, Megamendung District, Bogor Regency, West Java. The harvest age of cherry tomatoes is 95 days after planting (HST) with a maturity level of 60-90% light red classification (ripe phase). The materials used to make the edible coating solution consisted of chitosan powder and 1% acetic acid solution (1 ml acetic acid and 99 ml distilled water) as solvent.

The equipments used were magnetic stirrer (IKA C-MAG HS 7) to stir the chitosan solution, a digital balance (PM4800) to weigh the weight and chitosan powder, a rheometer (CR-500DX) to measure firmness, a refractometer (ATAGO PAL-α) to measure sweetness, a gas analyzer (IRA-107 Shimadzu) to measure respiration rate, a refrigerator to store cold temperature samples, and a HELMA thermometer to measure storage temperature.

2.2. Procedures

Freshly harvested cherry tomatoes were sorted by selecting the same color and size, and free from plant diseases. After sorting, cherry tomatoes were washed using food grade soap. The washing method refers to research conducted by Rosdiana *et al*. (2021). The chitosan concentrations used in this study were 1%, 2%, and 0% (control). The 1% (w/v) chitosan solution was prepared by dissolving 1 gram of chitosan powder in 100 ml of 1% acetic acid (1 ml acetic acid and 99 ml distilled water) at 40°C for 60 minutes using a magnetic stirrer. The resulting filtrate was then stirred for an additional 15 minutes. Similarly, the 2% (w/v) chitosan solution was prepared using the same method, with the only difference being the ratio of 2 grams of chitosan powder dissolved in 100 ml of 1% acetic acid. The coating was done by dipping the cherry tomatoes into chitosan solution at 1% and 2% concentration for 1 minute. Then the cherry tomatoes were removed and air-dried at an air-conditioned room temperature of 25°C so that the chitosan layer dried evenly on the surface of the cherry tomatoes before storage. After the chitosan coating process was completed, cherry tomatoes were placed in sample containers for each treatment and stored at 15°C and 25°C.

2.3. Experimental Design and Data Analysis

The experimental design used was a factorial complete randomized design using 2 factors with 2 repetitions. The first factor is chitosan concentration with levels, namely 1%, 2%, and control. The second factor was storage temperature with 3 levels, namely 15°C and air-conditioned room temperature (25°C). The treated samples were stored for 21 days at 3-day intervals (0, 3, 6, 9, 12, 15, 18, 21 days). Data on the effect of treatment on the observation response were analyzed using analysis of variance (ANOVA) at the 95% confidence level ($\alpha = 0.05$). If the results were significantly influenced, it was continued with Duncan's Multiple Range Test (DMRT). Analysis of variance and DMRT were performed using IBM SPSS 23 software.

2.4. Observation and Measurement

2.4.1. Respiration Rate

Respiration rate measurements obtained data in the form of changes in O_2 and CO_2 gas concentrations using the closed system method. Measurement with this method is done by inserting cherry tomato samples ±64 g into a 260 ml glass jar as a chamber with tightly closed conditions, where the edges of the lid are coated with plasticine to prevent potential leakage (Hasbullah, 2007). Measurements were made with two data collection times where in each data collection each treatment had two replicates. The interval between the first and second data collection was 3 hours. The rate of CO_2 gas production or O_2 consumption can be calculated through Equation (1).

$$R = \frac{V}{W}\frac{dx}{dt} \tag{1}$$

where R is respiration rate (ml.kg^{-1}.h^{-1}), x is gas concentration O_2 or CO_2 (%vol), t is time (h), V is free volume of the respiration chamber (ml), and W is product weight (kg).

