e-ISSN 2581-0405
ajarcde
Asian Journal of Applied Research for Community Development and Empowerment

Journal home page: http://ajarcde-safe-network.org ISSN 2581-0405

Physicochemical Analysis of Strawberries Coated with Potato Peel Starch Edible Coating with Sungkai Extract

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ARTICLE INFO

Article History:
Received: February 26, 2025
Final Revision: April 11, 2025
Accepted: April 11, 2025
Online Publication: April 15, 2025

KEYWORDS

Strawberry Preservation, Edible Coating, Potato Peel, Sungkai Leaf, Pure Starch

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A B S T R A C T

Strawberries are a fruit widely consumed globally, but they have a short shelf life. Consequently, maintaining and storing strawberries is quite challenging. Fruit preservation using edible coatings has gained significant attention due to their cost-effectiveness and ease of preparation. In this study, a comparison was made between an edible coating of potato peel starch and pure starch (Merck) with a formulation of 4% starch, 50% extract from sungkai leaves, and 34% glycerol (of the total starch). An edible coating formulation was applied to strawberries, and physicochemical analysis was carried out on days 0, 2, 4, and 6. The results showed that strawberries coated with edible coating showed more optimal results than strawberries without edible coating on day 4. Strawberries with an edible coating of potato peel starch with the addition of extract from sungkai leaves are the best results had a weight loss of 82,15%, total soluble solids of 9.67 brix, total titratable acid of 1.18%, and total antioxidants of 149,3 mg AAE/gFW, and total phenolics of 206,56 mg AAE/Gfw.

Contribution to Sustainable Development Goals (SDGs):

SDG 3: Good Health and Well-being
SDG 9: Industry, Innovation, and Infrastructure
SDG 12: Responsible Consumption and Production
SDG 13: Climate Action

1. INTRODUCTION

1.1. Research Background

Strawberries are highly valued for their rich content of plant metabolites, including minerals, flavonoids, polyphenolic compounds, and natural antioxidants, which contribute to their high nutritional value. As non-climacteric fruits, strawberries are harvested when fully ripe to ensure optimal quality. However, their delicate texture, high respiration rate, moisture loss, and susceptibility to mechanical damage make them highly perishable, with a short shelf life. [2]. Approximately 15% of strawberries are lost during production and pre-ripening stages, 11% during transportation and delivery, 9% during the sales process, and 35% post-consumer acquisition. [3].

Several methods have been employed to extend the shelf life of strawberries, such as atmospheric packaging modification, UV irradiation, and chemical treatments. However, these methods are expensive and may alter the fruit's texture, color, taste, and aroma. Edible coatings offer a promising alternative for extending the shelf life and maintaining the quality of strawberries. Furthermore, edible coatings can also serve to increase the fruit's content of vitamins, minerals, colorants, antibacterial agents, and probiotics. [4].

Edible coatings are biopolymer-based solutions applied to food surfaces to extend shelf life. They act as semi-permeable barriers that reduce respiration, moisture loss, and microbial growth while helping to preserve texture and flavor. By controlling gas exchange and transpiration, these coatings slow down the metabolic activity and deterioration of fresh produce [4].

Fruit preservation using edible coatings has gained significant attention due to their cost-effectiveness and ease of preparation. Natural polymers are particularly promising as edible coating materials for fruit preservation due to their widespread availability, biodegradability, and safety. [5]. Potato peels contain various compounds beneficial for nutrition, pharmacology, and material science. They are rich in polysaccharides, primarily composed of 30-85% starch. [6]. Starch is used to create an edible coating that effectively protects against O_2 and CO_2 and is colorless, odorless, and transparent. [4]. Modified edible coatings have proven effective in preserving fruit quality. Sungkai leaves, used as an additional ingredient, provide antifungal and antibacterial properties that help reduce microorganism activity and prevent product damage.[8]. Addressing these challenges requires strawberry preservation, It is important to review recent studies related to food waste, strawberry shelf life, and the potential of natural-based edible coatings.

1.2. Literature Review

In order to gain a deeper insight into the current challenges and innovations in strawberry preservation, especially through the use of edible coatings, it is crucial to examine recent literature on food waste, strawberry shelf life, and coating technologies.

