Incorporation of *Spirulina platensis* in Edible Coating for Shelf-Life Extension of Tomatoes (*Lycopersicon esculentum* Mill.) Umagna Variety

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Abstract. Tomatoes are a widely consumed fruit due to their rich nutritional profile and can command high market prices, exemplified by varieties like Umagna. Nevertheless, tomatoes are prone to damage. A viable solution involves applying an edible coating derived from Spirulina platensis. This study aims to investigate the effect of Spirulina platensis at different concentration on longevity of Umagna tomatoes during storage depending on the component of edible coating. Employing experimental techniques with descriptive analysis, the research underwent processing via regression and ANOVA tests. Findings demonstrated a connection between Spirulina platensis concentration and parameters such as respiration rate, weight loss, color changes, and shelf life. However, ANOVA results indicated no significant impact on factors like hardness, TAT content, water content, vitamin C content, or total sugar content (F < Fcrit). Notably, tomatoes coated with 0.5% Spirulina platensis displayed the most favorable outcomes, preserving attributes such as reduced respiration and weight loss, while maintaining hardness, TAT content, water content, vitamin C content, and total sugar content. A concentration of 0.5% Spirulina platensis extended the tomatoes' shelf life to 52 days.

1 Introduction

1.1 Background

Fruit and vegetables are foodstuffs that are widely consumed by the public. Fruit and vegetables contain micronutrients which play an important role in the body's metabolic processes. Recently, the consumption of foods with minimal processing has become very popular. Therefore, people prefer to consume fresh fruit and vegetables compared to

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processed products. One fruit that is widely consumed by people is tomatoes. Tomato fruit *(Lycopersicon esculentum* Mill.) is a fruit that is rich in nutritional content and has many health benefits. According Astuti et al. [1] to 100 grams of ripe tomatoes, they contain 7.85 mg of lycopene, 12 mg of vitamin K, 20 mg of vitamin C, folic acid, 0.06 mg of vitamins B1, B6, and minerals (0.5 mg of iron and 5 mg of calcium). Some tomatoes have high economic value, one example is the Umagna variety beef tomato. This type of tomato has a price ranging from IDR 30,000 – IDR 60,000 per kilogram.

Even though they have a high economic price, tomatoes are easily damaged. This is because the water content of tomatoes reaches more than 93% so that tomatoes have a short shelf life, high weight loss, rapid physical changes, triggering microbial growth and physicochemical changes [2]. Damage to tomatoes can also occur because tomatoes are climacteric fruits, where tomatoes have a high respiration rate [3]. One appropriate method to deal with this problem is to use edible coating. Edible coating is a thin layer that functions to provide resistance to mass transfer and increases ease of food handling. *Edible coatings* are made from edible ingredients, used and formed on the surface of products such as fruit and vegetables to maintain their quality [4]. Edible coating can extend the shelf life of fruit and vegetables, controls the process of maturation, development, and respiration rate.

The raw materials used in making edible coatings are generally made from polysaccharides, proteins, lipids and their derivatives. However, in recent years microalgae have also been used as raw material for making edible coatings. One example of microalgae that can be used in making edible coatings is *Spirulina platensis. Spirulina platensis* is a type of blue green algae containing 60-70% protein. This microalgae is rich in vitamin B12 (193 g/100 g), gamma linoleic acid, a source of calcium and iron (1043.62 and 338.76 mg/100g), vitamin E and vitamin C, rich in chlorophyll a pigment (1.472%) and phycocyanin (14.18%) (Ak et al., 2016). *Spirulina platensis* contains the pigment phycocyanin and phenolic compounds which can minimize the ripening oxidation process and extend the post-harvest shelf life of fruit and vegetables so that it has the potential to be used as raw material *for* edible coatings [5].