2.4.2. Weight Loss

Weight loss were calculated by observing the changes in tomatoes weight measured daily using a PM4800 analytical balance. Weight loss (S_b) was calculated from initial weight (W_o) and final weight (W_t) using Equation (2).

$$S_b\ (\%) = \frac{W_o - W_t}{W_o} \times 100\% \tag{2}$$

2.4.3. Firmness

The firmness of tomatoes were measured using a CR-300 model rheometer with setting mode of 20, maximum load 10 kg, at a pressing depth of 10 mm, load drop speed of 30 mm/minute, and needle diameter of 5 mm (Krismayanti, 2007). The position of the tomato was tested in the radial direction. The resulting data is in the form of the maximum weight that the fruit can receive until the rheometer test rod can penetrate the tomato peel.

2.4.4. Total Soluble Solids

Analysis of total soluble solid (TSS) content was conducted using the ATAGO PAL-α Digital Refractometer. The TSS value is indicated by a number on the LCD expressed in °brix in the range 0 to 85°. Some of the tomatoes are taken and squeezed to get the liquid extract. The extract was dropped onto a refractometer prism, and the total soluble solids value was recorded.

2.5. Organoleptic Test

Organoleptic tests were conducted to determine the level of acceptance of the tomatoes by the panelists. The assessment was carried out every 3 days of storage by 30 untrained panelists. The parameters tested consisted of color, aroma, and freshness. The test scale used is the value of 1 (dislike very much), 2 (dislike), 3 (neutral), 4 (like), and 5 (very much like) with a score of 3 indicating moderate preference (neutral).

3. RESULTS AND DISCUSSION

3.1. Respiration Rate

Respiration is a parameter that is closely related to the quality and shelf life of the fruit. The higher the respiration rate, the faster the ripening and the shorter the shelf life of the fruit (Putra, 2022). Changes in O_2 consumption rate during storage of cherry tomatoes at 15°C and 25°C can be seen in Figure 1 (a) and (b). There is a difference in the peak of ripeness between cherry tomatoes stored at 15°C and 25°C on the O_2 consumption rate. The chitosan coating treatment at each storage temperature delayed the spike in O_2 consumption rate for up to 3 days. The lowest O_2 consumption rate on day 15 was for cherry tomatoes with 2% chitosan coating treatment and 15°C storage temperature. This is due to the temperature treatment which provides a protective effect or inhibits the respiration rate process (Saiduna & Madkar, 2013). The lower the storage temperature, the less O_2 used for respiration. In addition, the concentration level of chitosan has a significant effect on the respiration of cherry tomatoes because the respiration process in the fruit occurs through the surface of the fruit skin.

The ANOVA test results showed that chitosan coating, storage temperature and the interaction between the two had a significant effect on the O_2 consumption rate of cherry tomatoes on the 6th day of storage. The results of Duncan's further test at the 5% level, chitosan coating with a concentration of 2% at a storage temperature of 15°C is significantly different from the control treatment, while 1% chitosan coating is not significantly different from the control treatment and 2% chitosan coating. At a storage temperature of 25°C, the chitosan coating treatment was significantly different from both the control treatment, as well as the coating with a concentration of 1% and 2%.