In recent years, growing concerns about food sustainability and postharvest losses have driven the development of environmentally friendly preservation methods. One critical issue is food waste, particularly of highly perishable fruits like strawberries. The following section reviews recent findings relevant to this context. Food waste has become a major concern recently, with alarming statistics revealing its scale and environmental impact. Globally, around a third of the food made for human dietary needs, which amounts to 1.3 billion tonnes each year, goes to waste. Household food waste makes up a significant portion, accounting for *61% of the total. [9].*

1.2.1. Strawberries Preservation

Strawberries are widely consumed globally, but they have a short shelf life because they are susceptible to fungal infections during post-harvest. Fungal infections cause changes in texture, smell, and color, which are the main reasons for strawberry spoilage. [10]. Besides that, Strawberries have delicate skin, high water content, and a tendency to spoil and decay, which complicates their storage and preservation. Consequently, maintaining and storing strawberries is quite challenging. [11].

Despite these challenges, strawberries are popular worldwide due to their low-calorie content, unique flavor, and high nutritional value [12]. Given the high production and perishable nature of strawberries, extending their storage period is crucial for both ecological and economic reasons. The current trend focuses on using natural coating materials and incorporating plant extracts as eco-friendly additives to enhance coating performance. [13].

1.2.2. Edible Coating

Edible coatings, which are thin layers composed of food-grade substances, aim to cover food items to prolong their shelf life. Typically, these coatings are formulated from proteins, lipids, and polysaccharides. They serve as barriers against moisture and oxygen throughout processing, handling, and storage. [14]. Edible coatings represent a sustainable and reliable technology for fruit preservation, maintaining quality, and providing antibacterial protection during postharvest storage. Ideal coatings should be transparent and have low water vapor permeability to help reduce weight loss, oxidation, and respiration rates [14].

Edible coatings, made from biocompatible materials, are designed to guarantee that the food is safe to eat and good for the environment. The production of edible coatings from food waste encourages a more environmentally sustainable food supply and advocates circular economy methods used in the food sector. Efficient edible coatings inhibit microbial proliferation, moisture loss, and oxidation, thus extending the shelf life of perishable fruits [15].

Figure 1 Potato Peel and Sungkai Leaf as the Base Materials for Edible Coating

Potato peels are rich in valuable components, including starch, phenolic compounds, flavonoids, glycoalkaloids, suberin, lignin, and dietary fiber. These beneficial compounds and nutrients exhibit antioxidant, chemopreventive, antibacterial, antidiabetic, and anti-inflammatory properties. Consequently, potato peel waste can be repurposed into promising products such as edible coatings. [16].

Sungkai is a medicinal plant from Indonesia with potential antioxidant, antibacterial, antihypericemic, and anticancer properties. This is due to the presence of secondary metabolites/phytochemicals in sungkai leaf extracts, which include phenolics, flavonoids, tannins, alkaloids, and saponins. [17]. The secondary metabolites present in sungkai leaves can be extracted through specific methods. By using water as a solvent and applying heat, sungkai leaves can be processed to yield an extract rich in antioxidants. [18]. The addition of sungkai leaf extract is expected to enhance the functional properties of potato peel starch-based edible coatings due to its antioxidant and phenolic compounds, thereby improving their ability to maintain strawberry quality and extend shelf life during storage.

1.3. Research Objective

This study aims to analyze the physicochemical properties of strawberries coated with edible coatings made from potato peel starch and sungkai leaf extract. The results were compared with edible coatings made from pure starch to evaluate the effectiveness in extending the shelf life of strawberries.

https://doi.org/10.29165/ajarcde.v9i1.635

2. MATERIALS AND METHODS

2.1 Material

The research was carried out in September 2024 in Padang, Indonesia. The materials used in this research were Potato Peel Waste (Riau), Pure Starch (Merck), Sungkai Leaves (Padang), Strawberries (Agam), glycerol (Ecocerol), distilled water, NaOH (Merck), oxalic acid (Merck), phenolphthalein indicator (Merck), ascorbic acid (Merck), Folin-Ciocalteu reagent (Merck), FeCl3 (Merck), sodium carbonate (Merck), gallic acid (Sigma-Aldrich), and 1,10-phenanthroline reagent (Merck).