Edible coatings are brittle due to interactions between polymer chains. To make it easier to process, plasticizers are used [6]. The type of plasticizer that is often used is glycerol. Glycerol has the property of being easily soluble in water, increasing the viscosity of the solution, binding water, and reducing water activity. Glycerol can also increase permeability to gas, water vapor and dissolved gas. Apart from using plasticizers, surfactants are also used in making edible coatings. Surfactants are added to the edible coating solution to obtain better uniformity. The type of surfactant most often used is Carboxymethyl Cellulose (CMC). CMC is a derivative of cellulose and is made through the reaction of cellulose with sodium hydroxide and chloroacetic acid [7]. CMC functions to inhibit dehydration, provide a selective barrier against moisture, oxygen and carbon dioxide, and helps retain volatile flavor compounds [8]. The use of CMC in making edible coatings can extend the shelf life of fresh fruit during storage [9].

Based on this description, further research is needed regarding the application of edible coating on tomatoes with various concentrations *of Spirulina platensis* to maintain the characteristics and shelf life of tomatoes. This research is intended to determine the relationship between the concentration of *Spirulina platensis* as a basic ingredient for edible coatings and the characteristics and shelf life of Umagna variety tomatoes during storage.

2 Material and method

2.1 Sampel preparation

Tomato var. Umagna was washed with water and dried. *Spirulina platensis* powder was weighed according to the treatment (0%, 0.5%, 1%, 1.5%, 2% and 2.5%) and dissolved in 400 ml of distilled water using a magnetic stirrer hotplate. The solution was heated until the temperature reaches 70°±5°C for 15 minutes. 1% CMC and 1% glycerol were added, and the solution was stirred again for 15 minutes at a temperature of 70°±5°C. The solution was allowed to stand until the temperature reached 50°C.

2.2 Tomato coating

The application of edible coating to tomatoes was carried out using the dip method. Tomatoes were dipped in the edible coating solution at 50°C for 1 minute. The dipped tomatoes were dried using a fan. Once half dry, the tomatoes were dipped again in the edible coating solution for 1 minute and then dried using a fan for 30 minutes. Tomatoes were stored in a container covered with a filter at room temperature. Tomatoes that were not coated with edible coating were also prepared as a control treatment. Observations were carried out every 24 hours for 12 days. Observations made included measurements of respiration rate [10], weight loss [11], color change [12], hardness level (it was measured at 3 different areas) [13], Total Titrated Acid (TAT) (AOAC, 2005), water content (AOAC, 2005), Vitamin C content (AOAC, 2005), total sugar content (AOAC, 2005), and shelf-life [14].

3 Results and discussion

3.1 Respiration rate

Respiration is a process of catabolism or decomposition of organic compounds into inorganic ones, where in respiration O_2 is absorbed to be used in the combustion (oxidative) process which produces energy followed by the release of combustion residues in the form of $CO_{2\,gas}$ and water. Determination of the respiration rate is based on the CO_2 levels released. Respiration rate testing is carried out every 2 days.

Based on Figure 1, the respiration rate of tomatoes from each treatment experienced a spike in the respiration rate on the 4th to the 6th day. After experiencing a spike on days 4 to 6, the respiration rate slowed down again on days 6 to 12. A spike in respiration rate can occur because tomatoes are climacteric fruit, where there will be a spike in respiration rate after harvest. For fruit that is classified as climacteric, respiration will increase at the beginning of storage.

The spike in respiration rate on the 4th to the 6th day indicates that the tomatoes are experiencing the ripening phase or ripening phase. In this phase, the tomato fruit will experience a color change from green (mature green) to yellow or orange (turning) [15]. On the 6th day, tomatoes that were not coated with edible coating experienced a peak respiration rate or climacteric peak. On the 8th day, almost all tomatoes treated with edible coating experienced a peak respiration rate, except for those treated with 0.5% edible coating. After the ripening phase, climacteric fruit will experience a scenecense phase or wilting phase. This phase is characterized by a decreased respiration rate and tomatoes that are red or have reached the red ripeness level. Tomatoes that were not coated with edible coating experienced a decrease in respiration rate on the 8th day, while almost all treatments experienced a decrease in respiration rate on the 10th day, except for tomatoes with 0.5% Spirulina platensis

