Development and Characterization of Edible Coating Potato Peel Starch (*Solanum tuberosum* L.) and Sungkai Leaves Extract to Prolong the Shelf Life of Strawberries (*Fragaria* sp.)

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Abstract: *This study developed and characterized edible coatings from potato peel starch (*Solanum tuberosum *L.) to prolong the shelf life of strawberries (*Fragaria *sp.). Due to its high starch content, the edible coating was formulated using potato peel starch as the base material, and Sungkai leaf extract was added to enhance its antioxidant properties. The coating was characterized by viscosity, pH, color, antioxidant content, and thickness; and analyzed using FTIR, XRD, and SEM. The coating was applied to strawberries, and its effectiveness was evaluated based on weight loss and decay rate during storage. The edible coating was characterized by lower viscosity (10 cP), lower pH (6.83), darker color indicating bioactive compounds, and higher antioxidant content (5.72 mg AAE/g). FTIR data confirmed physical interactions among components; XRD revealed a semi-crystalline structure; and SEM showed a porous surface with visible cracks. Application of strawberries reduced weight loss and decay by 22.88 and 1.33% (day 4 at 3–5 °C) and 46.1 and 2.67% (day 12 at 28–31 °C). These results demonstrate the potential of potato peel starch and Sungkai leaf extract as an eco-friendly preservation solution.*

Keywords: *starch edible coating; potato peel starch; Sungkai leaves extract; strawberry; circular economy*

■ INTRODUCTION

Food waste significantly contributes to greenhouse gas emissions, with households, retails, and food service industries generating 931 million tons of waste annually. Households alone account for about 570 million tons of this total. In Indonesia, household food waste is estimated to exceed 20 million tons annually. This issue exacerbates food insecurity, strains waste management systems, and contributes to climate change, biodiversity loss, and pollution [1]. Potato (*Solanum tuberosum* L.) is the world's third most important food crop in terms of human consumption after rice and wheat, with a global production of about 366 million tons cultivated on 20 million hectares annually [2]. In 2023, Indonesia's potato production reached 1.25 million tons [3].

The potato processing industry produces significant amounts of waste, with potato peels making up 15–40% of the biomass. Thus, converting potato peels into value-added products is essential to mitigate their environmental impact [4]. Potato peels are rich in starch, a biodegradable hydrocolloid that forms excellent films. Potato peel starch, which is clear, odorless, and flavorless, is perfect for making edible coatings and films due to its characteristics similar to synthetic polymers [5]. Edible coatings can be developed from biopolymers such as carbohydrates, proteins, lipids, or multicomponent blends, with starch being the most abundant and inexpensive option due to its film-forming ability, non-toxicity, and biodegradability. Starch-based edible coatings can regulate biochemical processes, improve food quality and shelf life, and can be enriched with plant extracts to enhance functional properties such as antioxidant activity [6].

One type of food with a short shelf life is strawberries, which last between 1 and 2 days at 28–31 °C. They are non-climacteric fruits, harvested when ripe. Due to their elevated water activity, sugar concentration, and acidic pH, strawberries are prone to post-harvest physiological damage and mold, affecting up to 40% of the fruit [7]. Edible coatings can be used to prolong the shelf life and improve the quality of strawberries. They can also enhance strawberries by adding vitamins, minerals, colorants, antibacterial agents, and probiotics [8]. Therefore, making edible coatings/films from potato peel starch can reduce food waste issues.

Previous studies have explored the development of edible coatings and films. Charles et al. [5] characterized the edible films from various concentrations of potato peel starch with glycerol as a plasticizer. However, its application to food products has not yet been carried out. Furthermore, Refilda et al. [9] studied the effect of adding water extract of Sungkai leaves to aloe vera gel-based edible coatings on the strawberries' quality and shelf life. Additionally, there are several other studies using starch as a raw material for edible coatings for strawberries, including yam starch [10], corn starch [11], and soybean starch [12]. Therefore, this study will involve developing and characterizing an edible coating made from potato peel starch with the addition of Sungkai leaves extract and its application on strawberries.

■ EXPERIMENTAL SECTION

Materials

The materials employed in this study included starch, gallic acid, ascorbic acid, oxalic acid, NaOH, $FeCl_3 \cdot 6H_2O$, Na_2CO_3, phenantroline (Merck, Germany), Folin-Ciocalteau reagent (Sigma, USA), potato peel (UKM, Tella 88, Tembilahan), Sungkai leaves (Lubuk Minturun, Padang), glycerol (ecoserol), and distilled water.

Instrumentation

The instruments utilized in this study included a UV-vis spectropotometer (Thermo Scientific, Genesys 20), X-ray diffraction (XRD, Merck PANanalytical type X'Pert PRO), Fourier transform infrared (FTIR, Shimadzu FTIR Tracer-100), SEM (HITACHI FLEXSEM 1000), ultrasonic (GT Sonic UC3LD), blender, analytical balance (KERN), and laboratory glasswares (Pyrex).