2.1. Methods

2.1.1. Edible Coating Preparation

Edible coatings were made using potato peel starch (PPS) and pure starch (PS), with and without extract from sungkai leaves (SL). The formulation consists of 4% starch, 50% extract from sungkai leaves, and 34% glycerol (of the total starch), detailed in Table 1. The formulation was heated for 15 minutes at 60-90°C while being continuously stirred with a magnetic stirrer. The resulting edible coating was then cooled to room temperature (28-31°C) [19].

Before the main analysis, a series of optimization experiments were conducted to determine the most effective concentrations of potato peel starch and sungkai leaf extract for strawberry preservation. The starch concentration was varied at 1%, 2%, 3%, 4%, 5%, and 6%, while the sungkai leaf extract concentration was tested at 10%, 30%, 50%, 70%, and 90%. These formulations were applied to strawberries, and the performance was evaluated based on the percentage of weight loss and decay index over a defined storage period. The results showed that the combination of 4% starch and 50% sungkai extract was the most effective in reducing weight loss and delaying spoilage. Therefore, this formulation was selected for further analysis in the present study. A starch concentration of 4% follows. [19] And the concentration of 50% sungkai leaf extract is by [8].

Table 1. Composition of Starch Edible Coating Formulation

Code	Potato Peel Starch PPS[%]	Pure Starch PS[%]	Sungkai LeavesS L[mL]	Glycerol Gly(%)	Total Volume (mL)
T0	0	0	0	0	0
T1	4	0	0	34	100
T2	4	0	50	34	100
T3	0	4	0	34	100
T4	0	4	50	34	100

Description:
PPS : Potato Peel Starch
PS : Pure Starch
SL : Extract from sungkai leaves
Gly : Glycerol

The prepared edible coating is applied to strawberries selected for uniform ripeness, shape, and size. After washing and drying, the strawberries are dipped in the coating for 30 seconds and then air-dried. The coated strawberries are stored at room temperature (25°C). Physicochemical analyses are conducted on days 0, 2, 4, 6, and 8 post-coating [8].

2.1.2. Weight Loss

Weight loss analysis was determined using five strawberries per treatment group, with each fruit weighed in triplicate, and the results were averaged to ensure data reliability. Weight loss of strawberries was determined by measuring the difference between their initial weight (W0) and the weight at the time of testing (Wt), then dividing by the initial weight (W0) (Equation 1). This measurement was repeated three times and expressed as a percentage [20].

$$\text{Weight Loss } (\%) = \frac{Wo-Wt}{Wo}\ x\ 100\% \qquad (1)$$

2.1.3. Total Soluble Solid (TSS)

Total Soluble Solids (TSS) were determined by measuring using a handheld refractometer. 1 strawberry was crushed using a mortar and pestle to obtain juice, then directly placed onto the prism surface of the refractometer. The refractometer was calibrated with distilled water to read °BRIX. The TSS measurement was determined at the interface of the blue and white regions. The measurement was performed in triplicate, and the average value was recorded in °Brix [21].

2.2.1 Total Titratable Acid (TTA)

Total titratable acidity (TTA) was determined by acid-base titration. 2 grams of strawberries were crushed and diluted in 20 mL of distilled water, then sonicated for 15 minutes and filtered. To obtain the strawberry extract. Next, 2 mL of the extract was pipetted and placed into an erlenmeyer flask, and one drop of phenolphthalein indicator was added. The solution was titrated using 0.1 N NaOH (which had been standardized using 0.05 N oxalic acid) until a pale pink endpoint was reached. All measurements were conducted in triplicate, and the TTA value was determined with Equation 4 and presented as a percentage [22].

$$TTA\ (\%) = \frac{NNaOH\ x\ VNaOH}{fruit\ weight} x\ 100\% \qquad (2)$$

2.3.1 Total Antioxidant Content

The total antioxidant content was determined using the modified phenanthroline method (MPM). The first step is to standardize spectrophotometric measurements. Distilled water was used as a blank, and a standard calibration curve was constructed using ascorbic acid at concentrations of 0, 15, 30, 45, 60, and 75 ppm. Each standard solution was treated using the same procedure and reagent volumes as the samples.