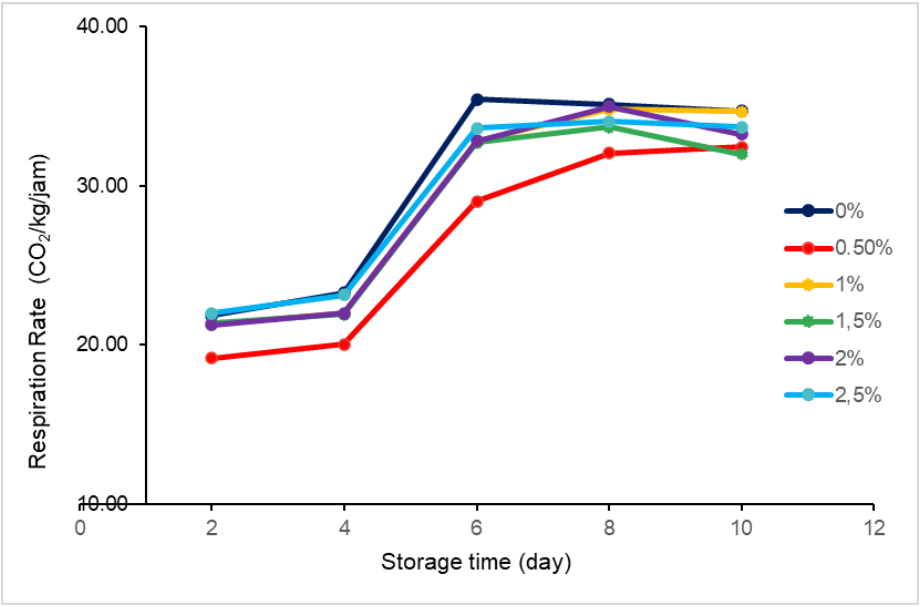

Fig. 1. Respiration rate of edible coated tomato at various concentrations of *Spirulina platensis.*

edible coating. Tomato fruit in this treatment still experienced an increase in respiration rate until the 10th day.

Overall, the highest respiration rate was shown in the treatment of tomatoes that were not coated with edible coating. The higher respiration rate can be caused by the process of diffusion of O_2 and CO_2 gases through the lenticels and cuticle which cannot be inhibited. The entry of O_2 gas into the fruit can increase the speed of respiration. Tomato fruit coated with *edible coating* has a lower respiration rate compared to fruit that is not coated. Treatment of tomatoes coated with 0.5% *Spirulina platensis* had the lowest respiration rate. This can be caused by *edible coating* with this concentration being able to provide optimal permeability and the required layer thickness so that the respiration rate is lower [17]. *The edible coating* that coats the surface of the fruit is able to cover the lenticels and cuticles. *Edible coating* on the surface of the fruit will inhibit the process of diffusion of O_2 and CO_2 gas into the fruit so that less $O_{2\ gas}$ enters and more CO_2 accumulates in the tissue. Low O_2 content can delay the synthesis of enzymes that play a role in respiration so that the respiration process becomes hampered.

3.2 Weight loss

Weight loss or weight loss is an important index of shelf life in fresh products such as fruit. Weight loss or weight loss seems to be the main factor that can damage the shelf life and quality of fruit and other horticultural crops.

Figure 2 shows that tomatoes that were not coated with edible coating experienced a higher percentage of weight loss compared to tomatoes coated with Spirulina platensis edible coating. Tomatoes that were not coated with edible coating experienced an increase in weight loss percentage of 6.47%. Among the fruit treatments coated with Spirulina platensis edible coating, tomatoes with 0.5% Spirulina platensis edible coating experienced the lowest increase in weight loss percentage, namely 5.05%. The percentage of weight loss increased along with increasing concentrations of Spirulina platensis used. This indicates that the effectiveness of fruit coating using natural coating materials is limited by the thickness of the

