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Effect of Edible Coating from Avocado Seed Starch with Cinnamon Extract on the Quality of Strawberry Fruit

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ABSTRACT

Strawberries are a high-value fruit with significant nutritional benefits but are highly susceptible to postharvest deterioration caused by mechanical, physical, and microbiological factors. To maintain fruit quality, appropriate postharvest treatments such as edible coatings are required. This study aimed to evaluate the effect of avocado seed starch–based edible coatings enriched with cinnamon extract and to determine the optimal concentration for maintaining strawberry quality. A one-factor Completely Randomized Design (CRD) was applied using cinnamon extract concentrations of 0%, 0.5%, and 1% (v/v). The results showed that the edible coating containing 0.5% cinnamon extract was the most effective treatment, maintaining strawberry quality for five days of storage. This treatment resulted in a weight loss of 9.58%, moisture content of 88.67%, firmness of 6.05 N/cm², total soluble solids of 6.85 °Brix, lightness (L*) value of 7.42, and a total microbial count of 2.4×10^1 CFU/g.

Keywords: strawberry fruit; edible coating; avocado seed starch; cinnamon extract

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1. Introduction

Indonesia is known as a country with great agricultural potential, rich in agricultural products such as fruits and vegetables. In this country, subtropical fruits grow well, one of which is strawberries which are available in abundance. Strawberry is a fruit with high economic value and provides various benefits. Based on data from the Central Bureau of Statistics, strawberry production has fluctuated, with increases and decreases recorded from 2020 to 2023. In 2020, strawberry production was

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recorded at 65 tons, then jumped to 274 tons in 2021. However, strawberry production declined to 99 tons in 2022 and dropped again to 87 tons in 2023 [1].

Despite these fluctuations, market demand for strawberries has not been fully satisfied. This condition is largely attributed to inadequate postharvest handling practices. Strawberries are highly perishable horticultural products that are susceptible to mechanical, physical, and microbiological damage. Their high moisture content accelerates bacterial and enzymatic activity, while the thin and delicate skin makes them vulnerable to temperature changes, sunlight exposure, friction, and pressure [1]. As a result, postharvest losses often occur, leading to economic disadvantages for farmers. Therefore, appropriate postharvest technologies, such as the application of edible coatings, are required to maintain strawberry quality.

Edible coating is a thin layer of natural material that can be consumed directly and applied to the surface of agricultural products. The application of edible coatings on fruit functions as a barrier that helps retain moisture and is permeable to certain gases [2]. One material that has the potential to be used for making edible coatings is avocado seeds. The starch contained in avocado seeds has a fairly high amylose and amylopectin content, which is around 43.3% amylose and 37.7% amylopectin, thus making it a potential material for making edible coatings. However, due to its hydrophilic nature, this edible coating is less effective in inhibiting water vapor penetration and tends to be susceptible to microbial attack.

To overcome these limitations, hydrophobic antimicrobial compounds can be incorporated into avocado seed starch–based edible coatings. Cinnamon extract (*Cinnamomum burmannii*) has been reported to contain essential oils such as carvacrol and citral, which exhibit antimicrobial activity against spoilage microorganisms [3]. In addition, cinnamon contains cinnamaldehyde, a bioactive compound with antioxidant properties that can reduce oxidative damage. Nevertheless, starch-based edible coatings tend to be brittle; therefore, the addition of plasticizers is necessary to improve flexibility and mechanical stability. Glycerol is commonly used as a plasticizer due to its liquid form and high solubility in water [4].

Previous studies, such as that conducted by Bukit et al. (2022), have examined the application of avocado seed starch–based edible coatings on strawberries. However, studies focusing on the combined use of avocado seed starch edible coating enriched

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with cinnamon extract as a natural antimicrobial agent for maintaining strawberry quality are still limited [5]. Therefore, this study aims to address this research gap by evaluating the effect of avocado seed starch edible coating with the addition of cinnamon extract at different concentrations on the quality of strawberry fruit during storage.

2. Materials and Method

This study employed an edible coating formulated from avocado seed starch with different concentrations of cinnamon extract using a one-factor Completely Randomized Design (CRD). The avocado seed starch concentration was fixed at 2%, based on previous studies and preliminary experiments [5], while cinnamon extract concentrations of 0%, 0.5%, and 1% (v/v) were adopted from earlier research [6]. Glycerol at a concentration of 2% was used as a plasticizer following Sari et al. [7].

Strawberries used in this experiment were carefully standardized at the beginning of the study to ensure experimental reproducibility. Fruits were selected based on uniform maturity, size, and appearance. Only strawberries harvested at the commercial ripe stage—characterized by red coloration covering at least 75% of the fruit surface—were used. In addition, fruits with an average weight ranging from 15 to 18 g were selected to minimize variation related to fruit size. Fruits exhibiting visible physical damage, decay, or signs of microbial infection were excluded from the experiment.