2 grams of strawberry were homogenized and diluted in 20 mL of distilled water to obtain the crude extract. From this mixture, 1 mL of extract was then further diluted with 2 mL of distilled water. 1 mL sample solution was mixed by adding 2 mL of distilled water, 1 mL from 0.1% FeCl3.6H2O, and 1 mL from 0.1% ortho-phenanthroline. The mixture was shaken and incubated in the dark for 20 minutes, then measured for absorbance using a spectrophotometer at wavelength of 515 nm. All measurements were conducted in triplicate, and total antioxidant content was expressed in mgAAE/gFW [23].

2.4.1 *Total Phenolic Content*

The total phenolic content was determined with the Folin-Ciocalteu method. The first step is to standardize spectrophotometric measurements. Distilled water was used as a blank, and a standard calibration curve was constructed using gallic acid at concentrations of 0, 40, 80, 120, 160, and 200 mg/L. Each standard solution was treated using the same procedure and reagent volumes as the samples.

2 grams of strawberries were homogenized and diluted in 20 mL of distilled water to obtain the crude extract. From this mixture, 0.4 mL extract was mixed with 0.4 mL of Folin-Ciocalteu reagent and set aside for 5 minutes. 4 mL of 7% Na2CO3 was introduced, and the volume was brought up to 10 mL using distilled water. The mixture was shaken and incubated in the dark for 1.5 hours, then measured for absorbance using a spectrophotometer at a wavelength of 750 nm. All measurements were conducted in triplicate, and total phenolic content was expressed in mgGAE/gFW [24].

3. *RESULT AND DISCUSSION*

3.1. *Characterization of Edible Coating Formulation*

The characterization of the edible coating formulation is shown in Figure 2. T1 and T3 represent starch-only coatings, differing in the starch source (potato peel vs. pure starch), while T2 and T4 include the addition of sungkai leaf extract. T1 coating has a viscous texture and appears grayish-white, T2 coating has a viscous texture and appears brownish-white, T3 has a liquid-like texture and appears clear white, T4 has a liquid-like texture and appears clear brownish.

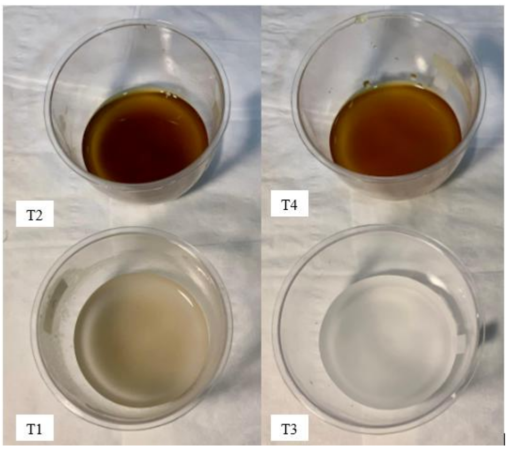

Figure 2. Edible coating formulations:

Description:

T1 : potato peel starch (PPS) edible coating

T2 : PPS and sungkai leaf extract edible coating

T3 : pure starch edible coating

T4 : pure starch and sungkai leaf extract edible coating

Strawberries coated with potato peel starch and pure starch with and without additional extract from sungkai leaves, as shown in Figure 2. The strawberries treated with the T2 coating maintained a better visual appearance. By the fourth day, these fruits were in superior condition compared to the uncoated control strawberries, which had discolored and begun to decay.

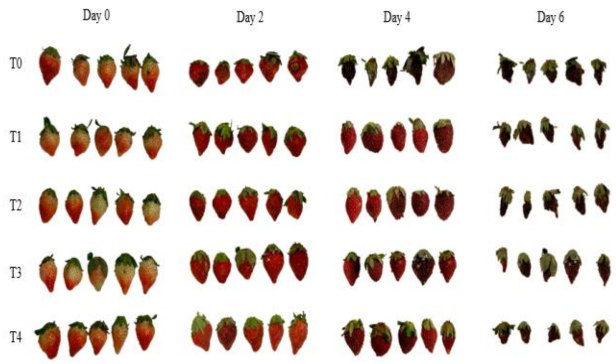

Figure 3. The visual appearance of strawberries during storage (Day 0, Day 2, and Day 4) under different coating treatments

Description:

T0 : uncoated strawberries (control)

T1 : coated with potato peel starch (PPS)

T2 : coated with PPS and sungkai leaf extract

T3 : coated with pure starch

T4 : coated with pure starch and sungkai leaf extract.