Procedure

Potato peel starch extraction

The extraction of potato peel starch (PS) was adapted from Choque-Quispe et al. [13] with modifications in the raw material (potato peels instead of whole potatoes), the ratio of water, filtration method (cheesecloth instead of mesh), drying conditions (air-dried instead of oven-dried), and the absence of fine sieving after grinding. The potato peels were first rinsed with running water. Then, 250 g of the peels were blended with 1 L of water (1:4 ratio). The mixture was filtered through cheesecloth to separate the starch, which was allowed to settle. This process was repeated three times with the remaining peel residue. The collected starch was washed twice with water until clean and white. The starch was then separated by decantation and air-dried for 2 days. Finally, the dried starch was ground into a powder using a mortar.

Sungkai leaves extraction

The extraction of Sungkai leaves was adapted from Refilda et al. [9] with modifications in leaf-to-water ratio (1:10 instead of 1:5), extraction time (40 min instead of 15 min), and the use of pre-treated leaves that were dried and ground into powder. The Sungkai leaves are rinsed under running water, chopped into small pieces, and allowed to air-dry. Once dried, the leaves are ground into a powder using a blender. A 50 g of Sungkai leaves powder is added to 500 mL of distilled water and heated to 90 °C for 40 min while stirring. After boiling, the mixture is cooled and filtered through filter paper to obtain the Sungkai leaves extract.

Formulating starch edible coating

The formulation of the starch edible coating follows the method described by Charles et al. [5] with modifications, including lower heating temperature (60–90 °C) and the addition of Sungkai leaf extract. Unlike the original study, this research did not employ response surface methodology; preliminary experiments were conducted using varying concentrations of starch, glycerol, and Sungkai leaf extract. Based on its ability to reduce strawberry weight loss and decay, the best-performing formulation was selected. The edible coating was prepared using 4% potato peel starch and 1.35% glycerol in a total volume of 100 mL. Two formulations were developed: CP, which contained no Sungkai leaves extract, and CPE, which incorporated 0.53% (w/v) Sungkai leaves extract.

The ingredient mixture is heated for 15 min at a temperature range of 60–90 °C while being continuously stirred with a magnetic stirrer. After heating, the edible coating is allowed to cool to 28–31 °C. Each formulation was prepared once with all measurements performed in triplicate to ensure data reliability, minimize instrument variability, and improve result consistency. All ingredients were mixed, and the final volume was adjusted to 100 mL with distilled water. The CPE formulation used 50 mL of 10% aqueous Sungkai leaf extract as part of the total volume.

Characterization of potato peel starch edible coating

FTIR spectroscopy was utilized to analyze the functional groups of the starch edible coating within the range of 500–4500 cm^{-1} [14]. XRD analysis of the starch edible coating was conducted to gather crystalline information about the coating materials. The XRD data were recorded from 5° to 50° at 40 kV and 30 mA [15]. The morphology of the starch edible coating was examined using an SEM at 20.0 kV. The samples were sputter-coated with a thin layer of gold, 5 nm thick, under vacuum for improved conductivity prior to SEM analysis. The coating procedure followed the instrument's standard operating protocol as specified in the equipment manual. Images of the samples were captured at 1000× magnification [7]. Color parameters were measured using a colorimeter under consistent lighting conditions. The results were represented as lightness (L*), red-green (a*), and yellow-blue (b*) [16].

The antioxidant content of edible coating was measured using the modified phenanthroline method (MPM) with a UV-vis spectrophotometer described by Refilda et al. [9] with slight modifications. The antioxidant content was quantified using a standard ascorbic acid curve. The results are expressed in units of mg of ascorbic acid per gram of fresh sample weight (mg AA/g FW). Viscosity was measured using a Brookfield Viscometer with spindle number 2 at a speed of 30 rpm. The viscosity was determined by adjusting the viscometer dial reading using a multiplier factor corresponding to the spindle number and rpm, and the results were expressed in centipoise (cP) [17]. The thickness of the edible coating is measured using a digital caliper (Krisbow) following [18]. Edible coating solutions were uniformly cast into a petri dish. The thickness was measured 3 times after drying and film formation.

Coating application and storage conditions for strawberries

Strawberries were divided into two groups for coating. Each group was immersed in different coating solutions (CP and CPE) for 30 s, while uncoated strawberries served as controls. After immersion, the strawberries were allowed to drip off excess coating and dry at 28–31 °C. The control strawberries were treated similarly without any coating. Once dried, all strawberries were stored at 28–31 and 3–5 °C. Observations were conducted on days 0, 2, 4, and 6 for storage at 3–5 °C, and on days 0, 2, 4, 6, 8, 10, and 12 for storage at 28–31 °C. The fruits were analyzed for weight loss and decay index to evaluate the effectiveness of the edible coating during storage [9].

Weight loss strawberry

The weight loss of the strawberry was measured following the previous method [19]. The analysis involved weighing 5 strawberries per treatment individually. The weight loss was calculated as Eq. (1);

$$\text{Weight loss}(\%) = \frac{M_i - M_f}{M_i} \times 100\% \quad (1)$$

M_i represents the initial mass, and M_f denotes the final mass. Measurements were conducted at intervals of no less than two days.