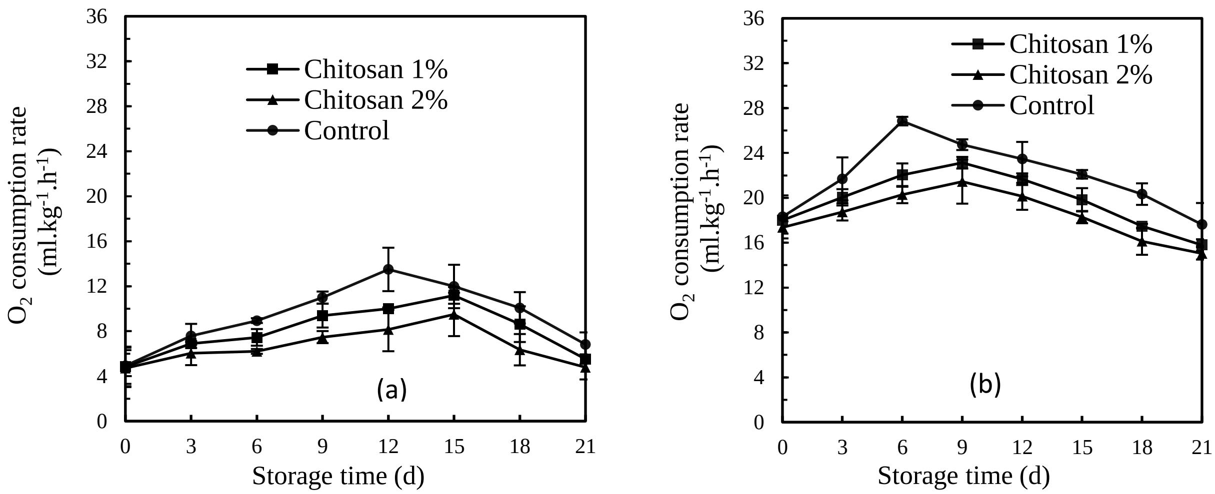

Figure 1. Effect of chitosan coating and storage temperature on O_2 consumption rate of cherry tomatoes (a) 15°C (b) 25°C

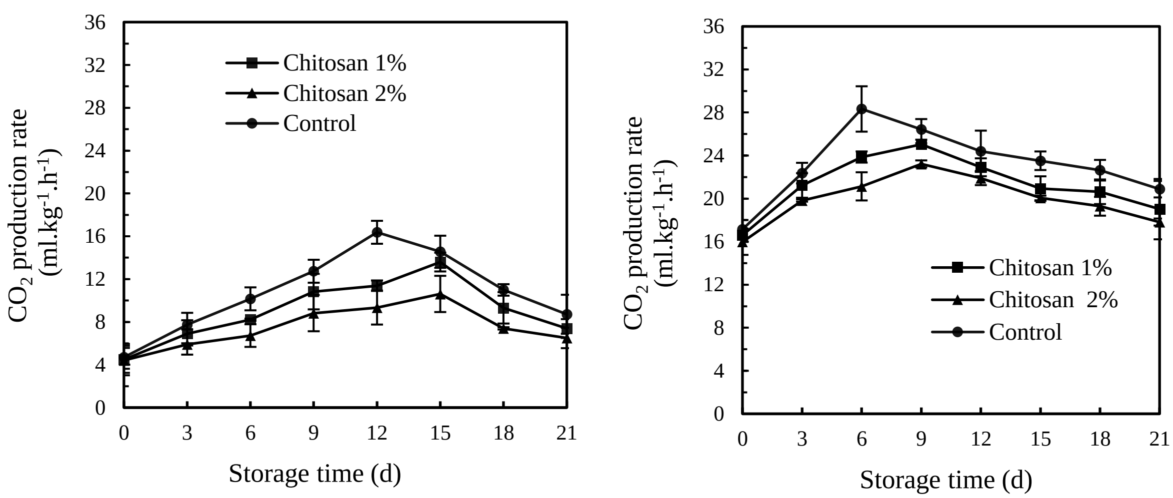

Figure 2. Effect of chitosan coating and storage temperature on CO_2 production rate of cherry tomatoes (a) 15°C (b) 25°C

Figure 2a and 2b show the changes in CO_2 production rate during storage at temperature of 15°C and 25°C. The figure show there is a difference in the peak of ripeness between cherry tomatoes stored at 15°C and 25°C on the rate of CO_2 production. Chitosan coating treatment at each storage temperature delayed the spike in CO_2 production rate up to 3 days equal to the O_2 consumption rate. The lowest CO_2 production rate on day 15 was for cherry tomatoes with 2% chitosan coating treatment and 15°C storage temperature. The rate of CO_2 production affects the shelf life of the fruit after harvest (Kusuma *et al*., 2022). The higher the CO_2 production and the faster the climacteric peak is reached, the shorter the potential shelf life of the fruit.

