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Sustainable Goat Skin Gelatin-Based Edible Coatings Incorporated with Konjac Glucomannan: Physicochemical Properties and Preservation Efficacy on Strawberries

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ABSTRACT

This study evaluated the effectiveness of edible coatings made from goat skin gelatin, with and without konjac glucomannan, for preserving strawberries at room temperature. Three groups were analyzed: a control group (EKG1), a gelatin coating group (EKG2), and a gelatin with konjac glucomannan group (EKG3). The addition of konjac glucomannan increased coating viscosity and thickness. While EKG3 initially raised total soluble solids, this difference disappeared by day 3. Both gelatin-based coatings maintained pH levels and showed no significant firmness difference between EKG2 and EKG3. The coatings effectively slowed color changes and pigment oxidation because they limited oxygen exposure. Weight loss was similar for EKG2 and EKG3, but EKG3 better preserved ascorbic acid on day 12. These results suggest that natural coatings can effectively reduce fruit spoilage, supporting sustainable food packaging and circular economy principles because they extend shelf life while being environmentally friendly.

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1. INTRODUCTION

Strawberries (*Fragaria ananassa*) are highly coveted on a global scale due to their distinctive aroma, vibrant color, appealing taste, and remarkable nutritional profile. This fruit is abundant in vitamins, minerals, flavonoids, anthocyanins, and phenolic compounds, all of which support overall health. Nevertheless, strawberries have a limited shelf life, generally lasting no more than five days, owing to their elevated respiration rate and inherent perishable nature. Furthermore, mechanical damage and fungal infections can expedite post-harvest deterioration, resulting in significant alterations to the fruit's color and firmness. One effective technology for extending the shelf life of strawberries at room temperature is coating technology. Using an edible coating made from natural materials is a promising approach. This coating serves as a physical barrier against oxygen and moisture, while also having antimicrobial properties that inhibit the growth of pathogens. Strawberries that are coated with this edible layer can maintain their firmness, color, and nutritional content for a longer period compared to uncoated strawberries. Edible coatings can effectively reduce respiration rates and enzymatic activity in fruits, which helps minimize damage and decay [1]. By doing so, these coatings enhance the economic value of strawberries by decreasing post-harvest losses and prolonging the marketing period. Two common materials used for these coatings are gelatin and konjac glucomannan, each offering unique properties and benefits. Gelatin, derived from animal collagen, forms a biodegradable and environmentally friendly gel. It possesses film-forming, antimicrobial, and emulsifying properties that protect the fruit from damage while extending its shelf life through the creation of a colloidal coating [2,3]. On the other hand, konjac glucomannan, a polysaccharide from konjac tubers, is known for its ability to form a stable gel when mixed with water, retaining moisture and being environmentally friendly [4]. When used as a coating, konjac glucomannan not only provides additional protection but also serves as a carrier for active molecules, such as antioxidants [5].

One of the primary challenges in the innovation of edible coatings is the formulation of a product that offers optimal protection for strawberries while preserving their organoleptic characteristics, including taste and texture, and maintaining their nutritional value. The selection of raw materials for edible coatings is crucial, particularly focusing on natural sources like gelatin derived from goat skin and konjac glucomannan. This method aligns with the growing “back to nature” trend in the food industry. As a result, there is an urgent need for experimental studies to assess the effectiveness of combining goat skin gelatin and konjac glucomannan as coating materials.

This study aims to provide insights into how this combination affects the quality, freshness, and shelf life of strawberries, while also contributing to the development of more natural and sustainable food products. The present research focuses on creating an edible coating using a combination of gelatin obtained from goat leg skin and konjac glucomannan. This combination offers unique advantages compared to previous studies. Prior investigations have shown that blending gelatin with konjac glucomannan can improve the physical and mechanical properties of the coating. Notably, this combination has been found effective for short-term preservation. However, existing studies predominantly explore the addition of Aomori Hiba essential oil and the use of Hinokitiol, without fully examining the standalone capabilities of gelatin and konjac glucomannan as edible coatings. This study accentuates the originality of employing gelatin derived from goat leg skin as the principal raw material. This innovative approach not only adds value by repurposing waste generated by the livestock industry but also contributes to waste reduction. The incorporation of konjac glucomannan

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enhances the physical and mechanical properties of the coating, thus increasing its durability and efficacy as a food packaging material. Additionally, this research utilizes homogenization and ultrasonic treatment methods to optimize the mixing and physical characteristics of the coating solution. The strategy of integrating these two materials through homogenization followed by ultrasonic treatment represents a novel approach that has not been extensively investigated within the domain of edible coatings. The hydrocolloid solution developed for this edible coating has the potential to extend the shelf life and preserve the nutritional quality, particularly the vitamin C content, of various food products, including fruits and vegetables.

This study aims to evaluate the effectiveness of the combination of goat skin gelatin and konjac glucomannan as an edible coating for strawberries stored at room temperature. Key parameters to be measured include viscosity, pH, texture, weight loss, color, decay percentage, total soluble solids, and ascorbic acid content. The novelties of this research contain three key innovations: (i) the use of gelatin specifically derived from goat leg skin, which is a rarely utilized by-product of livestock in food coating applications; (ii) the incorporation of konjac glucomannan without essential oil additives, emphasizing its synergistic interaction with gelatin to enhance both mechanical and barrier properties; and (iii) the implementation of a dual-step processing method (homogenization followed by ultrasonic treatment) to improve the performance and stability of the coating. These advancements not only promote the value-added utilization of agricultural waste but also contribute to sustainable food preservation strategies that align with the Sustainable Development Goals (SDGs), particularly SDG 12 (Responsible Consumption and Production).

2. METHODS

2.1. Preparation of Strawberries as a Material Sample

Organic strawberries (*Fragaria ananassa*) were acquired from a local market in Bangkok, Thailand, for a one-time purchase. The strawberries were subsequently stored at a controlled temperature of 0 ± 1°C and utilized within a 24 h period. For the experimental procedures, strawberries demonstrating uniform color and size, and exhibiting no visible damage, were carefully selected.

2.2. Preparation of Gelatin from Goat Skin

Gelatin was extracted from goat skin following the modified method of other literature [6,7]. The goat skin was initially treated with 0.5 M NaOH to remove hair and fat, followed by neutralization with tap water until the pH stabilized. Next, the pretreated skin was immersed in 0.5 M acetic acid for 24 h and neutralized again. After this, the swollen skin underwent ultrasound treatment using a VC 750 model (Sonic and Materials Inc., USA) at 80% amplitude for 2 h. Extraction was performed in a water bath (Model WNB 14, Memmert, Germany) at 60°C for 24 h, using a skin-to-distilled water ratio of 1:10. The gelatin extract was then frozen and subsequently freeze-dried using a freeze dryer (DK-3450 Lynge model, Labogene ApS, Denmark). The resulting freeze-dried gelatin had a foam-like structure, a Bloom value of 226, and a pH of 7.0 ± 0.1. The gelatin was stored in a freezer to ensure its quality was maintained.

2.3. Preparation of Coating Solutions

The coating solution was prepared according to other method [8] with slight modifications. The treatments were categorized into three groups: EKG1 (which contained neither gelatin nor konjac glucomannan), EKG2 (which included 2 g of goat skin gelatin), and EKG3 (which comprised 2 g of goat skin gelatin and 200 mg of konjac glucomannan) to create an edible

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coating solution. Subsequently, glycerol (20% w/w) and ascorbic acid (0.5% w/w) were incorporated into the mixture. Distilled water was then added until the total volume of the solution reached 100 mL. After combining all components, the solution was homogenized at 5000 rpm for 1 min and then subjected to ultrasound treatment at 40 kHz for 20 min. The solution was then prepared for use as an edible coating. The formulation and schematics of the edible coating production are shown in **Table 1** and **Figure 1**.