Decay index strawberry

The decay index of the strawberry is calculated using the method described in Li et al. [20]. The severity of strawberry decay was evaluated visually using a five-point scale: 0 representing no damage, 1 for slight damage (less than 25%), 2 for moderate damage (25–50%), 3 for severe damage (50–75%), and 4 for complete damage (75–100%) [16]. The decay index was then calculated as Eq. (2);

$$\text{Decay index strawberry}(\%) = \frac{\sum(L_i \times N_i)}{L \times N} \times 100\% \qquad (2)$$

In this context, L_i denotes the intensity of damage, N_i is the number of fruits at a particular damage level, L represents the highest observed damage level, and N signifies the total number of fruits assessed.

Statistical analysis

The experiments were conducted thrice, presenting the results as the mean ± standard deviation. Data analysis was conducted using one-way ANOVA with SPSS software (SPSS, Chicago, IL, USA). Significant differences between mean values were identified using Duncan's multiple range test at a significance level of 0.05 ($p < 0.05$) [21].

■ RESULTS AND DISCUSSION

Formulating Starch Edible Coating

This study developed the edible coatings: potato peel starch edible coating (CP), potato peel starch edible coating, and Sungkai leaves extract. As shown in Fig. 1, the edible coating solutions before the casting process are displayed. It is observed that the CP solution has a lighter and somewhat cloudy appearance, whereas the CPE solution exhibits a dark brown color due to the presence of active compounds in the Sungkai leaves extract. After the casting and drying processes, the resulting edible coatings are presented in Fig. 2. CP appears transparent with a few particles, whereas CPE exhibits a darker brown color.

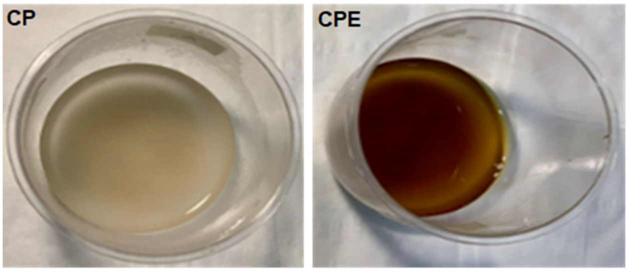

Fig 1. Edible coating solutions

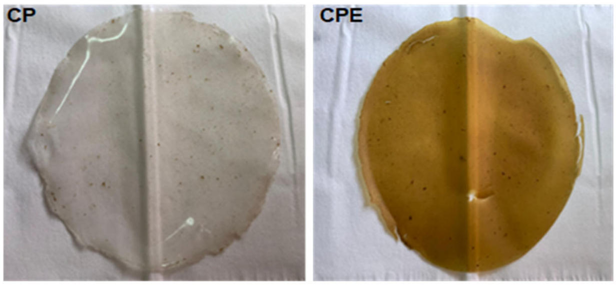

Fig 2. Film-form edible coating

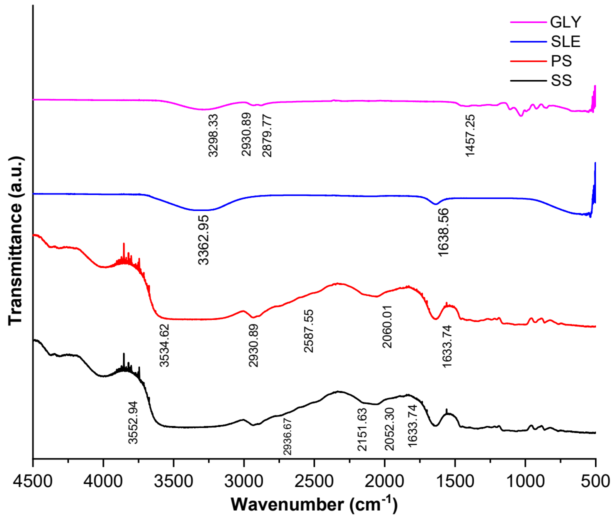

Fig 3. FTIR spectra of edible coating components

FTIR Analysis Edible Coating

The FTIR spectra of the edible coating components, including PS, standard starch, glycerol, and Sungkai leaf extract, are presented in Fig. 3. The FTIR spectrum of PS showed absorption bands similar to those of standard starch (SS), indicating comparable structural components. Broad bands around 3552–3298 cm^{-1} correspond to –OH stretching vibrations in polysaccharides, while bands near 2930–2942 cm^{-1} indicate C–H stretching. A distinct peak at 1633 cm^{-1} represents C=O stretching from ketone or amide groups. Unique bands at 2587 and 2060 cm^{-1}, present in PS but absent in SS, suggest residual compounds from the potato peel matrix [22]. Glycerol exhibited characteristic O–H and C–H bands within the same regions, consistent with glucose units and plasticizer components [23]. Meanwhile, the FTIR spectrum of Sungkai leaf extract showed strong absorption at 3364 cm^{-1}, indicating O–H groups from phenolic and flavonoid compounds, and a band at 1639 cm^{-1} attributed to C=O stretching in phenolics and amides [24].