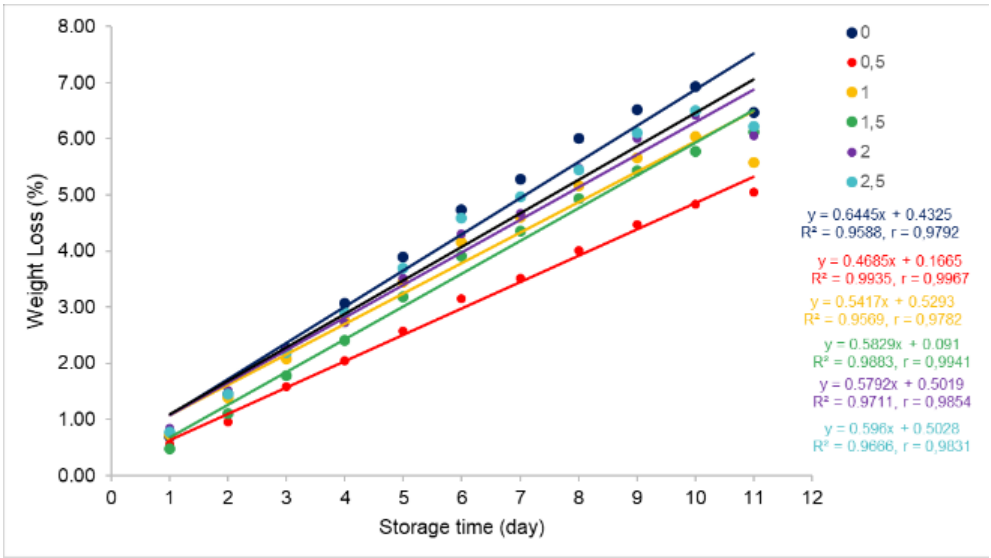

Fig. 2. Relationship between *Spirulina platensis* concentration in *Edible Coating* and Tomato Fruit Weight Loss.

layer. The research results showed that the optimum concentration of Spirulina platensis to inhibit weight loss was 0.5%. If the concentration is higher, the layer thickness will not be effective in inhibiting weight loss.

The edible coating that coats tomatoes can act as a barrier to reduce the process of water vapor migration in the fruit [18]. Edible coating can reduce oxygen absorption so that it can slow down the process of respiration rate and weight loss in fruit [19]. Edible coating is able to protect fruit from excessive water loss so that it can prevent high weight loss in fruit.

3.3 Color changes

Color is a very important indicator of maturity and determines quality and consumer acceptance. Color is a parameter that can determine the level of ripeness and freshness of fruit. On the color measurement tool, the values read are L*, a*, and b*. The L* value indicates the brightness of the fruit, the a* value indicates a red-green color tendency, the b* value indicates a yellow-blue tendency. Changes in tomato color during storage can be seen in Table 1.

3.3.1 L value*

The L* value indicates the brightness of a color, where 0 indicates black and 100 indicates white. The more positive or higher the L value, the brighter the fruit, conversely, the more negative or lower the L* value, the darker the fruit.

Figure 3, the L* value or brightness value of tomatoes from each treatment decreased during storage. In general, the brightness of tomatoes will decrease because the color of tomatoes changes to a darker color due to chlorophyll degradation due to the influence of and physiological changes which make tomatoes change color from green to red [21]. The L* value in tomatoes treated with a coating decrease as the concentration of Spirulina platensis used increases. This can happen because Spirulina platensis has a dark green color, which affects the color of the resulting edible coating solution. The higher the concentration

of Spirulina platensis used, the darker and more concentrated the color of the resulting edible coating solution will be, so the resulting L* value will also be lower.

A high respiration rate can cause color changes in the fruit to occur more quickly, thereby reducing the brightness of the fruit. Meanwhile, the decrease in the lower L* value can be caused by a slower respiration rate so that the fruit is able to maintain brightness. This is supported by data on lower respiration rates in tomatoes coated with 0.5% Spirulina platensis edible coating. Previous research conducted Rastegar & Atrash [16] regarding the application of edible coating from alginate with the addition of Spirulina platensis and alove vera on mango fruit also showed that the L* value decreased the lowest compared to fruit that was not coated.

Table 1. Changes in color of tomato fruit during storage chemical.