Table 1. Composition of edible coating treatment.

Edible coating treatment	Gelatin (mg)	Konjac glucomannan (mg)
EKG1	0	0
EKG2	2000	0
EKG3	2000	200

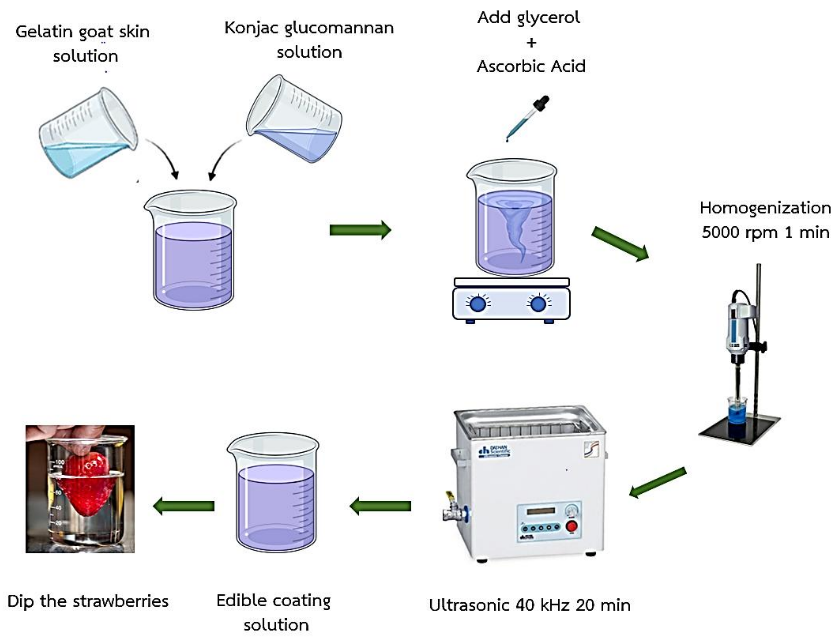

Figure 1. Schematic process of edible coating prepared from goat skin gelatin and konjac glucomannan.

2.4. Fruit Coating

The edible coatings were prepared according to **Table 1** (EKG1, EKG2, and EKG3). Strawberries of uniform size and color were selected, washed with distilled water for 1 min, and air-dried at room temperature for 1 h to eliminate any residual water. Next, the strawberries were dipped into the edible coating solution for 30 s and allowed to dry at room temperature to remove any excess coating. Control samples consisted of strawberries that did not receive any coating treatment. All strawberries were stored at room temperature, and their physicochemical properties were evaluated every 3 days for a total duration of 12 days.

2.5. Analysis of Goat Skin Gelatin/Konjac Glucomannan-based Edible Coating and Coated Strawberries

2.5.1. Determination of viscosity

Determination of edible coating viscosity was conducted following other method with slight modifications [9]. Viscosity was measured using a Brookfield DV-III Ultra (Brookfield

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Engineering Laboratories, Inc., USA) with spindle no. 31 at a speed of 100 rpm at room temperature.

2.5.2. Determination of pH

The pH of the edible coating was determined following the method of da Silva et al. (2024) with slight modifications. The pH of the strawberry after dipping in the edible coating was measured using a Mettler Toledo pH meter (AG 8603, Greifensee, Switzerland), which was standardized with pH buffers of 4.0, 7.0, and 9.0.

2.5.3. Firmness measurement

The firmness of the strawberry was measured according to other method described by [10] with some slight modifications, using a Texture Analyzer (TA-XT2 Plus, Stable Microsystems, Surrey, UK). Firmness values were obtained using a cylindrical probe (P/36R). The analysis conditions were set as follows: pretest speed of 1 mm/s, test speed of 3 mm/s, post-test speed of 10 mm/s, distance of 5 mm, and trigger force of 0.2 N.

2.5.4. Determination of weight loss

Weight loss of the strawberry samples was determined through other method [11] with slight modifications. The weight loss (WL) of strawberry samples during storage was determined by weighing the fruits in the tray before storage and on each day of analysis.

2.5.5. Color measurement

The color of the sample was measured through other method [11] with slight modifications. The color was assessed in two ways: first, by evaluating the color of the edible coating, and second, by examining the color of the strawberries that had been coated with this edible layer. Color measurements were conducted at specified observation times. A colorimeter (Konica Minolta, Chroma Meter CR-400/410, Tokyo, Japan) was used for color testing, analyzing three parameters: L* (lightness), a* (redness), and b* (yellowness). Before use, the colorimeter was calibrated with white standards, which had the following calibration values: L1 = 94.43, a1 = 0.27, and b1 = 2.05. The total color difference (ΔE) was calculated according to the appropriate equations (equation (1)).

$$\Delta E=\sqrt{\left(L^{*}-L_{1}\right)^{2}+\left(a^{*}-a_{1}\right)^{2}+\left(b^{*}-b_{1}\right)^{2}} \quad (1)$$

Depending on the value of ΔE range could measure the difference between two samples in the following range: (a) ΔE = 0-0.5 trace level difference, (b) ΔE = 0.5-1.5 slight difference, (c) ΔE = 1.5-3.0 noticeable difference, (d) ΔE = 3.0-6.0 appreciable difference, (e) ΔE = 6.0-12.0 large difference and (f) ΔE > 12.0 obvious difference.

2.5.6. Decay of strawberry

The decay of strawberries was determined through other method [12] with slight modifications. Strawberries were analyzed every three days throughout the evaluation of storage, and the number of fruits exhibiting surface mycelia growth or bacterial damage was noted as decayed. The decay (%) for each treatment was determined by dividing the count of decayed strawberries by the total number of initial fruits and then multiplying by 100.

2.5.7. Determination of total soluble solid content

The total soluble solid (TSS) content of the samples was determined using a refractometer (Model #Erma, Tokyo, Japan), following the method described by [13] with minor

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modifications. Strawberry juice was extracted as part of the procedure, and the TSS content was analyzed and quantified. The results were reported as a percentage by weight, reflecting the concentration of soluble solids present in the juice.

2.5.8. Determination of ascorbic acid

Ascorbic acid in strawberries was determined following the method of [14]. Two milliliters of each juice sample were quickly added to 5 mL of a solution containing 3% metaphosphoric-acetic acid after homogenizing them. Then, they were titrated with a DCPIP solution (50 mg in 200 mL of distilled water), and the results were reported as g/kg on a fresh weight basis.

2.6. Statistical Analysis

Data analysis was performed using the Statistical Package for Social Sciences (SPSS, version 28.0, IBM, USA). A two-factor analysis of variance (ANOVA) was conducted, followed by Duncan's multiple range test to assess the differences between means. All experiments were carried out in triplicate.