The FTIR spectra of the starch-based edible coatings are shown in Fig. 4. The FTIR results of PS coatings, both with and without Sungkai leaf extract, exhibit similar absorption patterns. This indicates that no significant

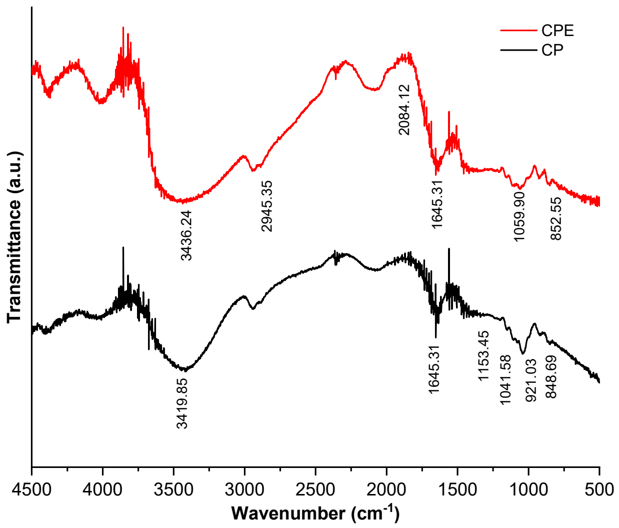

Fig 4. FTIR spectra of edible coatings

chemical structural changes occurred in the edible coating. The addition of Sungkai leaf extract did not result in the formation of new chemical bonds, but rather physical interactions such as hydrogen bonding between phenolic compounds and the starch matrix. The similarity in spectral patterns suggests good compatibility and the absence of phase separation within the edible coating [25]. The absorption bands at 3420 and 3436 cm^{-1} correspond to O–H stretching vibrations from starch, glycerol, and water. The bands at 2945 and 2084 cm^{-1} represent C–H stretching vibrations from the starch matrix. The band at 1645 cm^{-1} in both samples is attributed to H–O–H bending vibrations, indicating the presence of bound water. The absorption band at 1153 cm^{-1} corresponds to the C–O–C ether stretching vibration from the starch structure [26]. Moreover, a shift and change in the intensity of the O–H band from 3420 to 3436 cm^{-1} indicate physical interactions through hydrogen bonding between the phenolic compounds in the Sungkai leaf extract and the starch matrix. This finding is consistent with the study by Mushtaq et al. [27], which reported that the incorporation of olive leaf polyphenol fractions into starch-based films reduced the intensity of the O–H absorption band.

XRD Analysis Edible Coating

The XRD patterns of CP and CPE are displayed in Fig. 5. CP shows sharp diffraction peaks at several 2θ positions, especially around 15°, 17°, 23°, 30°, and 44° with a wide peak at around 20°. These peaks indicate that PS has a type B crystal structure with a semi-crystalline structure, which means the presence of both crystalline and amorphous structures. The semi-crystalline structure of PS can improve the mechanical and barrier properties of edible coatings, making them more effective in protecting food [28]. CPE also presents a semi-crystalline structure, with similar peaks at 17°, and a wide peak at around 20° and 44°. According to González-Torres et al. [29] chemical modifications do not significantly affect the diffraction pattern. Instead, they primarily influence the percentage of starch crystallinity, as modifications tend to occur first in the amorphous phase and later in the crystalline phase. The degree of crystallinity is directly related to the amylopectin content, while the amorphous phase is associated with the amylose present in the polymer.

The higher peak intensity in CP reflects the higher degree of crystallinity (36.76%). Nevertheless, CPE shows a diffraction pattern similar to CP, but with lower peak intensities. This decrease in intensity causes the crystallinity level to become lower (21.27%). The decrease in diffraction peak intensity and crystallinity indicates that the crystal structure is disrupted and more amorphous areas are formed. The extract of Sungkai leaves contains polyphenols that can interact with starch molecules in the edible coating. Polyphenols have many O–H groups that can form hydrogen bonds with starch

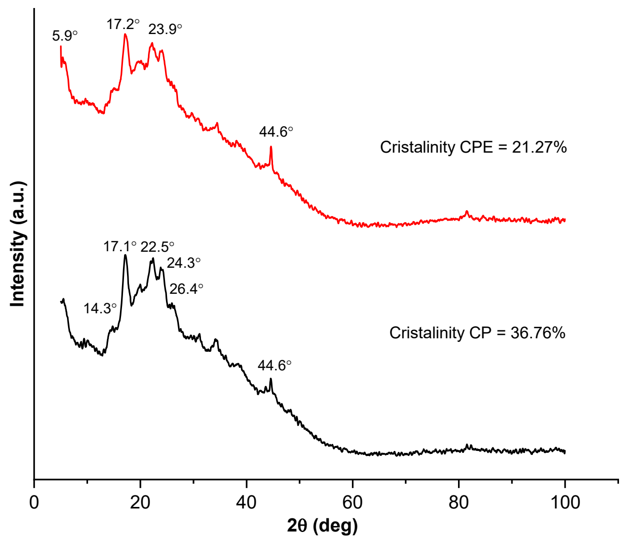

Fig 5. XRD diffraction pattern of edible coatings

molecules. These hydrogen bonds can disrupt the orderly arrangement of starch molecules, leading to a decrease in crystallinity. Zhang et al. [30] also reported that the polyphenols from sweet potato peel disrupted the crystal structure of starch.