3.2. *Weight Loss*

Figure 3 shows that all strawberry samples experienced significant weight loss during storage, mainly because of the respiration and transpiration process. Based on the ANOVA test, ($p<0.05$) was obtained, demonstrating a significant difference between all treatments. The control strawberries (T0, uncoated) exhibited the highest weight loss, reaching about 90.59% by day 4. In contrast, coated strawberries (T1-T4) showed slower weight loss. The most effective treatments were T2 and T3, showing the lowest weight loss at approximately 82.15% and 79.26%, respectively, on day 4, followed by T1 at 84.1% and T4 at 87.44%.

This reduction is mainly due to the movement of moisture from the fruit to its surroundings, which is a major contributor to weight loss during the storage period. The starch-coated strawberries had reduced weight loss because the semi-permeable barrier of the starch coating slowed, reducing moisture diffusion through the stomata. This is similar to [25], where the Strawberries treated with sodium alginate showed a notable decrease in weight loss compared to the control group.

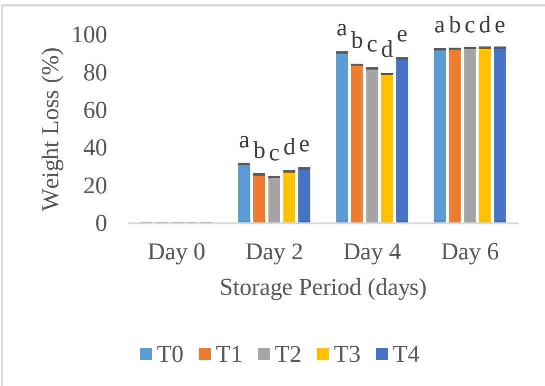

Figure 4 Effect of weight loss on strawberries coated with different edible coatings during the storage period

Data are presented as mean ± standard deviation (SD). Error bars represent the standard deviation from triplicate

https://doi.org/10.29165/ajarcde.v9i1.635

measurements (n =3). Different lowercase letters (a, b, c, d, e) indicate significant differences ($p < 0.05$) between samples according to Duncan's multiple range test (DMRT).

3.3. Total Soluble Solids

Total Soluble Solids (TSS) in fruit include compounds such as sugars, vitamins, amino acids, acids, and pectins. As the fruit ripens, TSS levels typically rise as a result of biosynthesis and the breakdown of polysaccharides. This increase in TSS can lead to cell wall deterioration and may indicate the conversion of carbohydrates into sugars [26].

Figure 4 shows that the total soluble solids (TSS) of strawberry samples increased during storage. Based on the ANOVA test, ($p<0.05$) was obtained, demonstrating a significant difference between all treatments. The control strawberries (T0, uncoated), exhibited the highest increase in TSS, reaching 25.00°Brix by day 6. In contrast, coated strawberries experienced a slower rise. The most effective treatment was T3, which showed the lowest TSS values, reaching only 14.00°Brix by day 6, followed closely by T2 and T4 at 15.00°Brix. This is similar to [27] where the strawberries coated with Cassava Starch and Poly (VinylAlcohol) experienced a smaller increase in TSS because It forms a protective layer that limits the exchange of gases (CO_2 and O_2) between the coated fruit and the surrounding air, while also regulating other metabolic processes.