3. RESULTS AND DISCUSSION

3.1. Viscosity of Edible Coatings

The viscosity of edible coatings (EKG) in **Table 2** shows significant differences between treatments ($p < 0.05$), which directly impact the quality and effectiveness of the coating in protecting strawberries. In EKG 1 (control), viscosity was recorded at 0 cP, as this formulation does not contain gelatin or konjac glucomannan. The absence of these structural components prevents the formation of a coating layer, leaving strawberries more susceptible to water loss, oxidation, and microbial contamination. As a result, strawberries coated with EKG1 lack protection and tend to decay more quickly. In contrast, EKG2, which uses goat skin gelatin in a 100 mL distilled water solution, had an increased viscosity of 1.08 cP. Although the layer formed is thin, the presence of gelatin still provides basic protection for the strawberries. This gelatin layer functions to reduce water evaporation and slow down the respiration rate of the fruit. However, the protection offered is relatively minimal due to the low viscosity, meaning the layer is not strong enough for long-term protection or to withstand higher environmental pressures [1]. Meanwhile, EKG3, which contains a combination of goat skin gelatin and 20% konjac glucomannan, exhibited a significant increase in viscosity, reaching 137.62 cP. Konjac glucomannan, a highly viscous polysaccharide, produces a thicker and stronger coating layer compared to EKG2. Higher viscosity allows for the formation of a more compact and uniform coating, which provides more effective protection against water loss, slows the respiration rate, and prevents microbial contamination [15]. Thus, EKG3 can significantly extend the shelf life of strawberries, maintaining their quality and freshness for a longer period compared to EKG2.

The significant difference in viscosity between EKG 2 and EKG 3 highlights the advantage of higher viscosity in producing a thicker and more effective coating layer. EKG 3, with a viscosity of 137.62 cP, can form a more durable and protective layer, better retain moisture, and inhibit microbial growth. On the other hand, EKG 2, with a viscosity of only 1.08 cP, creates a thinner layer that provides only minimal protection. This indicated that the addition of konjac glucomannan significantly enhanced the performance of the edible coating in protecting strawberries. Konjac glucomannan significantly enhanced edible coatings for strawberries due to its high viscosity, which formed a thicker, more robust layer. This resulted in a compact, uniform coating that reduced moisture loss and enhanced gas exchange [16]. Konjac glucomannan had barrier properties that maintained moisture and slowed respiration,

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extending shelf life. It also had antimicrobial effects, improving protection against microbial contamination [17]. Konjac glucomannan also enhanced the mechanical strength and flexibility of coatings, ensuring durability. When combined with gelatin, Konjac glucomannan synergistic effects further improved the coating's ability to preserve strawberry quality and freshness [18,19]. The increase in viscosity from EKG 2 to EKG 3 clearly shows that the edible coating has improved its ability to protect strawberries from environmental damage, slow down spoilage, and significantly extend the fruit's shelf life. More viscous coatings provide better protection, making higher viscosity formulations, such as EKG 3, more suitable for edible coatings on perishable fruits like strawberries. Measuring the viscosity of edible coatings is essential as it influences the thickness and uniformity of the layer applied to products [17]. Appropriate viscosity ensures a protective layer against physical damage, oxidation, and microbial contamination, while preserving taste and texture. It also facilitates application and stability during storage. In large-scale production, consistent viscosity is crucial for maintaining quality across batches. Therefore, viscosity is key to optimizing product protection and quality [18].

Table 2. Viscosity of edible coatings for strawberries.

Treatment	Viscosity (cP)
EKG1	nd
EKG2	1.08^{a}
EKG3	137.62^{b}

Note: Data are presented as mean ± standard deviation (n = 3).
Different superscript letters in the same column denote significant differences ($p < 0.05$).
nd = not determined.

3.2. pH

Measuring the pH of fruits coated with edible coatings is crucial, as it significantly affects quality, taste, and shelf life. Elevated acidity often corresponds with a fresh taste, making pH monitoring essential for preserving organoleptic characteristics during storage [20]. Variations in pH may indicate microbial activity or spoilage. An effective edible coating should stabilize pH, inhibit decay, and extend shelf life while ensuring active compounds remain effective. By monitoring pH, producers can assess the coating's role in maintaining fruit quality and freshness [21]. According to the information shown in **Figure 2(a)**, the changes in pH levels of strawberries observed over 12 days displayed significant differences ($p < 0.05$) between the control group (EKG1) and the treatments that included edible coatings made from goat skin gelatin (EKG2) and a blend of goat skin gelatin with konjac glucomannan (EKG3). The daily variations in pH of the strawberries were affected by molecular, chemical, and biological factors linked to the characteristics of the edible coatings. In the case of EKG1 (without any coating), the pH of the strawberries rose steadily from 3.56 on day 0 to 4.15 by day 12. This rise was attributed to fruit respiration, which resulted in a decrease in organic acids such as citric acid and malic acid, leading to a higher pH. Additionally, without the protective layer that an edible coating provides, the development of microorganisms that convert sugars into lactic acid was only slightly hindered. Decay processes also progressed more rapidly, as strawberries without coating were more vulnerable to enzymatic and microbiological breakdown, which caused an accumulation of alkaline compounds produced by microbial metabolites and a rise in pH. Uncoated strawberries underwent faster respiration, whereby the fruit utilized oxygen and emitted carbon dioxide. This respiration

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activity contributed to the breakdown of organic acid compounds like citric acid and malic acid, ultimately increasing in pH [20,22].

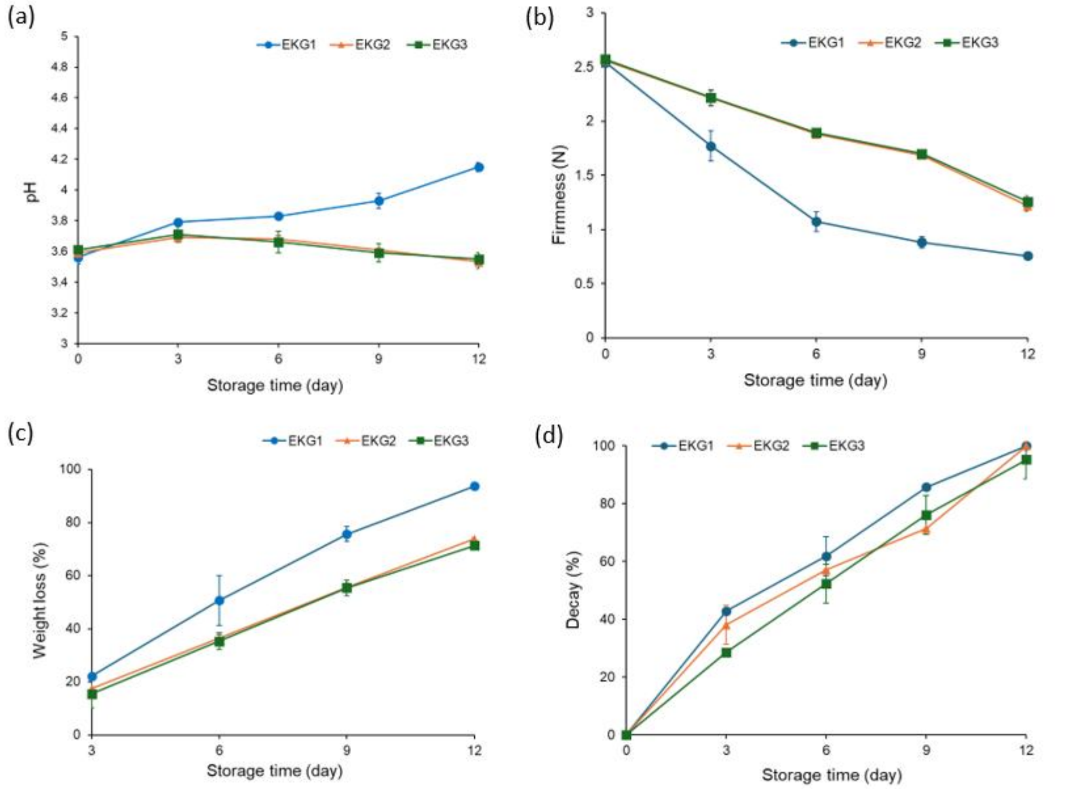

Figure 2. pH (a), firmness (b), weight loss (c), and decay (d) of strawberries coated with different edible coatings stored at room temperature for 12 d. Data are presented as mean ± standard deviation (n = 3).