The ANOVA test results showed that chitosan coating and storage temperature had a significant effect on the value of CO_2 production rate, but the interaction between the two factors had no effect, presumably there was a leak in the CO_2 production measuring device hose on the 6th day of storage. The results of DMRT at the 5% level, chitosan coating with a concentration of 2% at a storage temperature of 15°C is significantly different from the control treatment, while 1% chitosan coating is not significantly different from the control treatment and 2% chitosan coating. At a storage temperature of 25°C, the 2% chitosan coating treatment was significantly different from the control. For coating with 1% concentration, it was significantly different from the control, but not significantly different from 2% chitosan coating.

3.2. Fruit quality

During the storage of the fruit, there is an increasing in the fruit weight loss, decreasing in the fruit firmness and decreasing in the total soluble solids. The effect of chitosan coating and storage temperature on tomato quality after being stored for 15 days can be seen in Table 1. Chitosan coating and storage temperature had significant effects on weight loss, firmness and total soluble solids.

Table 1 Effect of chitosan coating and storage temperature on tomato quality after being stored for 15 days.

Coating material	**Temperature (°C)**	**Weigh loss (%)**	**Firmness (kgf)**	**Total soluble solid (°Brix)**
Chitosan 1%	15	8.09±0.93 b	1.54±0.06 cd	6.45±0.26 abc
Chtosan 2%		6.19±0.42 a	1.74±0.17 d	6.08±0.12 a
Control		9.17±0.76 b	1.37±0.09 bc	7.02±0.45 cd
Chitosan 1%	25	21.67±1.10 d	1.15±0.03 ab	6.78±0.21 bc
Chitosan 2%		15.83±0.47 c	1.35±0.10 bc	6.37±0.09 ab
Control		24.93±0.17 e	0.93±0.10 a	7.48±0.17 d

Notes: Numbers followed by different letters in the same column indicate significantly different in the Duncan test at the 5% level.

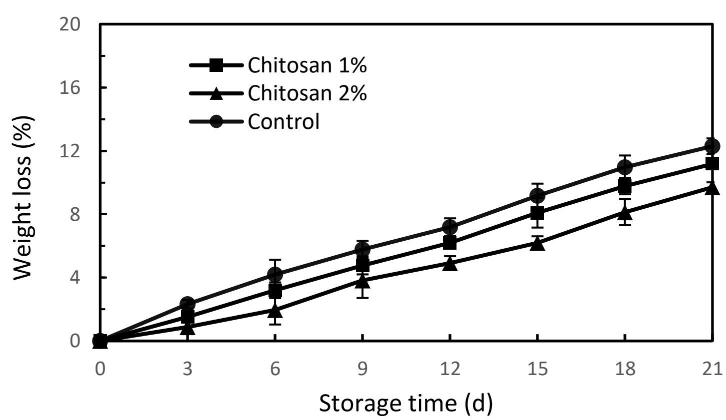

Figure 3. Effect of chitosan coating on weight loss of cherry tomatoes at 15°C of storage.

3.2.1. Weight Loss

Weight loss is a process where there is a decrease in fruit weight caused by respiration and transpiration. In the respiration process, the fruit absorbs oxygen to burn organic materials in the fruit to produce energy accompanied by the release of combustion residues in the form of carbon dioxide gas and water. The release of carbon dioxide, water, and energy in the form of heat from the fruit will cause the weight of the fruit to shrink (Yu *et al*., 2023). Table 1 shows the weight loss of tomatoes after being stored for 15 days. Chitosan coating and storage temperature significantly affected weight loss of tomato. Cherry tomatoes coated with 2% chitosan and stored at 15°C resulting in the lowest weight loss, which was 6.19%. Putra (2022) reporting that the coating acts as a barrier to the transfer of water and gas as well as a protector against injury to the fruit wall so as to prevent transpiration and respiration. The weight loss after being stored for 15 days at 15°C was 6.19%, 8.09% and 9.17% for chitosan coating 1%, 2% and control (without coating), respectively. After being stored for 21 days, the weight loss reached 9,70 %, 11,18 % and 12,30 % for chitosan coating 1%, 2% and control (without coating), respectively (Figure 3). Meanwhile, at room temperature (25°C) the weight loss has reached 15.83% - 24.93%. At room temperature tomatoes with 2% chitosan coating only lasted up to 9 days of storage with a weight loss of 9.53%. At 10 percent weight loss, cherry tomato is still acceptable in the market. Based on Table 1, storage at 25°C is not able to maintain the quality of cherry tomatoes within two weeks. Storage at 15°C is able to maintain marketable conditions for up to 2 weeks, and even 3 weeks with the application of 2% chitosan (Figure 3).