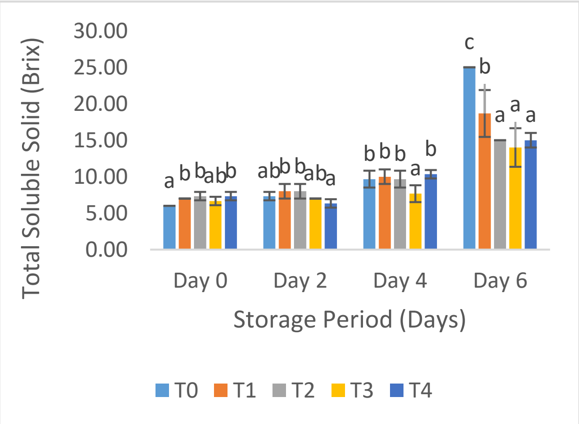

Figure 5 : Effect of total soluble solid on strawberries coated with different edible coatings during storage period

Data are presented as mean ± standard deviation (SD). Error bars represent the standard deviation from triplicate measurements (n =3). Different lowercase letters (a, b, c, d, e) indicate significant differences ($p < 0.05$) between samples according to Duncan's multiple range test (DMRT).

3.4. Total Titratable Acid (TTA)

Strawberry acidity, measured by Total Titratable Acid (TTA), is primarily due to citric and malic acids, with citric acid being the predominant one. TA levels are highly dependent on the fruit's maturity and are positively correlated with sourness. However, the perception of sourness is also influenced by the sugars in the fruit, which contribute to its sweetness [21].

Figure 5 shows that the total titratable acid (TTA) of strawberries decreases during the storage period. Based on the ANOVA test, ($p<0.05$) was obtained, demonstrating a significant difference between all treatments. Fruits use organic acids for respiration and other metabolic processes, leading to a decrease in titratable acidity during the storage period. The control strawberries (T0, uncoated), exhibited the most significant increase in acidity, increasing from 2.36% on day 0 to 5.82% on day 6. In contrast, the coated strawberries showed less significant increase. The most effective treatment was T3, which showed the most stable TTA, starting at 2.16% and only reaching 3.73% by day 6. This is similar to [28]. strawberries coated with Alginate/Ascorbic Acid, which also had a lower decline rate and optimal preservation of organic acids. This suggests that polysaccharide coatings are effective in maintaining organic acids in fruit over a specific duration.

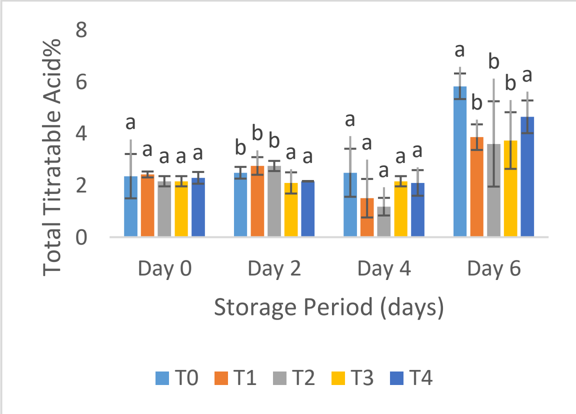

Figure 6 Effect of total titratable acid on strawberries coated with different edible coatings during storage period

Description:

Data are presented as mean ± standard deviation (SD). Error bars represent the standard deviation from triplicate measurements (n =3). Different lowercase letters (a, b, c, d, e) indicate significant differences ($p < 0.05$) between samples according to Duncan's multiple range test (DMRT).

3.5. Total Antioxidant

The antioxidant activity in strawberries is influenced by several key compounds, namely phenolics, flavonoids, anthocyanins, and ascorbic acid. A standard calibration curve is shown in Figure 7. The calibration standard equation was $y = 0.0126x + 0.055$ as the reference for determining the antioxidant content of the sample extracts, with $R^2 = 0.9876$ indicating high linearity.