Additionally, without a physical barrier such as an edible coating, strawberries became more vulnerable to microbial attacks. Bacteria and fungi could proliferate rapidly, contributing to the decline in organic acid content and the production of basic compounds from microbial metabolism, thus increasing the pH of the fruit. Enzymatic degradation also accelerated spoilage, as enzymes within the fruit broke down strawberry cells, altering chemical components and hastening the increase in pH. In EKG 2, the initial pH was 3.59, with only minor fluctuations, decreasing to 3.53 by day 12. Gelatin acted as a semipermeable barrier that reduced the rate of respiration, slowed the decline in organic acids, and prevented a significant increase in pH, as observed in EKG 1. Additionally, gelatin contained antimicrobial peptides that inhibited the growth of spoilage bacteria and fungi, maintaining the pH at a lower range compared to the control. The slight drop in pH on day 12 may have been due to the accumulation of organic acids resulting from the partial degradation of sugars by enzymes. Gelatin functioned as a semi-permeable barrier that limited gas exchange, such as oxygen and carbon dioxide, thereby slowing the respiration rate in strawberries. With reduced respiration, the degradation of organic acids within the fruit was also slowed, preventing a significant increase in pH [23]. Moreover, gelatin has natural antimicrobial properties that inhibit the growth of harmful microorganisms. As a result, microbial activity, which usually leads to a decrease in organic acid content in strawberries, was reduced. This helped maintain a more stable pH compared to uncoated strawberries. The drop in pH observed on day 12 may have been due to the accumulation of organic acids produced by the partial breakdown of residual sugars in the fruit [12]. In EKG 3, the initial pH of 3.61 decreased to 3.55 by day 12, demonstrating better stability compared to the other treatments. Konjac glucomannan, which formed a stronger gel when mixed with gelatin, created a more effective coating layer that inhibited gas exchange, such as O_2 and CO_2. This reduction in gas exchange decreased respiration rates, preserved organic acids, and prevented an increase in pH. Additionally, konjac glucomannan, being hydrophilic, helped retain moisture and reduced the evaporation of volatile compounds, including acids, thus maintaining the fruit's chemical stability. The combination of gelatin and konjac glucomannan also exhibited stronger antimicrobial effects, reducing the growth of microorganisms that could produce alkaline compounds [24,25].

Konjac glucomannan had a strong gel-forming ability when combined with gelatin, creating a denser protective layer on the strawberries. This layer was more effective in reducing the respiration rate compared to gelatin alone, thus helping to preserve the organic acid content in the fruit and preventing a rise in pH [26]. Additionally, konjac glucomannan is a hydrophilic polysaccharide; it could retain moisture and prevent the evaporation of volatile compounds such as organic acids, which helped maintain the fruit's chemical stability and kept the pH stable during storage. The synergistic antimicrobial effect of the gelatin and konjac glucomannan combination further inhibited microbial growth, reducing the production of alkaline compounds from microbial activity and maintaining a low and stable pH in the strawberries [16,27]. The comparison of EKG1, EKG2, and EKG3 demonstrated that the edible coatings effectively preserved the stability of organic acids and reduced fruit degradation. The more consistent decrease in pH observed in EKG3 compared to EKG2 suggested that the inclusion of 20% konjac glucomannan provided enhanced pH stability. This improvement is attributed to glucomannan's gas barrier properties and its ability to retain water. Overall, the edible coatings made from goat skin gelatin (EKG2) and a combination of gelatin and konjac glucomannan (EKG3) slowed the pH increase caused by respiration and microbial activity. Notably, EKG3 offered superior protection against internal chemical and biological changes in the fruit, maintaining its quality up to day 12.

3.3. Firmness

The firmness test was an essential technique for assessing the quality and appeal of coated fruit, as well as for improving storage and distribution conditions. Firmness acted as a key indicator of fruit texture, representing the desired resilience and hardness that enhances consumer satisfaction [28]. The purpose of applying coatings to fruit was to prolong shelf life and maintain quality, and firmness testing served to evaluate how effectively coatings preserved fruit firmness over time. Additionally, firmness provided insights into potential damage or bruising; firmer fruit showed increased resistance to damage from handling. Firmness was also linked to freshness, as firmer fruit was usually regarded as fresher and of higher quality. Furthermore, firmness influenced the sensory experience of fruit, where fruit that is too soft might be seen as lacking freshness, while overly firm fruit could be perceived as less enjoyable [29]. **Figure 2(b)** shows that untreated strawberries (EKG1) experienced a significant decrease in firmness ($p < 0.05$) over 12 days when compared to strawberries coated with goat skin gelatin (EKG2) or those treated with a combination of gelatin and konjac glucomannan (EKG3). The firmness of EKG1 strawberries dropped sharply from 2.5421 N on day 0 to 0.7577 N on day 12. This decline is likely attributed to the degradation of structural components, moisture loss, and enzymatic activity. Specifically, without a protective coating, naturally occurring pectinase and cellulase broke down pectin and cellulose [30], compromising structural integrity. The increased activity of these enzymes over time accelerated softening [28]. Furthermore, the lack of coating led to significant water loss and

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subsequent reduction in cell turgor [13], further contributing to the loss of firmness. In contrast, strawberries coated with goat skin gelatin (EKG 2) exhibited a slower decline in firmness, decreasing from 2.5595 N on day 0 to 1.2186 N by day 12. Gelatin acted as a physical barrier, inhibiting the activity of enzymes that break down the cell wall. By reducing the rate of water evaporation, gelatin helped maintain the internal moisture of the strawberries, preventing a significant drop in turgor pressure [31]. Gelatin also functioned as a semi-permeable barrier that reduced gas exchange, slowing respiration and the degradation of chemical compounds within the cell walls [23]. Strawberries that were treated with a combination of gelatin and 20% konjac glucomannan (EKG3) showed the slowest decrease in firmness, going from 2.5710 N on day 0 to 1.2575 N by day 12. The strong gelling ability of konjac glucomannan created a denser and more effective coating for the strawberries. Its hydrophilic properties allowed it to attract and retain moisture, helping to keep the internal moisture of the strawberries intact for a longer period. This combination was particularly effective in inhibiting the activity of degradative enzymes, thereby reducing the breakdown of structural components such as pectin. Additionally, the more efficient reduction of respiration slowed down the degradation of chemical compounds that contribute to fruit softening. As a result, the decline in firmness was significantly delayed [21,28]. The comparison of treatments revealed that the edible coating significantly protected strawberry firmness. Uncoated strawberries experienced a rapid loss of firmness due to unrestricted enzymatic activity and moisture loss. In contrast, strawberries coated with gelatin demonstrated better protection. The combination of gelatin and konjac glucomannan provided optimal protection by reducing moisture loss and inhibiting the activity of enzymes that cause degradation. This helped maintain the fruit's firmness for a longer period and improved the storage quality of the strawberries [1, 13, 29].