The experiment consisted of three treatments with three replications, resulting in nine experimental units. A total of 207 strawberries were used in this study. Destructive observations, including moisture content, fruit firmness, total soluble solids, total microbial count, and organoleptic tests, were conducted on 198 fruits. Non-destructive observations, namely weight loss and color measurements, were performed on 9 fruits.

The research stages included the preparation of tools and materials, determination of starch moisture content, preparation of cinnamon extract, formulation of the edible coating, application of the coating to strawberry fruits, observation of quality parameters, and data analysis. Observations were conducted daily over five days of storage at room temperature. On the sixth day, the fruits showed visible signs of deterioration, such as black spots and exudate formation [8]. Data were analyzed

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using analysis of variance (ANOVA). When significant differences among treatments were detected, mean comparisons were performed using a post-hoc test at a 95% confidence level.

3. Result

Weight Loss

According to Astutiningsih et al. (2024), weight loss is defined as a reduction in fruit mass brought on by physiological processes like respiration and transpiration or other harm like decay brought on by microbial activity. Figure 1 displays the findings of observations about the weight loss of strawberry fruit covered with an edible avocado seed starch coating with different amounts of cinnamon extract.

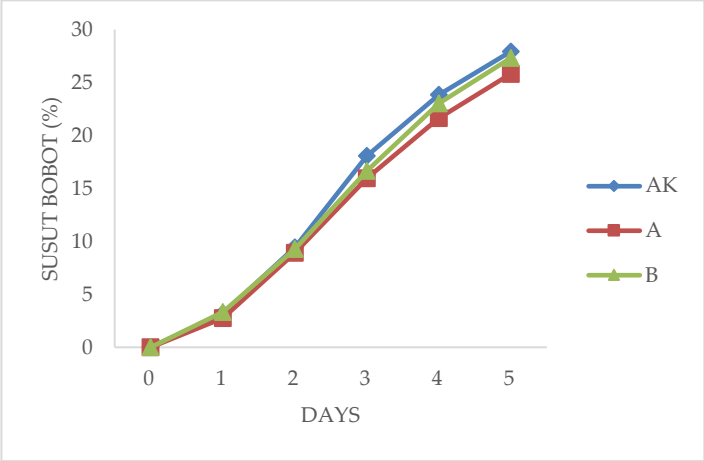

Figure 1. Strawberry Fruit Weight Loss Value

Keterangan :
AK : Pati Biji Alpukat + Ekstrak Kayu Manis 0%
A : Pati Biji Alpukat + Ekstrak Kayu Manis 0,5%
B : Pati Biji Alpukat + Ekstrak Kayu Manis 1%

Moisture Content

Agricultural goods' moisture level is a crucial factor as it influences the product's flavour, texture, and appearance. The degree of customer acceptability, freshness, and product storability are all influenced by water content.The measurement results of the moisture content of strawberry fruit coated with avocado seed starch edible coating with added cinnamon extract are shown in Figure 2.

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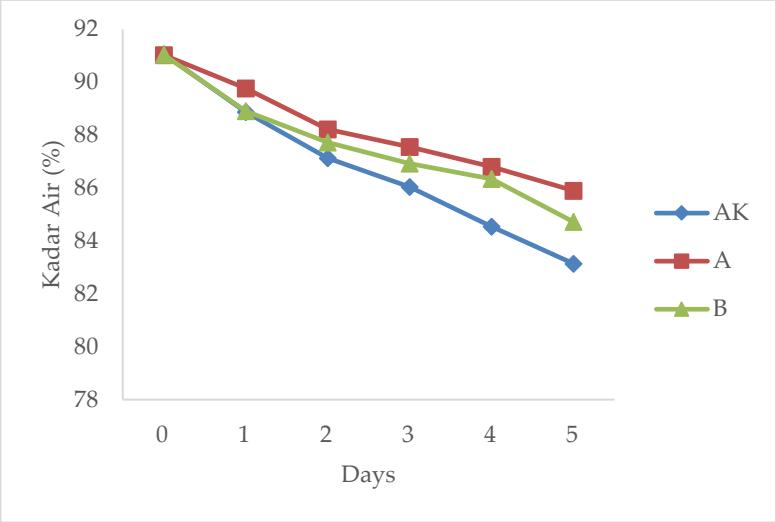

Figure 2. Strawberry Fruit Moisture Content Value

Fruit Firmness

Fruit firmness is one of the main aspects that affect the acceptability of fresh fruit in the market. The degree of hardness has a role in determining the fruit's quality and shelf life. [9]. Figure 3 shows the results of measuring the hardness of strawberries after applying an edible coating made of avocado seed starch with different amounts of cinnamon extract.