SEM Analysis Edible Coating

The microstructure of the edible coating was analyzed using an SEM instrument. In Fig. 6, SEM results showed that the surface of the PS edible coating was not completely smooth, with a slightly wavy structure, and the uneven distribution of components in the PS matrix may cause small pores or microcracks. This affects the barrier properties and mechanical strength, making it less effective in protecting strawberries [31]. The observed phenomenon may be attributed to air bubbles' entrapment during the coating solution's. Inadequate dissolution and gelatinization of starch can result in an uneven film structure. This suggests that while the edible coating derived from PS is capable of forming a continuous film layer, certain regions exhibit limitations in the dispersibility and molecular interactions of starch during the film formation process [32]. SEM results indicated that adding Sungkai leaves extract made the surface of the edible coating from PS more uneven, with small lumps, pores, and microcracks. This lack of homogeneity is due to the extract particles not fully dispersed in the starch matrix. These findings align with Nowak et al. [33] that plant extracts can influence the homogeneity and microstructure of films or coatings, subsequently affecting their barrier and mechanical properties.

Viscosity Analysis Edible Coating

The viscosity analysis of starch edible coatings, as shown in Table 1, revealed that the highest viscosity was observed in CP, which is 182 cP. In comparison, the lowest viscosity found in CPE is 10 cP. Low viscosity facilitates easier application and the formation of a more uniform and effective layer. Conversely, very high viscosity can lead to application difficulties, such as the formation of excessively thick and uneven layers. The

Table 1. Analysis of viscosity, color, thickness, pH, and antioxidant content

Analysis	CP	CPE
Viscosity (cP)	182 ± 0.27^a	10 ± 0.2^b
Color	Colorless	Colorless
L*	51.76 ± 0.01^a	5.49 ± 0.01^b
a*	2.97 ± 0.01^a	24.49 ± 0.01^b
b*	20.10 ± 0.11^a	9.30 ± 0.1^b
Thickness (mm)	0.12 ± 0.006^a	0.10 ± 0.006^b
pH	8.03 ± 0.06^a	6.83 ± 0.06^b
Antioxidant content (mm AAEgFW)	0.45 ± 0.044^a	5.72 ± 0.024^b

Information: a and b show statistically significant differences ($p < 0.05$) based on the t-test

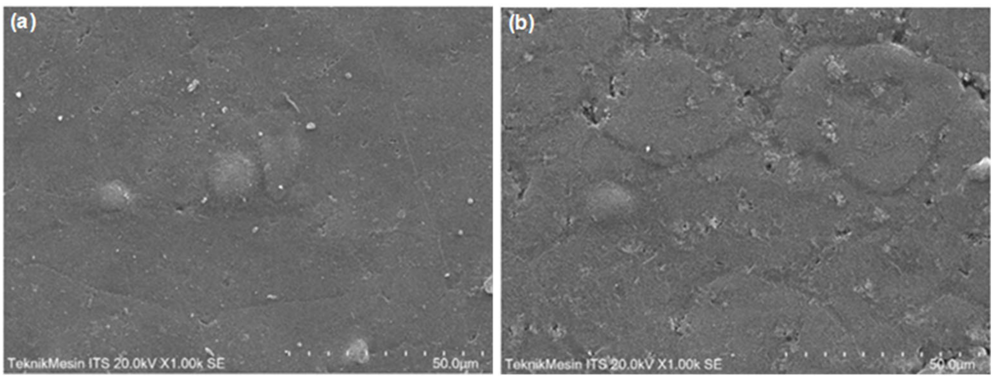

Fig 6. SEM analysis of edible coating

addition of plant-based extracts such as Sungkai leaf extract can reduce the viscosity of edible coatings due to their active compounds, particularly polyphenols. These polyphenols may weaken the intermolecular forces within the coating matrix by disrupting hydrogen bonding interactions between starch and plasticizer components [34]. This aligns with Aayush et al. [35], which identified an optimal viscosity of 14.7 cP, providing a good balance between thickness, ease of application, and the ability to form an effective and uniform protective layer on the fruit.

Viscosity plays a crucial role in defining the rheological properties of edible coatings. Higher viscosity typically results in thicker and more stable coatings, enhancing protection against weight loss and fungal infections in fruits. However, excessively high viscosity can hinder even application and negatively impact the fruit's appearance and texture. On the other hand, lower viscosity facilitates easier and more uniform application but may not offer adequate protection. Ideally, the viscosity should be sufficiently high to ensure effective protection without compromising the ease of application [36].