3.4. Weight Loss

Assessing weight loss in coated fruits was essential for gauging the effectiveness of the edible coating. Significant weight loss suggested that the coating was not successful in minimizing water evaporation, which could impact the fruit's quality and freshness [13]. This assessment also played a role in determining shelf life, as effective coating can help reduce water loss and inhibit microbial growth. Measuring weight loss was vital for evaluating different coating formulations and promoting improved product development [32]. This measurement served as a key factor in assessing the quality, effectiveness, and shelf life of coated fruits. According to **Figure 2(c)**, significant differences ($p < 0.05$) in weight loss data for strawberries were noted on days 3, 6, 9, and 12, highlighting the efficacy of the edible coatings applied. The findings showed that EKG1 had the greatest weight loss at each measurement interval, whereas EKG3 had the least weight loss. For EKG1, the weight loss on day 3 was recorded at 22.16 ± 1.28%, which notably rose to 93.71 ± 1.29% by day 12. Without a coating layer, these strawberries were particularly vulnerable to water loss from direct environmental exposure, as well as to oxidation and microbial contamination. On the other hand, EKG2 presented a weight loss of 17.42 ± 0.56% on day 3, which escalated to 73.75 ± 0.67% by day 12. While gelatin offered some degree of protection, its low viscosity rendered this layer less effective in minimizing water loss compared to EKG 3. In contrast, EKG3 displayed a weight loss of 15.48 ± 5.15% on day 3, demonstrating the most effective protection relative to the other treatments. By day 12, the weight loss for EKG 3 reached 71.24 ± 0.68%. The inclusion of konjac glucomannan, known for its high viscosity, created a thicker layer that efficiently reduced water evaporation. Gelatin and konjac glucomannan formed a gel network that could reduce transpiration and respiration rates on the surface of the strawberries [29]. This

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network acted as a physical barrier, reducing water and gas loss, thereby slowing down the decay process and weight loss. The combination of gelatin and konjac glucomannan increased viscosity and gel strength, which was more effective in retaining water compared to gelatin alone. This was evident in EKG3, which demonstrated a lower weight loss compared to EKG2 and EKG1. The edible coating containing gelatin and konjac glucomannan (EKG3) was more effective in reducing water evaporation than the control (EKG1) and gelatin alone (EKG2). This was attributed to the hydrophilic nature of konjac glucomannan, which could bind water more effectively. The addition of citric acid in the coating solution also acted as an antioxidant, helping to protect strawberries from oxidation and chemical degradation during storage. The edible coating could inhibit microbial growth by creating an environment less conducive to microorganism proliferation [11,12]. This helped reduce spoilage and maintain strawberry quality [13]. Strawberries without coating (EKG1) exhibited higher weight loss due to faster respiration rates, leading to quicker loss of water and nutrients. The edible coatings on EKG2 and EKG3 helped slow down the respiration rate, thus reducing weight loss. The significant differences in weight loss data among the strawberries indicated that the composition and formulation of the edible coating greatly influenced protective effectiveness. EKG3, which contained gelatin and konjac glucomannan, showed the best ability to reduce weight loss, attributed to its higher viscosity and thickness. Thus, the selection of appropriate materials and proportions in the formulation of edible coatings became crucial for improving the quality and shelf life of strawberries [15, 20, 28, 33].

3.5. Color of Strawberries

Measuring the color changes of strawberries coated with edible coating was important because color was a primary indicator of freshness and quality of the fruit. Color changes, such as from bright red to darker shades, indicated a decline in quality and appeal to consumers [34]. This evaluation also examined how effective the edible coating was in reducing oxidation and enzymatic reactions that led to browning. Color changes were crucial for managing the ripening and decay processes, serving as a key visual indicator for ensuring the quality of strawberries during storage. According to the data in **Table 3**, there were significant variations ($p < 0.05$) in the L^* (lightness) values of strawberries coated with different treatments throughout the storage period lasting up to day 12. In EKG 1 (control), the strawberries underwent natural color changes because of oxidation, respiration, and the breakdown of anthocyanin pigments. The L^* value declined from 28.58 on day 0 to 25.19 on day 9, signifying browning and a reduction in the visual appeal of the fruit. Nevertheless, on day 12, there was a notable increase in the L^* value (37.73), likely attributed to tissue damage that caused the fruit surface to appear brighter due to decreased soluble solids and the development of a layer of dead cells on top. The decline in anthocyanin pigments from oxidative deterioration resulted in the strawberries becoming less red and appearing paler.

In EKG2, the fluctuations in the L^* value were observed. The brightness showed a notable rise from 27.40 on day 0 to 32.58 on day 3, suggesting that the gelatin layer initially succeeded in preventing oxidation. However, on days 6 and 9, the L^* value dropped to 27.42 and 23.85, respectively, indicating a lack of stability in the layer and an increase in oxidation. By day 12, the L^* value climbed again to 37.59, which resulted from further deterioration, causing the fruit to look paler. The semi-permeable gelatin layer managed to diminish the rates of oxidation and water loss, yet it lacked the stability needed to preserve its integrity over an extended period.

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Table 3. The color of strawberries coated with different edible coatings was stored at room temperature for 12 days.

Colors	Days	Treatments		
		EKG1	EKG2	EKG3
*L**	0	28.58 ± 0.12 ^{df}	27.40 ± 1.20^{f}	29.04 ± 0.75^{df}
	3	27.40 ± 0.19^{f}	32.58 ± 0.40^{c}	32.99 ± 0.63^{c}
	6	28.58 ± 0.12^{df}	27.42 ± 0.97^{f}	29.41 ± 0.31^{d}
	9	25.19 ± 0.39^{f}	23.85 ± 0.76^{g}	24.46 ± 1.38^{g}
	12	37.73 ± 0.38^{b}	37.59 ± 0.88^{b}	43.57 ± 1.84^{a}
*a**	0	19.18 ± 0.56^{cd}	19.05 ± 0.04^{cd}	18.98 ± 0.45^{cd}
	3	23.88 ± 0.58^{b}	28.90 ± 0.54^{a}	26.01 ± 0.36^{ab}
	6	20.52 ± 2.73^{c}	19.05 ± 0.04^{cd}	23.49 ± 0.26^{b}
	9	14.59 ± 0.71^{ef}	16.31 ± 4.62^{de}	11.49 ± 0.12^{f}
	12	13.04 ± 0.46^{f}	14.57 ± 0.09^{ef}	11.41 ± 0.18^{f}
*b**	0	8.35 ± 0.32^{cd}	8.31 ± 0.27^{cd}	8.45 ± 0.39^{cd}
	3	10.42 ± 0.65^{b}	15.72 ± 0.45^{a}	14.46 ± 0.32^{a}
	6	9.68 ± 1.52^{bc}	8.44 ± 0.14^{cd}	10.72 ± 0.12^{b}
	9	10.68 ± 1.84^{b}	7.70 ± 1.80^{d}	6.84 ± 0.05^{d}
	12	4.85 ± 0.27^{e}	4.60 ± 0.81^{e}	7.58 ± 0.11^{d}
ΔE	0	68.80 ± 0.23^{b}	80.40 ± 4.54^{a}	81.13 ± 4.21^{a}
	3	79.14 ± 3.48^{a}	77.38 ± 2.42^{a}	78.94 ± 2.65^{a}
	6	81.98 ± 4.41^{a}	80.81 ± 4.13^{a}	79.64 ± 3.76^{a}
	9	81.22 ± 3.94^{a}	83.24 ± 4.30^{a}	82.44 ± 5.46^{a}
	12	82.63 ± 5.40^{a}	83.16 ± 6.01^{a}	84.32 ± 2.44^{a}

Note: Data are presented as mean ± standard deviation (n = 3).
Different superscript letters in the same column denote significant differences ($p < 0.05$).