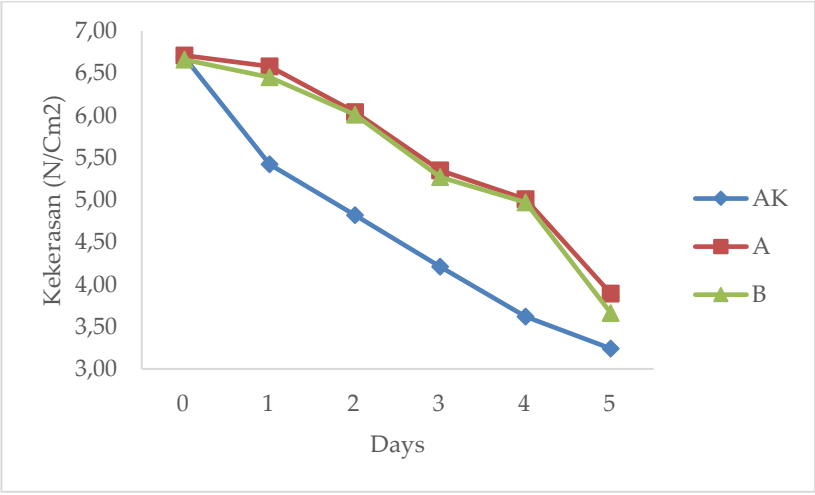

Figure 3. Hardness Value of Strawberry Fruit

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Total Dissolved Solids

The overall quantity of sugar in the fruit, including non-reducing sugars like sucrose and reducing sugars like glucose and fructose, is represented as overall Dissolved Solids (TPT).In addition, TPT also includes pectin, organic acids, soluble amino acids, fats, water-soluble minerals, and proteins [10]. The results of TPT measurement of strawberry fruit in each treatment are presented in Figure 4.

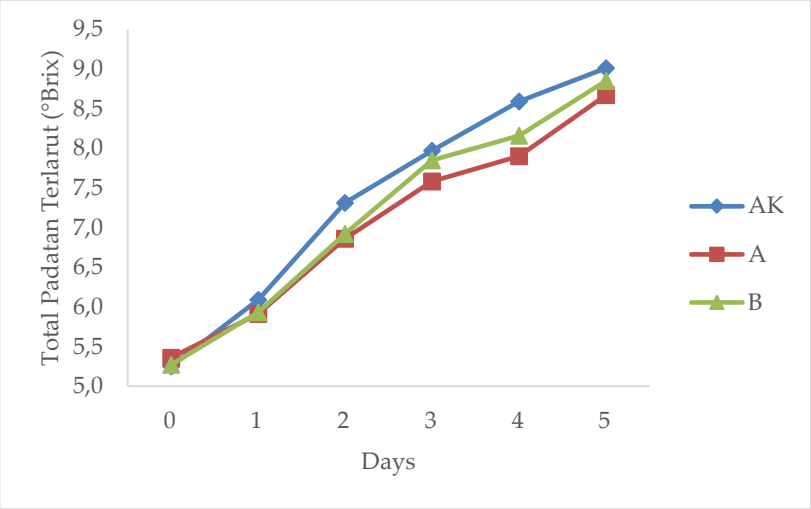

Figure 4. TPT Value of Strawberry Fruit

Color Analysis

Color is a visual indicator that is easy to use to assess the quality or level of liking for food products. Color also reflects the condition of the product and acts as a determining factor for consumer attractiveness, because attractive colors tend to be more desirable [11]. The observation results of strawberry fruit color parameters in various treatments are presented in Figure 5.

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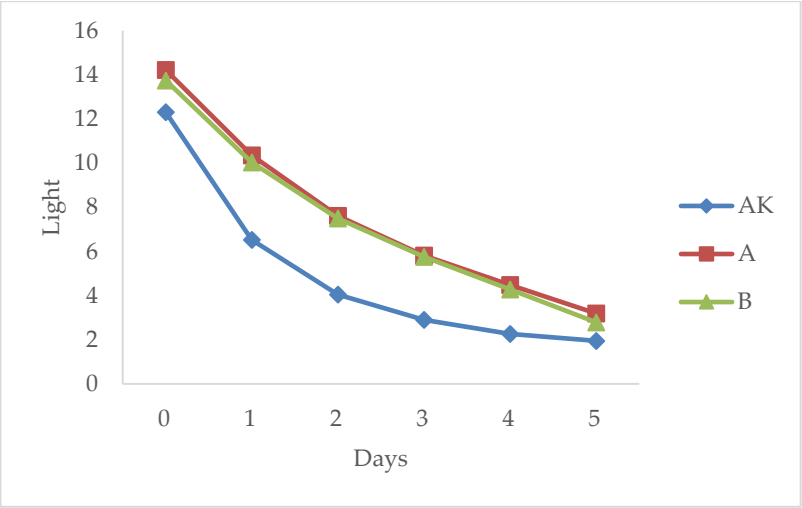