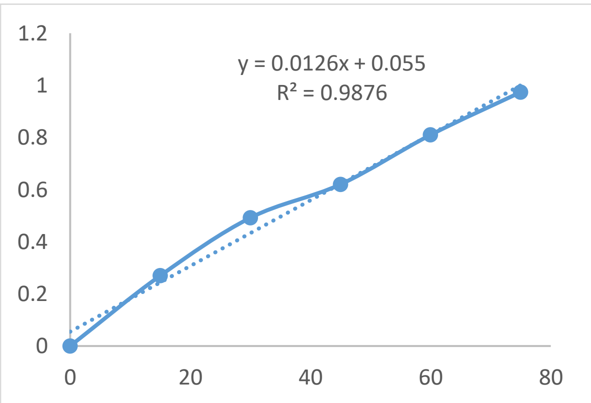

Figure 7 Ascorbic Acid Standard Calibration Curve

Figure 8 shows the changes in total antioxidant content of strawberries during storage. Based on the ANOVA test, ($p<0.05$) was obtained, demonstrating a significant difference between all treatments. In general, antioxidant levels in all treatments fluctuated over the six days. The control strawberries (T0, uncoated), exhibited the most drastic changes, increasing sharply from 68.41 mg AAE/gFW on day 0 to 166.61 mg AAE/gFW on day 2, but then dropping significantly to 82.86 mg AAE/gFW on day 4, before rising again to 296.83 mg AAE/gFW by day 6. In contrast, the coated samples exhibited more stable antioxidant retention. The most effective treatment was T2, showing the highest antioxidant retention, reaching *149,3 mg AAE/gFW on day 4 and* 308.99 mg AAE/gFW on day 6. While T3 showed more consistent values over time, T2 was the most effective in enhancing the overall antioxidant content, making it the best-performing treatment in this parameter.

Edible coatings don't control water vapor permeability but do control oxygen and carbon dioxide permeability, which helps delay the decomposition of complex sugars during the storage period [23]. This is similar to [30] Where strawberries coated with cross-linked starch and grape juice had the highest antioxidant content, while uncoated strawberries had the lowest antioxidant content.

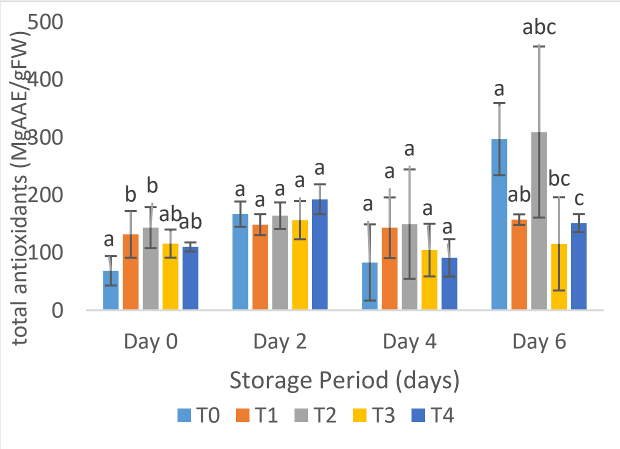

Figure 8 : Effect of total antioxidants on strawberries coated with different edible coatings during storage period

Data are presented as mean ± standard deviation (SD). Error bars represent the standard deviation from triplicate measurements (n =3). Different lowercase letters (a, b, c, d, e) indicate significant differences ($p < 0.05$) between samples according to Duncan's multiple range test (DMRT).

3.6. *Total Phenolic Content*

Total Phenolic Content (TPC) reflects antioxidant activity due to phenolic compounds that possess redox and free radical scavenging properties in fruits. Berries, including strawberries, are rich in natural antioxidants such as flavonoids and vitamin C, which operate through the glutathione pathway. A standard calibration curve is shown in Figure 9; the calibration equation standard was $y = 0.0049x + 0.0096$ as the reference for determining the phenolic content of the sample extracts with $R^2 = 0.9996$, indicating high linearity.