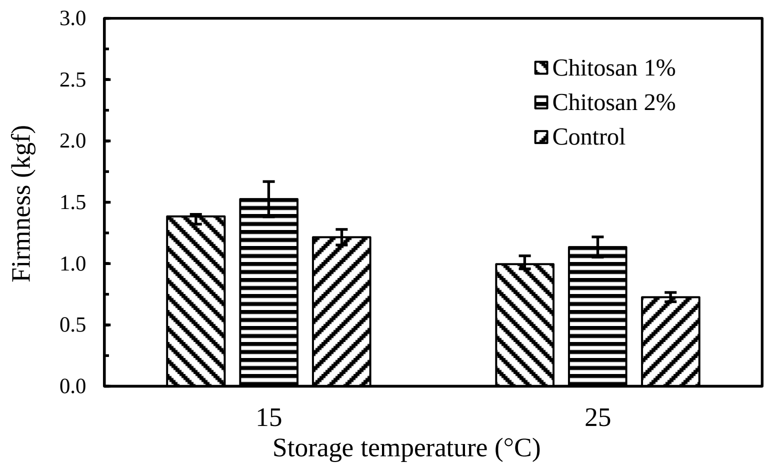

Figure 4. Effect of chitosan coating and storage temperature on the firmness of cherry tomatoes on day 21 of storage

3.2.2. Firmness

Firmness is a critically important parameter for fruit to be accepted by consumers to determine its quality. This is because the level of fruit ripeness or the level of fruit spoilage is related to firmness. Changes in texture or firmness is one of the physiological changes that occur as a direct result of the loss of water content in cherry tomatoes. Figure 4 shows that cherry tomatoes with chitosan coating treatment with a concentration of 2% had the lowest firmness reduction value compared to the other treatments on the 21st day of storage, which was 1.14 kgf. According to Iflah & Titi (2012), too high storage temperature can cause the process of respiration and transpiration to take place faster, causing the water content of the fruit to decrease faster, which can lead to a reduction in firmness. In addition, it can also be seen that chitosan with a concentration of 2% can withstand a significant decrease in the firmness of cherry tomatoes. This happens because edible coatings can inhibit the respiration rate process so that respiration and tissue softening activities become less active (Sulistyowati *et al*., 2019). The Anova test results showed that chitosan coating, storage temperature, and the interaction between the two did not significantly affect the firmness value of cherry tomatoes on the 21st day of storage. The results of the Duncan further test at the 5% level, chitosan coating with a concentration of 2% at a storage temperature of 15°C is significantly different from the control treatment, while for coating with a concentration of 1% is not significantly different from the treatment of 2% chitosan coating and control. At a storage temperature of 25°C, the 2% coating treatment had no significant effect with the 1% chitosan coating, but was significantly different from the control.