Spirulina Concentration	Color changing during storage										
	Day-1	H-2	Day-1	H-4	Day-1	H-6	Day-1	H-8	Day-1	H-10	Day-1
0%											
0,5%											
1%											
1,5%											
2%											
2,5%											

3.3.2 a Value*

The a* value represents the chromatic color of a mixture of red and green, with a value of +a from 0 to 100 for red and -a from 0 to -80 for green. The -a value at the beginning of storage of tomatoes indicates that tomatoes tend to be green.

Figure 4. shows the a* value at the beginning of storage of tomatoes indicates that tomatoes tend to be green. This is because tomatoes are still at the *mature green stage of maturity* and tomatoes at that stage of maturity are green. The a* value in each treatment increases over time and shows a positive value which indicates the fruit tends to be red. The increase in a* value can be caused by the ripening process that takes place during storage. During the ripening process, tomatoes will change color from green to red. This is caused by degradation of chlorophyll pigments and accumulation of carotenoids, namely lycopene which makes tomatoes red.

Based on the ΔE value, tomatoes that were not coated with *edible coating* had the highest ΔE value, while tomatoes treated with 0.5% *Spirulina platensis edible coating* had the lowest value compared to other coating treatments. This shows that tomatoes with 0.5% *Spirulina platensis edible coating experienced the lowest color change.* The increase in a* value and

higher ΔE value in tomatoes that were not coated with *edible coating* indicates that the tomato fruit experienced a red color change more quickly compared to other treatments. This can occur because tomatoes that are not coated with *edible coating* are not protected by *edible coating* so that the color change occurs more quickly due to the higher respiration rate . The increase in a* value and lower ΔE value in tomatoes coated with 0.5% *Spirulina platensis edible coating indicates that edible coating* at this concentration can inhibit the fruit's respiration rate, thereby suppressing chlorophyll degradation. This is also supported by the respiration rate that occurs when tomatoes are treated with *Spirulina platensis edible coating* which is lower compared to other treatments. In research conducted by Azhar Shapawi et al. [22] stated that star fruit coated with *Spirulina platensis* experienced a smaller decrease in the a* value compared to fruit coated with chitosan and control fruit, which indicates that *Spirulina platensis* can help slow down the fruit ripening process and slow down the fruit color change process.

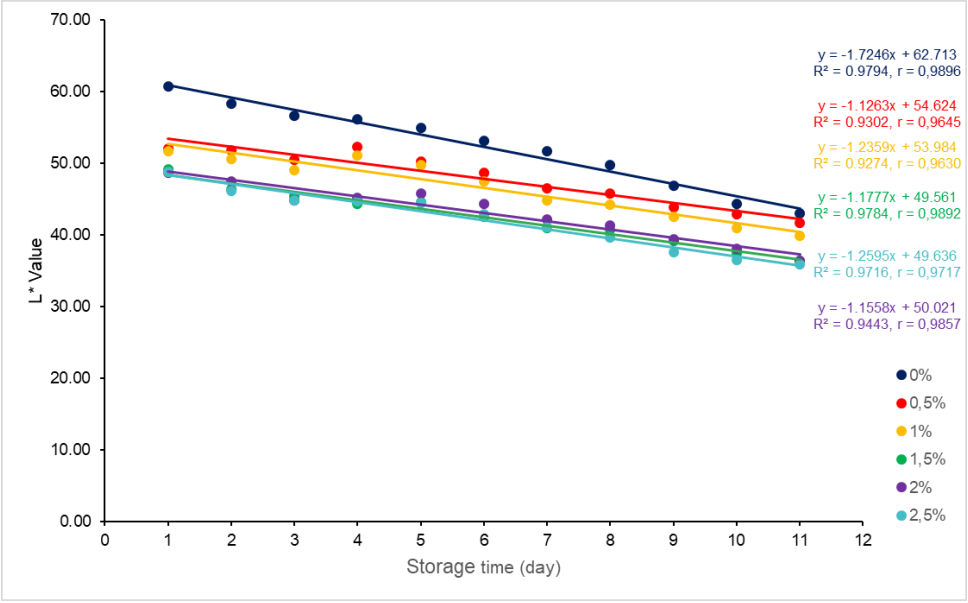

Fig. 3. Relationship between *Spirulina platensis Edible Coating* Concentration and L* Value in Tomatoes

3.3.3 b value*

The b* value represents the chromatic color of a mixture of yellow and blue with a value of +b from 0 to 70 for yellow and –b from 0 to -70 for blue.