In EKG3 (which involves the coating of goat skin gelatin and 20% konjac glucomannan), the most consistent results in maintaining the *L** value during storage were noted. The *L** value significantly increased from 29.04 on day 0 to 32.99 on day 3, suggesting that the mixture of gelatin and konjac glucomannan created a more robust and stable layer, thereby enhancing its effectiveness in preventing oxidation, as shown in **Figure 3**. On day 6, the *L** value remained steady at 29.41, but there was a slight decline on day 9 (24.46). By day 12, the *L** value surged to 43.57, likely due to pigment breakdown and a reduction in soluble solids; however, this change happened in a more regulated fashion because the coating layer offered enhanced protection. Konjac glucomannan contributed to the viscosity and mechanical stability of the layer, consequently reducing the rates of water evaporation and oxidation [17,20]. The oxidation of anthocyanin pigments was a major factor affecting changes in *L** value. Strawberries without coating experienced pigment oxidation more rapidly due to exposure to oxygen, whereas the coatings in EKG2 and EKG3 inhibited contact with oxygen and slowed down the degradation rate.

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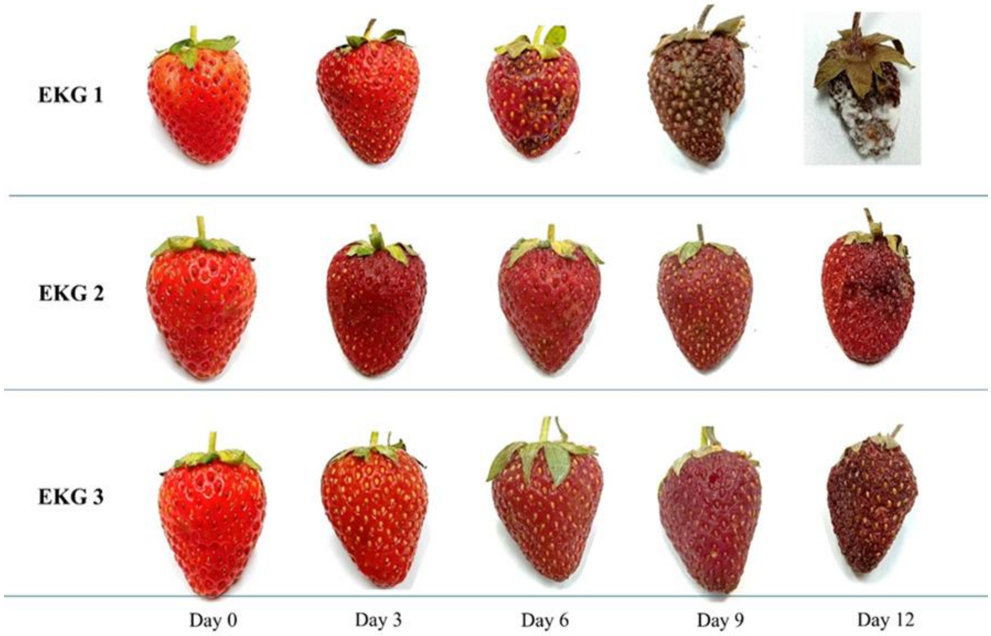

Figure 3. The appearance of strawberries coated with different edible coatings stored at room temperature for 12 days.

In addition, the coatings also served as semi-permeable barriers that reduced respiration and transpiration rates. The combination of gelatin and konjac glucomannan in EKG3 provided a more stable layer, maintaining moisture and preventing structural degradation, thus being the most effective in preserving the brightness of strawberries during storage [10,27]. This study found significant differences ($p < 0.05$) in color changes of strawberries with various edible coatings (**Table 3**). The *a** value decreased over time in EKG1 from 19.18 on day 0 to 13.04 by day 12 due to oxidation, directly affecting the fresh appearance of strawberries by reflecting red-green components influenced by anthocyanin pigments. In EKG2, the value increased initially to 28.90 on day 3 but declined to 14.57 by day 12, indicating the gelatin's instability from humidity and damage. EKG3 showed the most stability, with the *a** value increasing to 26.01 on day 3 and stabilizing around 23.49 on day 6, despite a decrease to 11.41 on day 12. Overall, EKG3 was most effective in reducing oxidation and maintaining moisture, attributed to the mechanical stability of konjac glucomannan. Changes in a* value were linked to the concentration of anthocyanin pigments and their oxidation due to oxygen exposure and poor storage conditions. EKG1 experienced faster pigment oxidation due to the absence of a protective layer, whereas EKG2 and EKG3, despite having good initial increases, experienced a decline in *the** value in the later stages of storage. The presence of antioxidant compounds in gelatin and konjac could slow the rate of oxidation, but if the coating layer was not stable, its effectiveness decreased over time. High humidity also affected the stability of the coating layer and transpiration rates, contributing to color changes [35-37]. The significant differences in the changes of the *a** value for strawberries coated with various treatments can be attributed to the complex interactions among the oxidation of anthocyanin pigments, the stability of the coating layer, and the storage conditions. EKG3 showed the best performance in maintaining the *a** value during storage compared to EKG1 and EKG2. This indicates that the combination of gelatin and konjac glucomannan is a more effective choice for preventing color degradation in strawberries.

Table 3 shows significant differences ($p < 0.05$) in the changes of the *b** value of strawberries treated with different coatings. The b value reflects the yellow-blue attributes

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of the fruit, which were affected by the makeup of pigment compounds, especially anthocyanins and carotenoids, along with the oxidation processes that took place during storage. EKG3 showed the greatest ability to maintain the *b** value of strawberries throughout storage when compared to EKG1 and EKG2. The blend of gelatin and konjac glucomannan proved to be more successful in slowing down color loss and preserving the aesthetic quality of the strawberries, whereas treatments without any coating and those with only gelatin experienced a more significant reduction in the *b** value. Uncoated strawberries (EKG1) had a relatively stable *b** value on day 0 (8.35), but this increased to 10.68 by day 9. Despite this noticeable rise, the *b** value sharply fell to 4.85 on day 12. This drop indicated that in the absence of a protective coating, the strawberries faced deterioration of color components, mainly due to oxidation, which hastened the loss of yellow pigments (carotenoids), resulting in a more washed-out and less vibrant appearance. Elevated respiration rates also played a role in the reduction of color quality [38,39]. Strawberries coated with goat skin gelatin (EKG2) showed a *b** value increase from 8.31 on day 0 to 15.72 on day 3, indicating initial oxidation protection. However, by day 6 (8.44) and day 9 (7.70), the *b** value sharply declined, reaching 4.60 by day 12, suggesting inadequate protection against degradation. In contrast, strawberries with a coating of gelatin and konjac glucomannan (EKG3) had a more stable *b** value, rising from 8.45 to 14.46 on day 3 and remaining relatively higher (10.72) on day 6. Although it dropped to 6.84 on day 9 and 7.58 by day 12, EKG3 still outperformed EKG2 by reducing oxidation and maintaining color stability. The coatings inhibited oxygen contact, slowing degradation, while the konjac glucomannan enhanced mechanical stability and moisture retention.

ΔE quantifies the color difference perceived by the human eye and is crucial for color accuracy. A study found no significant differences ($p > 0.05$) in ΔE values of strawberries with various edible coatings from day 0 to day 12. On day 0, the ΔE value for control (EKG1) was 68.80 ± 0.23, suggesting initial color differences due to natural variations. After day 0, EKG1's ΔE increased, aligning more closely with EKG2 and EKG3, indicating that environmental factors and pigment degradation influenced color changes more than the coatings themselves. Anthocyanin pigments in strawberries remain stable in acidic conditions but are susceptible to oxidation and light exposure [40]. While edible coatings with gelatin and konjac glucomannan offered some protection against oxidation, they did not fully prevent pigment degradation [6,7]. This was evident from the relatively stable ΔE values across all treatments from day 0 to day 12. Goat skin gelatin had good film-forming properties but was vulnerable to high humidity and mechanical damage. The addition of konjac glucomannan improved the mechanical stability and water retention capability of the coating, which helped maintain color stability. However, the insignificant changes in ΔE indicated that this combination was not sufficient to completely inhibit color changes caused by environmental factors [20]. The chemical interactions between the components of the edible coating and anthocyanin pigments could affect color stability. Gelatin and konjac glucomannan could form a matrix that protected the pigments from oxidation, but environmental changes such as humidity and temperature could influence the effectiveness of this protection [21].