Color Analysis Edible Coating

The color analysis of starch edible coatings, shown in Fig. 7 and Table 1, indicates that the addition of Sungkai extract caused significant changes in the color parameters. The L* value decreased from 51.76 in the edible coating without extract to 5.49, and the b* value also decreased from 20.10 to 9.30 after the addition of the extract, indicating a reduction in brightness and an increase in opacity. The a* value increased dramatically from 2.97 to 24.49, indicating a shift in color towards red. This is similar to [37], the addition of *Flourensia microphylla* extract to PLA and chitosan-based edible coating decreased the L* value and increased the b* value.

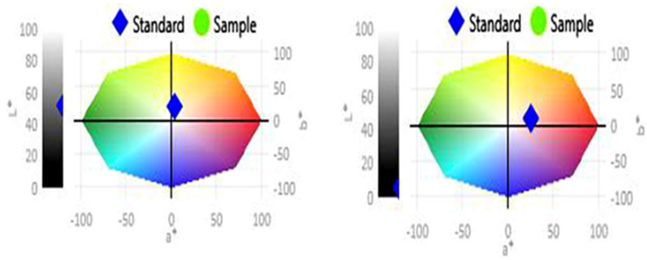

Fig 7. Color analysis of edible coating

In contrast, the a value varied depending on the extract's pigment characteristics. The observed reduction in brightness and alteration in color are likely attributed to the presence of phenolic or flavonoid pigments in the Sungkai leaves extract. This is similar to Huang et al. [38], which linked a positive b* value in edible films to natural pigments like quercetin, luteolin, and apigenin. Moreover, edible films with low transparency, such as CPE, can diminish food sensitivity to light, potentially safeguarding the coated products from light-induced degradation during storage.

Thickness Analysis Edible Coating

The thickness analysis of the edible coating is shown in Table 1. CP is 0.12 mm, and CPE is 0.10 mm. The higher compared to CPE. The edible coating CP exhibits a greater thickness compared to CPE. The thickness of the edible coating is influenced by the volume of the casting solution and the total solids it contains. When plant extract is added, the edible coating's thickness decreases due to a reduction in the total solids, while the volume of the casting solution remains unchanged [39].

pH Analysis Edible Coating

The pH analysis of edible coating is shown in Table 1, revealing that the pH of CPE is 6.83, lower than that of CP, which is 8.03. The pH or acidity level result indicates the H^+ ion content in an edible coating product. The more H^+ ions contained, the lower the pH value, indicating a higher acidity level. The inclusion of the extract led to changes in both the pH and the appearance of the resulting coating. The reduction in pH after adding the extract is attributed to the slightly acidic nature of the extract [40]. This is similar to Nur et al. [41]; the addition of curry leaves extract to corn starch-based edible coating reduces pH; this edible coating is applied to strawberries.

Antioxidant Content Analysis of Edible Coating

An analysis of the antioxidant content of edible coating is shown in Table 1, where CPE contains higher antioxidants at 5.72 mg AAE/gFW than CP at 0.45 mg AAE/gFW. This is caused by the polyphenol compounds contained in the Sungkai leaves extract. Sungkai leaves extract contains phenolics, flavonoids, tannins, alkaloids, and saponins. Phenolics are plants' most abundant active chemical compounds. High phenolic content is associated with antioxidant activity that can neutralize free radicals [42]. Similar trends and outcomes have been reported by Bodana et al. [6] that the addition of pomegranate peel extract to edible films and coatings based on jackfruit seed starch also increased the antioxidant and total phenolic content, Akkuzu et al. [43] shows that the addition of fireweed water extract significantly enhances the antioxidant activity in corn edible films.

Weight Loss Strawberry

Weight loss in strawberries increased significantly with longer storage times, at 28–31 °C (Fig. 8(a)) and 3–5 °C (Fig. 8(b)). This weight loss is typically due to the fruit's respiratory process, humidity transfer, and oxidation. However, strawberries coated with CPE showed a reduction in weight loss ($p < 0.05$) compared to the control strawberries, 48.16% at 28–31 °C after 6 days and 46.09% at 3–5 °C. The coating reduces the respiration rate, thereby decreasing weight loss. Conversely, strawberries coated with CP at 28–31 °C experienced increased weight loss, likely due to cracks in the coating [44].

The percentage of weight loss is associated with the decline in quality and freshness due to transpiration during the ripening process. Coated fruits can better retain their weight because the coating serves as a hydrophobic barrier at the fruit's stomata, preventing water loss and reducing transpiration [45]. This is similar to previous works on strawberries coating with the SPI-SF layer experienced less weight loss and maintained fruit quality for a longer period compared to uncoated strawberries [46-47]. Those strawberries coated with chitosan and *trans*-resveratrol experienced less weight loss. This inhibited water loss, thus prolonging the freshness of the fruit during storage.