Figure 5 shows tomatoes from each treatment experienced an increase in the b* value from day 1 to day 4. After the 4th day, the b* value increased and also decreased during storage. An increase in the b* value in tomatoes can occur because during the ripening storage, the tomatoes become riper so that the skin color of the tomatoes tends to become red and dark process of tomatoes, the fruit changes color from green to yellow and orange before

finally turning red. Meanwhile, the decrease in the b* value can be caused by the fact that during.

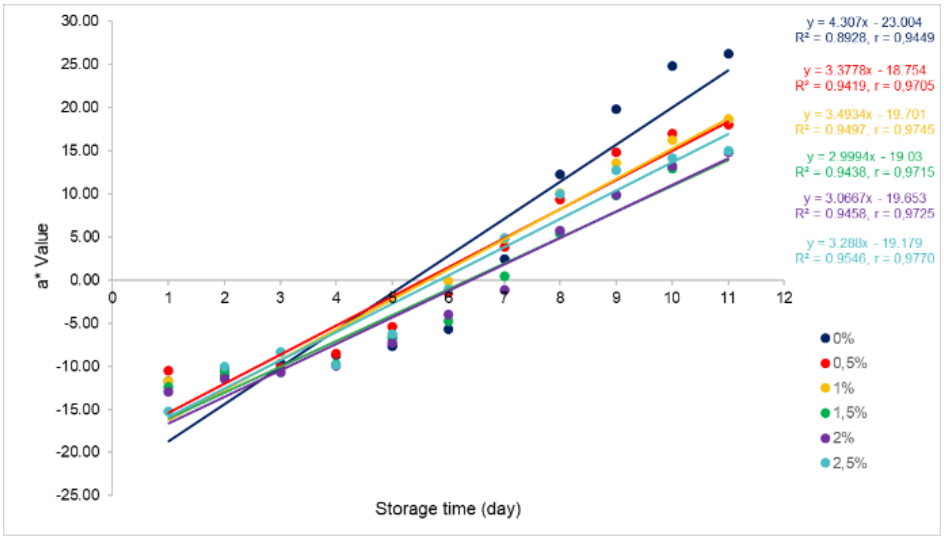

Fig. 4. Relationship between *Edible Coating Spirulina platensis concentration* and a* value in tomatoes

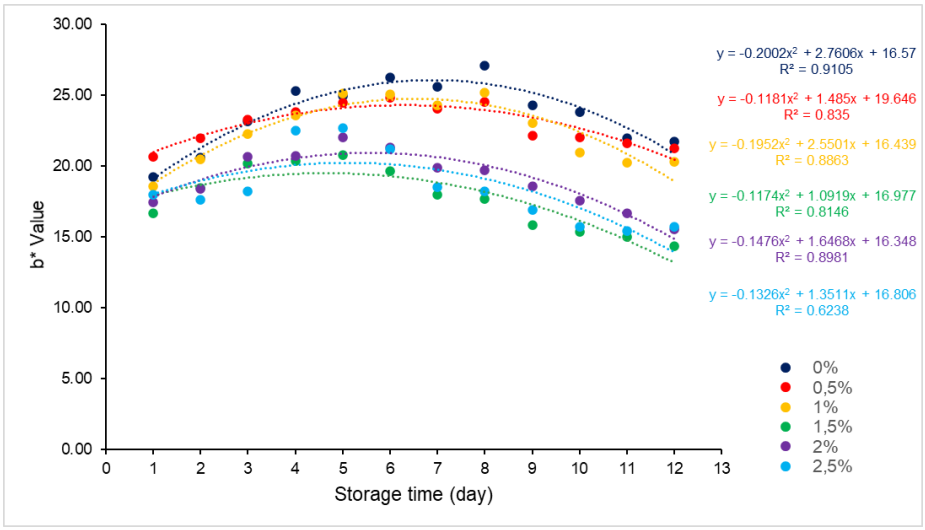

Fig. 5. Relationship between *Edible Coating Spirulina platensis* concentration and b* value in tomatoes