3.6. Decay of Strawberries

Measuring the percentage of decay in fruits treated with edible coatings was essential for assessing how effective these coatings are in extending the shelf life of the produce. Edible coatings act as barriers that reduce moisture loss, limit gas exchange, and inhibit the growth of microorganisms. The information regarding fruit decay (%) offered valuable information about how well the coatings slow down spoilage, fine-tune formulation parameters, and

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evaluate the commercial viability of these coatings in improving the physical and chemical stability of fruits throughout storage [28]. According to **Figure 2(d)**, there was a notable difference ($p < 0.05$) in the decay rates of strawberries treated with various edible coatings over the days, attributed to chemical and biological alterations at the molecular level during storage, alongside the efficacy of each edible coating in preventing decay. In the EKG1 group (control), where no coating was applied, the decay rate rose rapidly, particularly from day 3 (42.86%) to day 12 (100%). This increase was a result of moisture loss and heightened microbial activity that went unchecked due to the absence of a physical barrier. Additionally, chemical changes, including the breakdown of ascorbic acid and elevated respiration rates, contributed to the acceleration of decay [28]. In EKG2, where goat skin gelatin was used as the coating, the decay percentage also rose, but at a slower rate than the control. On day 3, EKG2 exhibited a decay of 38.10%, which was lower than EKG1. This can be attributed to the gelatin creating a semi-permeable protective layer that reduces the exchange of gases and moisture. Nonetheless, while the gelatin coating slowed down the decay rate, it was still less effective in comparison to EKG3, as gelatin by itself was not sufficient to manage microbial growth or preserve the physical integrity of the fruit over an extended period. The edible coating that utilized gelatin along with 20% konjac glucomannan demonstrated superior protection, resulting in a decay percentage of just 28.57% on day 3 and 95.24% on day 12. Konjac glucomannan enhanced the viscosity and reinforced the coating layer, chemically inhibiting water loss, restricting oxygen movement, and more effectively curtailing microbial growth than gelatin alone [27]. Biologically, konjac glucomannan also affected the permeability of the edible coating, slowing fruit respiration and thus delaying decay [41,42]. These significant differences indicated that the combination of gelatin and konjac glucomannan (EKG 3) provided more optimal protection, both chemically and biologically, compared to other treatments, particularly in reducing decay through moisture control and inhibition of microorganism growth [43]. The application of coatings in the study by [27] significantly reduced the decline in ascorbic acid content during storage, thus helping to maintain fruit quality. In the same way, the research carried out by [43] revealed that the percentage of decay in strawberries coated with konjac glucomannan and pullulan diminished over the storage period, whereas uncoated strawberries exhibited the quickest deterioration. These earlier findings align with the results of this study, demonstrating that using specific materials in edible coatings can significantly reduce fruit decay.

3.7. Total Soluble Solids

Assessing the Total Soluble Solids (TSS; °Brix) in fruits that have been treated with edible coatings is crucial, as TSS indicates the quality, flavor, and ripeness of the fruit [1]. In addition, measuring TSS aids in detecting the chemical transformations that happen during storage and offers insights into any degradation or fermentation processes. TSS has become an established quality criterion for marketing, with consumers favoring fruits that exhibit higher TSS levels. As a result, TSS measurement acts as a gauge for the effectiveness of the coating and the chemical stability, while also contributing to the formulation of improved coating solutions [13]. The total soluble solids (TSS) in strawberries coated with an edible coating made from goat skin gelatin and konjac glucomannan showed significant differences ($p < 0.05$), as presented in **Table 4**. This finding indicates that the various treatments had a significant impact on the stability of TSS in strawberries throughout the 12-day observation period. In the EKG1, which acted as the control group without any coating, strawberries showed a marked decrease in total soluble solids (TSS). The initial TSS reading was 4.13, which rose to 4.70 by day 3. However, later measurements indicated a significant drop to 4.43 on

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day 6, followed by further declines to 4.13 on day 9, and ultimately to 3.73 on day 12. This pattern implies that, without a protective coating, strawberries underwent a fast reduction in sugar content due to heightened respiration. During this respiratory process, sugars were utilized for energy, leading to the generation of water and carbon dioxide, which subsequently caused a reduction in the sugar levels of the fruit [20,44]. In contrast, the EKG2, which used a coating made from gelatin derived from goat skin, produced more promising outcomes. By day 3, the total soluble solids (TSS) increased to 4.73 and rose further to 4.77 by day 6. These results suggest that the edible coating successfully maintained the sugar levels in the strawberries. Although the TSS decreased to 4.07 by day 12, this figure was still higher than what was recorded in EKG 1. The gelatin coating served as a barrier, minimizing gas and moisture exchange, which in turn slowed down respiration and the depletion of sugars [35].

Table 4. Total soluble solids (°Brix) of strawberries coated with different edible coatings stored at room temperature for 12 days.

Treatment	Total soluble solids (°Brix)				
	0 day	3 days	6 days	9 days	12 days
EKG1	4.13 ± 0.05^{de}	4.70 ± 0.00^{a}	4.43 ± 0.05^{c}	4.13 ± 0.05^{de}	3.73 ± 0.05^{f}
EKG2	4.13 ± 0.05^{de}	4.73 ± 0.05^{a}	4.77 ± 0.00^{a}	4.43 ± 0.05^{bc}	4.07 ± 0.05^{e}
EKG3	4.17 ± 0.05^{de}	4.77 ± 0.05^{a}	4.77 ± 0.05^{a}	4.57 ± 0.05^{b}	4.20 ± 0.00^{d}

Note: Data are presented as mean ± standard deviation (n = 3).
Different superscript letters in the same column denote significant differences ($p < 0.05$).

The most favorable outcomes were noted in the EKG3, where strawberries were treated with goat skin gelatin and 20% konjac glucomannan. On the third day, the total soluble solids (TSS) reached 4.77 and remained steady until day 6, showing only a slight drop to 4.20 by day 12. The addition of konjac glucomannan facilitated moisture retention, aiding in the stabilization of TSS levels. The elevated moisture content diminished respiration rates and sugar loss. Furthermore, the chemical structure of konjac glucomannan hinders the diffusion of oxygen and water vapor, making the coating more effective than gelatin alone. On day 3, the TSS in EKG1 was lower when compared to both EKG2 and EKG3 ($p < 0.05$). By day 6, the TSS for EKG1 measured 4.43, which was less than the 4.77 recorded in both EKG2 and EKG3. More significant reductions were also seen on days 9 and 12, with the TSS in both EKG2 and EKG3 remaining higher than that of EKG1. The findings of this study indicated that edible coatings made from goat skin gelatin and konjac glucomannan significantly enhanced the stability of TSS in strawberries. The EKG3 treatment produced the most effective results for preserving sugar content, emphasizing the potential of these natural materials in fruit preservation methods. The respiration process in fruits consists of biochemical reactions where carbohydrates are transformed into energy in the form of ATP (adenosine triphosphate), along with the generation of water (H_2O) and carbon dioxide (CO_2) [45]. In unprotected fruits, such as those in EKG1, this process occurred more quickly, leading to a notable reduction in TSS. As fruits undergo respiration, their inherent sugar content, which is a crucial factor in TSS, diminishes. The edible coating composed of goat skin gelatin and konjac glucomannan served as a physical barrier, with gelatin creating a matrix that enveloped the fruit's exterior, while konjac glucomannan, a gel-forming polysaccharide, improved the structural stability of the film. Once this coating was applied, the rates of gas and moisture exchange between the fruit and its environment diminished, thereby slowing down sugar consumption and prolonging TSS retention. Gelatin demonstrated hygroscopic characteristics, indicating its ability to absorb and hold moisture. The inclusion of gelatin helped preserve the moisture within the fruit, leading to reduced weight loss and a slower