Decay Index Strawberry

The decay of strawberries increases progressively throughout the storage period at 28–31 °C (Fig. 9(a)) and 3–5 °C (Fig. 9(b)). Strawberries, known for their high perishability and vigorous post-harvest physiological processes, frequently fall victim to decay caused by fungal infections. This susceptibility significantly shortens their shelf life [20]. The results of the edible coating made from potato starch with Sungkai leaves extract showed effectiveness in slowing down the decay index of strawberries at both 28–31 °C (Fig. 10(a)) and at 3–5 °C (Fig. 10(b)). Based on the observed decay index, untreated strawberries (control) decayed the fastest, with a significant increase from day 4 to day 6 at 28–31 °C and from day 8 to day 12 at cold temperature. Strawberries coated with CP showed a reduction in decay rate compared to the control, while strawberries with CPE had the best resistance with the lowest decay index throughout storage. These results prove that the developed edible coating can effectively prolong the shelf

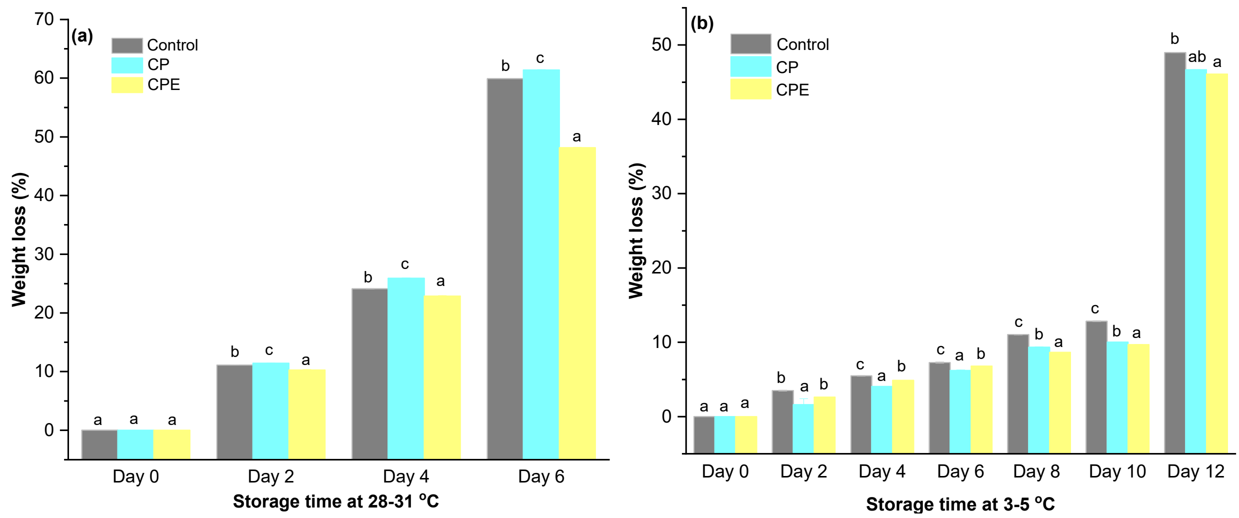

Fig 8. Weight loss strawberries at (a) 28–31 °C and (b) 3–5 °C

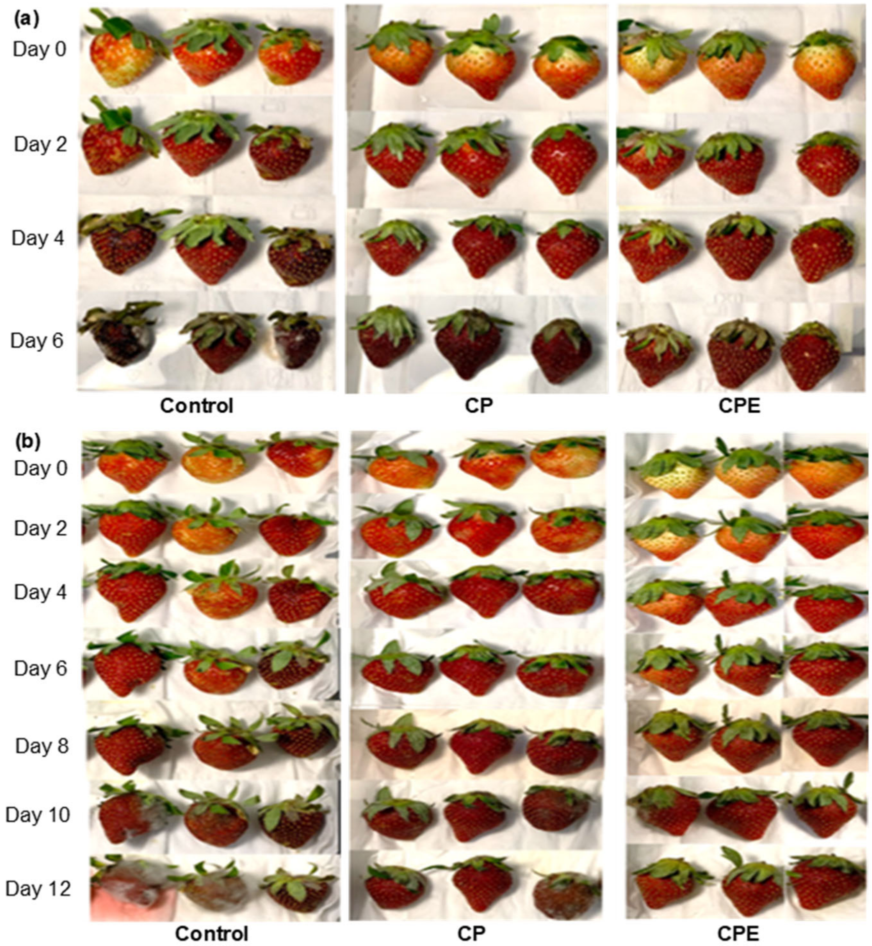

Fig 9. Coated and Uncoated strawberries at (a) 28–31 °C and (b) 3–5 °C

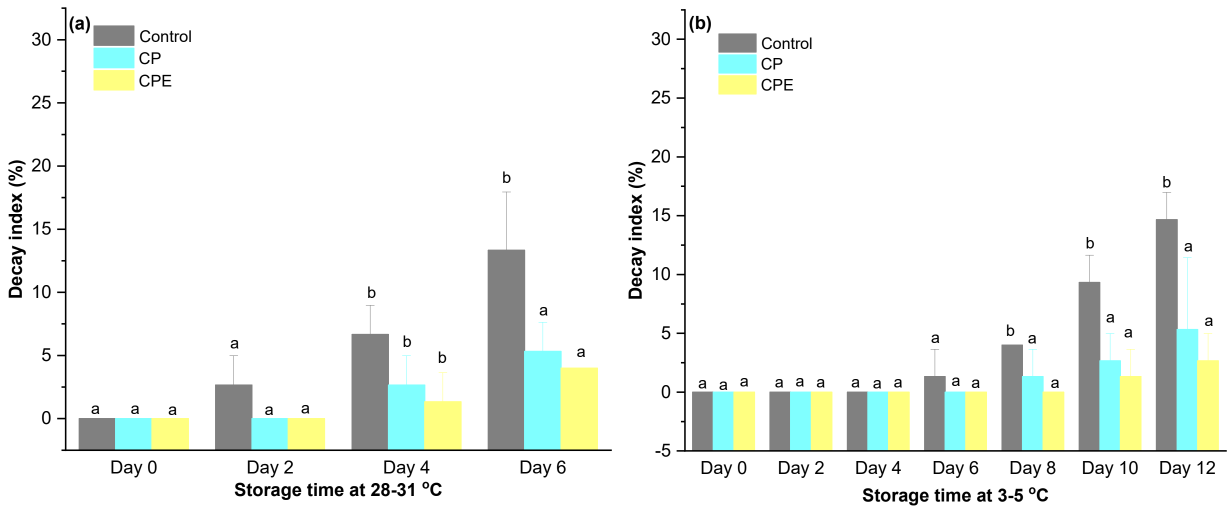

Fig 10. Decay index of coated and uncoated strawberries at (a) 28–31 °C and (b) 3–5 °C

life of strawberries, especially at 3–5 °C. This finding is similar to previous work, whereas the edible coating based on silver nanoparticle starch applied to strawberries at 25 ± 3 °C lasts up to 6 days, and strawberries at refrigerated temperature (6 ± 2 °C) last up to 16 days [48]. The xanthan gum-based edible coating at 4 ± 1 °C showed the lowest decay rate in strawberries [49].

■ CONCLUSION