Based on the ΔE value, tomatoes that were not coated with *edible coating* had the highest ΔE value, while tomatoes treated with 0.5% *Spirulina platensis edible coating* had the lowest ΔE value compared to other coating treatments. This shows that tomatoes with 0.5% *Spirulina platensis edible coating experienced the lowest color change.* Mark ΔE which was higher in tomatoes that were not coated with *edible coating,* indicating that the tomatoes experienced a red color change more quickly compared to other treatments. This can occur because tomatoes that are not coated with *edible coating* are not protected by *edible coating*

so that the color change occurs more quickly due to the higher respiration rate. The lower ΔE value on tomatoes coated with 0.5 % *Spirulina platensis edible coating indicates that the edible coating* at that concentration can inhibit the rate of fruit respiration and have better resistance in holding O_2 and CO_2 which ultimately can inhibit chlorophyll degradation and the color of tomatoes can be maintained. Azhar Shapawi et al. [22] conducted research on the application of *edible coating* from chitosan and *Spirulina platensis* to star fruit. Star fruit coated with *edible coating* from *Spirulina platensis* had the lowest decrease in b* values compared to the control treatment and *edible coating treatment* with chitosan from day 0 to day 14.

3.4 Hardness

One of the physiological changes that occur in fruit during storage is a change in the level of hardness. Hardness is the main attribute that can determine postharvest age and fruit freshness. Measuring the level of hardness in tomatoes is done by observing *the skin puncture force* or the strength to penetrate the skin of the fruit.

Based on Figure 6, tomatoes that are not coated with *edible coating* have the lowest level of hardness compared to tomatoes that are coated with *edible coating.* A low level of hardness indicates that the tomato fruit has a soft texture. This can be caused by a high respiration rate so that the water content in the fruit decreases and the cell tissue becomes weak. The ANOVA test results showed that the concentration of *Spirulina platensis* had no significant effect on the level of hardness tomatoes ($F < Fcrit$).

According to Gede et al. [23], water loss can cause the appearance of the material to become less attractive and the texture to become less good. The tissue texture of fruit and vegetables is greatly influenced by pectin. Changes in the level of hardness in fruit can also occur due to deterioration of cell wall components, especially due to the presence of pectin and the activity of polygalacturonase and other enzymes. Some protopectin changes from being water-insoluble to water-soluble in fruit, resulting in a decrease in the cohesive power of the cell walls that bind cells to one another.

According to research conducted by Zekrehiwot et al. [12], tomatoes coated with *edible coating* show better results compared to tomatoes that are not coated. On the 15th day of storage, tomatoes that were not coated with *edible coating* had a very soft texture so that the fruit became damaged. *Edible coating* means less oxygen enters the fruit tissue so that the enzymes involved in the respiration process and tissue softening become less active [24]. Buendía−Moreno et al. [25] also stated that *edible coatings* have the capacity to maintain textural value and inhibit enzymes that can cause damage to fruit.

3.5 Shelf Life

Shelf life indicates the period of time a product is still safe for consumption, has a taste, texture and appearance that are acceptable to consumers. The shelf life of tomatoes is calculated by calculating the number of days needed to reach the final stage of maturity and until the tomatoes experience damage.

Based on Figure 7, tomatoes from each treatment have different shelf lives. Tomatoes with 2% treatment have the shortest shelf life compared to tomatoes with other treatments. This is thought to have occurred because there was a technical error during the observation. The quality of the tomato fruit from this treatment decreased, such as the texture of the fruit being too soft, watery, smelling bad, and the fruit turning wrinkled so that the fruit could not be stored and was not suitable for consumption. Tomatoes coated with 2.5% *Spirulina platensis edible coating* have a shelf life of 38 days. In this treatment, the texture of the fruit changes to become very soft. Tomatoes that are not coated with *edible coating* have a shelf

life that is not much different from tomatoes coated with 2.5% *Spirulina platensis edible coating , namely 36 days.*

In this research, the material used as an *edible coating* is the microalgae *Spirulina platensis* which has a fairly high protein content, namely around 56-62%. Proteins are made from amino acid chains, the reactions that occur between amino acid chains during the coating formulation process occur due to hydrogen bonds, non-ionic and covalent bonds which cause protein molecules to have excellent mechanical strength and gas permeability properties so that they can extend the shelf life of the product fresh like fruit [27].