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decline in total soluble solids (TSS) [46]. The inclusion of konjac glucomannan in EKG3 improved the water retention properties even further, as konjac has a greater capacity for water absorption than gelatin. This established a more stable environment for sustaining higher TSS levels. The molecular structures of gelatin and konjac glucomannan interacted intricately with various components in the fruit, including organic acids and sugars. These interactions can affect the physical stability of the edible coating, resulting in lower respiration rates and the retention of soluble components in the fruit. The coating created a barrier that helped to better preserve soluble sugars such as glucose and fructose [35]. Observations indicated an increase in TSS during the early days for EKG2 and EKG3, likely due to sugar accumulation from reduced respiration and slower cell breakdown. However, over time, TSS declined for all treatments, with EKG1 showing a more significant decrease and EKG2 and EKG3 a more gradual drop. The use of edible coatings from goat skin gelatin and konjac glucomannan positively affected TSS stability in strawberries by lowering respiration rates and enhancing water retention, maintaining higher sugar levels compared to uncoated fruits. This study supports the development of natural and eco-friendly fruit preservation technologies.

3.8. Ascorbic Acid Content

Assessing ascorbic acid levels in fruits with edible coatings is essential, as this nutrient significantly affects nutritional quality [47]. It acts as a powerful antioxidant, helping to reduce oxidative damage and extend shelf life [48]. Data in **Figure 4** shows a significant variation ($p < 0.05$) in ascorbic acid levels in strawberries, where the blend of goat skin gelatin and konjac glucomannan (EKG3) provided the best protection against oxidation, followed by gelatin alone (EKG2). Uncoated strawberries (EKG1) showed the most substantial decline due to increased exposure to oxygen, which fosters the oxidation of ascorbic acid into dehydroascorbic acid. The coatings also limit enzymatic degradation by creating a less favorable environment for enzymes like ascorbate oxidase [43,49]. The decrease in ascorbic acid content of EKG1 during storage time was followed by an increase in pH value, as shown in **Figure 2(a)**.

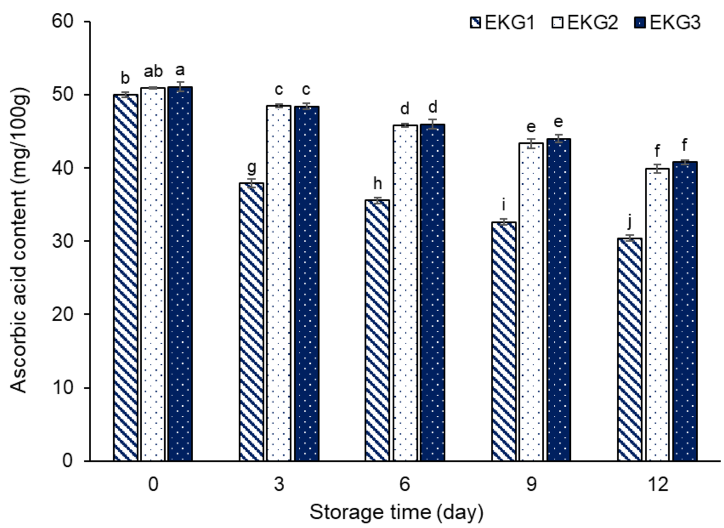

Figure 4. Ascorbic acid content of strawberries coated with different edible coatings stored at room temperature for 12 days. Bars represent the standard deviation (n=3). Different lowercase letters on the bar denote significant differences ($p < 0.05$).

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The edible coating offered a physical safeguard against mechanical damage and microorganisms, which could speed up the degradation of ascorbic acid. EKG3, which included konjac glucomannan, demonstrated superior protection compared to EKG2. This was because konjac glucomannan had enhanced thickening abilities, forming a more effective layer to shield the strawberries. EKG1 showed the quickest reduction in ascorbic acid levels. By day 12, the ascorbic acid content decreased to 30.41 mg/100 g, which was lower than that of EKG2 and EKG3. This suggested that direct exposure to the environment led to quicker oxidation of ascorbic acid. On day 12, EKG2 still maintained a greater ascorbic acid content (39.94 mg/100 g) compared to the control. However, without konjac glucomannan, this coating was not as efficient as EKG3 in minimizing the decrease of ascorbic acid. EKG3 offered the best protection, as ascorbic acid levels remained at 40.78 mg/100 g by day 12. The inclusion of konjac glucomannan improved the layer's barrier against oxygen and water, thus slowing down the oxidation of ascorbic acid more effectively than in EKG 2. The extension of shelf life noted in EKG3 can be ascribed to several complementary mechanisms: (1) The combination of gelatin and konjac glucomannan forms a more efficient oxygen barrier through their synergistic molecular interactions, which reduces oxidative degradation; (2) The increased viscosity of the coating (137.62 cP) offers better surface coverage and adhesion, leading to a more consistent protective layer; (3) The hydrophilic characteristics of konjac glucomannan assist in maintaining moisture balance while its gel-forming properties strengthen the coating matrix, minimizing moisture loss and preserving cellular integrity [50,51], and (4) The presence of ascorbic acid (0.5% w/w) in the coating formulation provides additional antioxidant protection [49,52]. The combined mechanisms effectively delay ripening, reduce respiration, and maintain the structural integrity of strawberries, extending shelf life compared to uncoated samples or those with only gelatin. Konjac glucomannan, added to EKG3, improved water-binding and viscosity, creating a thicker layer than gelatin alone (EKG2). This thicker layer significantly slowed ascorbic acid oxidation by reducing oxygen and water penetration, which are key factors in degradation.

3.9. Sustainability Implication and Contribution to SDG 12

Overall, the combination of gelatin and konjac glucomannan (EKG3) showed superior protective effects on strawberry quality indicators, such as ascorbic acid retention and reduced decay. These outcomes highlight the potential for using bio-based edible coatings as a sustainable preservation method that supports the reduction of postharvest food loss (SDG 12.3) and minimizes reliance on synthetic packaging materials. This approach aligns with global efforts to promote environmentally responsible food supply chains.

4. CONCLUSION

This study showed that edible coatings made from goat skin gelatin, especially when combined with konjac glucomannan, effectively preserved strawberries at room temperature. The addition of konjac glucomannan improved the coating's viscosity and barrier properties against oxygen and moisture. Both coatings maintained pH stability, slowed color changes, and reduced pigment oxidation. Notably, the gelatin-konjac coating (EKG3) better preserved ascorbic acid levels through day 12 of storage. While there were no significant differences in firmness and weight loss between the coatings, the findings highlight the potential of these natural coatings to enhance the shelf life of strawberries. Further research could optimize and scale up for commercial use. The use of biodegradable, food-grade ingredients supports sustainability goals, especially SDG 12 (Responsible Consumption

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and Production), by minimizing food waste and utilizing livestock by-products. These findings highlight the potential for developing natural food preservation systems that align with the SDGs and encourage innovation in sustainable packaging.

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6. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. The authors confirmed that the paper was free of plagiarism.

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