3.2.3. Total Soluble Solids

Total soluble solids (TSS) indicate the total sugar content contained in the fruit. Figure 5 shows that cherry tomatoes treated with 2% chitosan coating and 15°C storage temperature were able to reduce their TSS value on the 21st day of storage by 3.90 °Brix. The ANOVA test results on the TSS value of cherry tomatoes showed that the chitosan coating treatment and storage temperature had a significant effect on changes in the TSS value of cherry tomatoes, but the interaction between the two had no significant effect on the TSS value of cherry tomatoes on the 21st day of storage. The results of DMRT at the 5% level, chitosan coating with a concentration of 1% and 2% at a storage temperature of 15°C was significantly different from the control treatment, while coating with a concentration of 1% was not significantly different from the 2% chitosan coating treatment. At a storage temperature of 25°C, the 2% coating treatment had a significant effect with the control and 1% chitosan coating. While cherry tomatoes coated with 1% chitosan were not significantly different from the control.

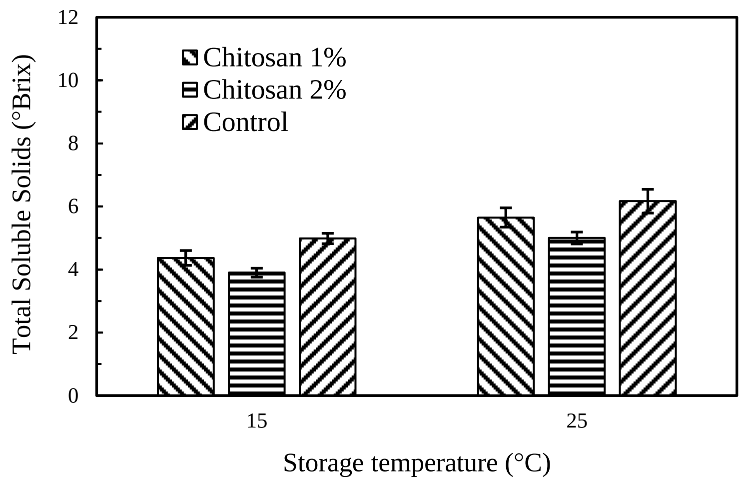

Figure 5. Effect of chitosan coating and storage temperature on total soluble solids of cherry tomatoes at day 21 of storage

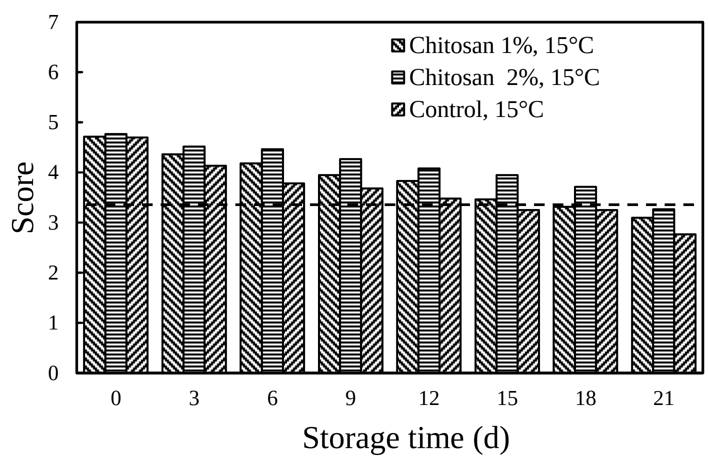

Figure 6. Effect of chitosan coating and storage temperature on the freshness of cherry tomatoes.

3.3. Organoleptic Test

Organoleptic test is a test to determine the level of panelist acceptance of a product based on the level of liking or hedonic scale using the five senses, such as sight, smell, taste and touch. The parameters tested include color, aroma, and freshness (Ayu *et al*., 2020). Figure 6 shows the effect of coating and storage temperature on the freshness score of cherry tomatoes. The figure shows thet the freshness score of cherry tomatoes coated with chitosan at a concentration of 2% and stored at 15°C resulting in the best panelist acceptance with the score of 4.13. These results are in accordance with research conducted by Putra (2022) that chitosan coating on cherry tomatoes resulting fresher fruit appearance. In addition, cold storage temperatures also affect the freshness level of cherry tomatoes compared to room temperature.