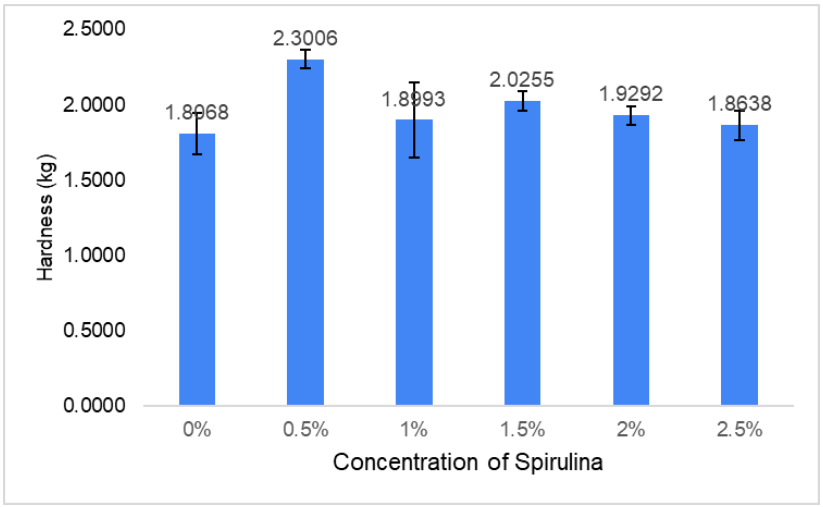

Fig. 6. Relationship between *Spirulina platensis* concentration in *Edible Coating* and *Skin Puncture Force* of Tomato Fruit

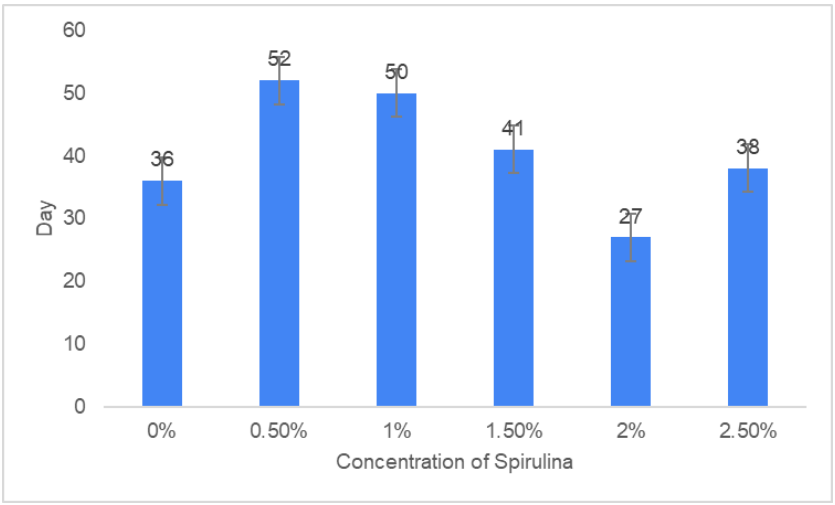

Fig. 7. Relationship between *Spirulina platensis* concentration and shelf life of tomatoes

4 Conclusions

Based on research results, the concentration of Spirulina platensis is related to respiration rate, weight loss, color changes and shelf life of tomatoes. The results of the ANOVA test showed that the concentration of *Spirulina platensis* had no significant effect on the level of hardness content of tomatoes (F < Fcrit). Tomato fruit coated with Spirulina platensis 0.5% showed the best relationship because it was able to maintain fruit characteristics such as slowing down the rate of respiration, slowing down weight loss, slowing down color change, and maintaining hardness levels. Tomatoes coated with 0.5% *Spirulina platensis* edible coating can also extend the shelf life of tomatoes to 52 days.

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