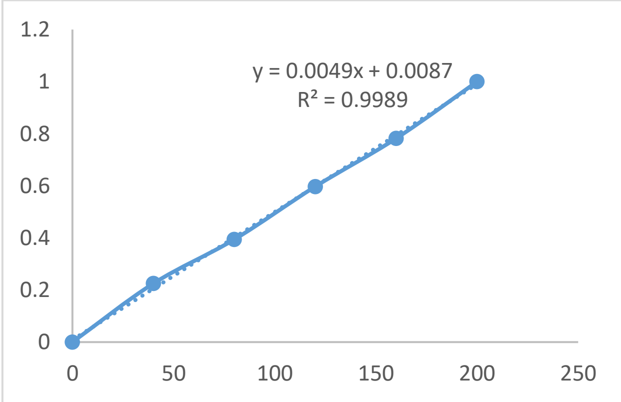

Figure 9 A Gallic Acid Standard Calibration Curve

Figure 10 shows the total phenolic content of strawberries during storage. Based on the ANOVA test, ($p<0.05$) was obtained, demonstrating a significant difference between all treatments. The control strawberries (T0, uncoated), showed the lowest phenolic content at day 0, 145.42 mgGAE/gFW, and day 4 173.09 mgGAE/gFW, indicating its inability to maintain phenolic stability in the early storage period. In contrast, T2 exhibited relatively stable and consistently high phenolic content from day 0 199.03 mgGAE/gFW, to day 4 206.56 mgGAE/gFW, suggesting that the edible coating in T2 effectively preserved phenolic compounds.[31]. This is similar to [32] where strawberies coated with jicama starch and calcium having the highest total phenolic content (TPC).

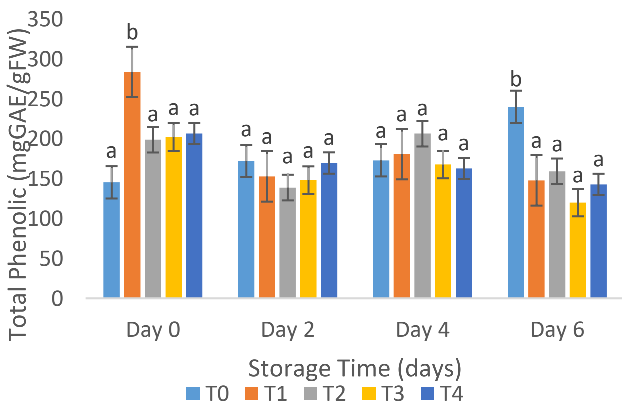

Figure 10 : Effect of total phenolic on strawberries coated with different edible coatings during storage period

Data are presented as mean ± standard deviation (SD). Error bars represent the standard deviation from triplicate measurements (n =3). Different lowercase letters (a, b, c, d, e) indicate significant differences ($p < 0.05$) between samples according to Duncan's multiple range test (DMRT).

Among all coating formulations, T2 composed of potato peel starch combined with sungkai leaf extract, was the most effective treatment overall in preserving strawberry quality during storage. This formulation consistently showed superior performance in minimizing weight loss and maintaining higher levels of antioxidant and phenolic compounds compared to other treatments.

Although T3, which consisted of pure starch without extract, demonstrated the best stability in total soluble solids (TSS) and total titratable acidity (TTA), these advantages were limited to

https://doi.org/10.29165/ajarcde.v9i1.635

specific parameters. The broader effectiveness of T2 is likely due to the synergistic effect of the starch matrix and the bioactive compounds present in the sungkai extract, which not only improved the physical barrier of the coating but also contributed functional benefits such as antioxidants. Notably, the T2 coating extended the shelf life of strawberries up to 4 days at room temperature.

Compared to the study by [33] Which applied potato peel starch coatings with varying concentrations (2%, 4%, and 6%) and reported optimal fruit quality only up to Day 1 for the best treatment, the addition of sungkai leaf extract in our formulation provided a functional enhancement. This suggests that bioactive compounds in sungkai extract, such as antioxidants and phenolics, contributed to delaying deterioration more effectively than starch alone. Thus, the current formulation offers an improved and practical alternative for extending strawberry shelf life using plant-based, biodegradable coatings.

4. CONCLUSION

Utilizing an edible coating made from potato peel starch and extract from sungkai leaves is an environmentally friendly technique that can extend the shelf life of postharvest strawberries by as much as 4 days. This is achieved using the T2 edible coating formulation, which consists of 4% starch, 50% extract from sungkai leaves , and 34% glycerol (based on the total starch content).

5. ACKNOWLEDGEMENT

The authors express their gratitude to the Directorate of Research, Technology, and Community Service, Directorate General of Higher Education, Research, and Technology, Ministry of Education, Culture, Research, and Technology of the Republic of Indonesia providing funding for the the 2024 Fiscal Year with the contract number 041/E5/PG.02.00.PL/2024.

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