Based on Figure 7, it can be seen that the color of cherry tomatoes coated with 2% chitosan and stored at 15°C is the best treatment in maintaining color as indicated by the average acceptance score of panelists during storage, which is 4.17. This value was higher than the average score of the other treatments. The treated cherry tomatoes also maintained panelist acceptance until the 21st day of storage.

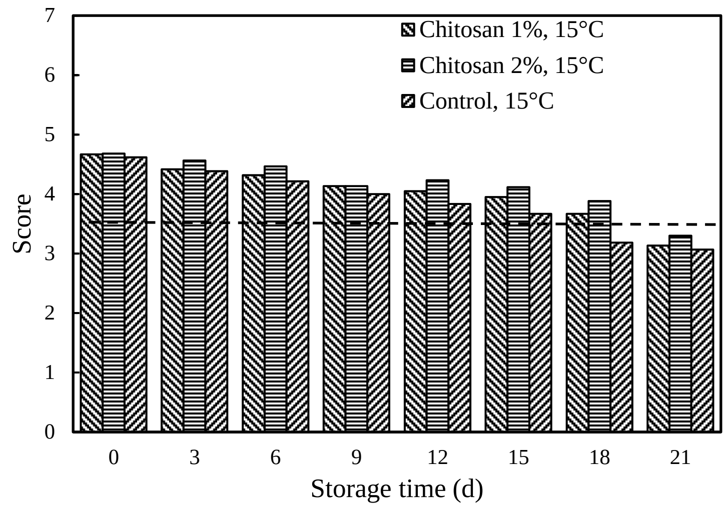

Figure 7. Effect of chitosan coating and storage temperature on the color of cherry tomatoes.

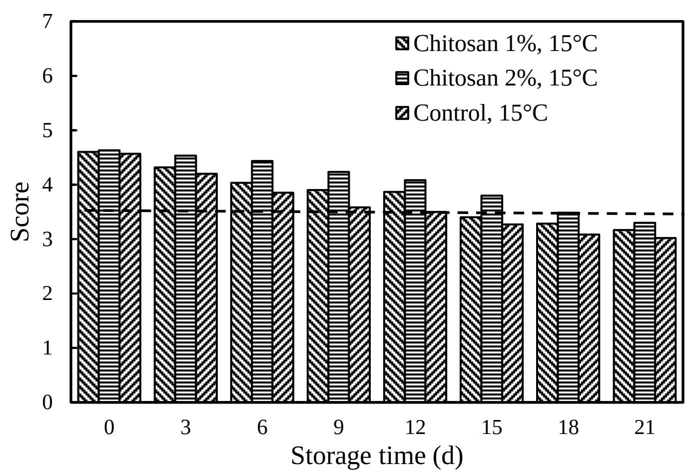

Figure 8. Effect of chitosan coating and storage temperature on the aroma of cherry tomatoes.

Based on Figure 8, it can be seen that the aroma of cherry tomatoes coated with 2% chitosan and stored at 15°C is the best treatment in maintaining aroma as indicated by the average acceptance score of panelists during storage, which is 4.06. This score was higher than the average score of the other treatments. The treated cherry tomatoes also maintained panelist acceptance until the 21st day of storage.

4. CONCLUSIONS

1. Chitosan coating and storage temperature on cherry tomatoes significantly affected respiration rate, weight loss, firmness, total soluble solids, and organoleptic tests on freshness, color, and aroma. The interaction of chitosan coating of various concentrations and storage temperature significantly affected weight loss and respiration rate (O_2 consumption), but had no effect on firmness, total soluble solids, and respiration rate (CO_2 production).

2. Cherry tomatoes coated with 2% chitosan were able to extend the shelf life of tomatoes until 21 days at 15°C of storage temperature and 9 days at room temperature. Meanwhile, tomatoes without coating (control) could only last for 15 days at 15°C of storage and 6 days at room temperature based on the quality parameters of weight loss, hardness, TSS, and panelist acceptance.

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