This study developed an edible coating from potato peel starch with the addition of Sungkai leaves extract, which shows longer shelf life of strawberries. However, further optimization is needed to address limitations such as surface cracks. Strawberries treated with edible coating exhibited a significant decrease in weight loss and decay index compared to the control group, prolonging the shelf life up to day 12 at 3–5 °C and up to day 4 at 28–31 °C. The addition of Sungkai leaf extract significantly influenced the physicochemical and structural properties of the starch-based coating. It decreased viscosity and pH, a darker solution color (indicating the presence of bioactive compounds), and higher antioxidant content. The extract-containing coating also exhibited reduced thickness. There is a physical interaction based on FTIR data, decreased crystallinity from XRD analysis, and a more heterogeneous and rougher surface morphology, as shown in SEM results. These findings indicate the potential of this formulation as a biodegradable food preservation material, though further improvements in physical stability are still necessary.

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■ CONFLICT OF INTEREST

The researcher confirms the absence of any conflicts of interest in this study. All stages of the research were carried out independently, ensuring no external parties influenced the outcomes or data interpretation.

■ AUTHOR CONTRIBUTIONS

Ajeng Putri Ardiani contributed to the conceptual design and methodology, as well as the formulation and characterization of the edible coating. Refilda and Yefrida contributed to the conceptual design, methodology and manuscript revision. All authors agreed to the final version of this manuscript.

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