Figure 5. Strawberry Fruit Light Value

Total Microbial Test

Microbial testing aims to measure the total microorganisms in agricultural products, especially in the harvest and post-harvest stages. Damage during harvest or storage can increase the potential for microbial growth. The results of the total microbial measurement on strawberry fruit edible coating avocado seed starch with various concentrations of cinnamon extract are shown in Figure 6.

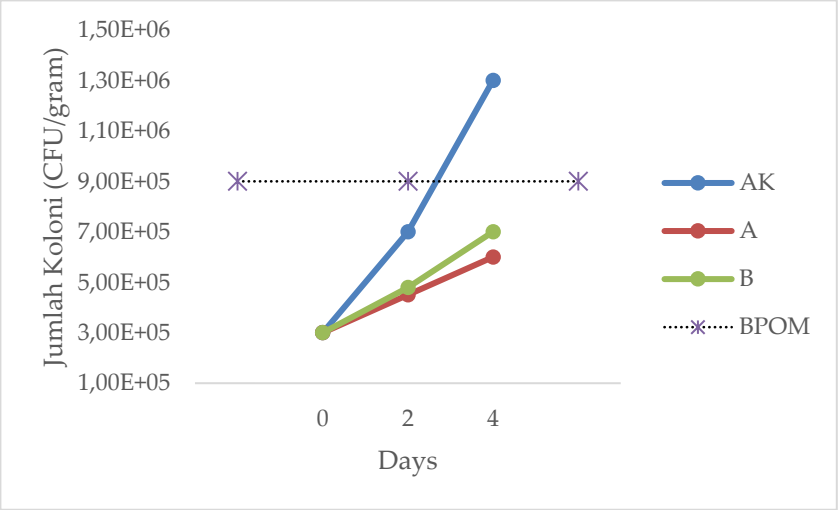

Figure 6. Total Microbial Test Value of Strawberry Fruit

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Recapitulation of Research Results

Table 1 below summarises the findings of observations about weight loss, moisture content, hardness, total soluble solids, colour analysis, and total microbial test.

Table 1. Recapitulation of Research Results

Observation Parameters	AK	A	B
Weight Loss (%)	$11{,}32^{bc}$	$9{,}58^{c}$	$10{,}52^{b}$
Moisture Content (%)	$87{,}89^{a}$	$88{,}67^{ab}$	$88{,}19^{ab}$
Fruit Firmness (N/cm²)	$5{,}02^{b}$	$6{,}05^{a}$	$5{,}87^{ab}$
Total Dissolved Solids (°Brix)	$7{,}08^{b}$	$6{,}85^{c}$	$7{,}03^{bc}$
Color Analysis (Light)	$5{,}49^{ab}$	$7{,}52^{c}$	$7{,}29^{bc}$
Total Microbial Test	$8{,}300\times10^{3b}$	$2{,}400\times10^{1a}$	$4{,}610\times10^{1ab}$

Weight loss, moisture content, hardness, total soluble solids, colour, and organoleptic tests of taste and aroma are all significantly affected by applying an edible coating of avocado seed starch with different concentrations of cinnamon extract during storage, according to Table 1, which summarises the observation results. When 0.5% cinnamon extract was added to avocado seed starch, the edible coating produced the greatest results. According to Celikel and Kavas (2018), harmful bacteria can be effectively inhibited from growing at lower concentrations of essential oils. The active ingredients in cinnamon extract, such eugenol and sinamaldehyde, which act as antimicrobials by denaturing cell proteins, rupturing cell membranes, and lowering cell surface tension, are responsible for this efficacy. [12]. Additionally, polyphenols and flavonoids included in cinnamon extract function as antioxidants, strengthening tissues and fending off free radicals to lessen damage and decay brought on by fungal development. [13]. The amount of total soluble solids in strawberries coated with edible avocado seed starch and cinnamon extract is also linked to the proliferation of microbes.

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4. Discussion

Weight Loss

Figure 1 shows that strawberry weight loss increased progressively during storage across all treatments, which may indicate ongoing respiration, transpiration, and microbial activity during storage [14]. As a non-climacteric fruit with a relatively high respiration rate, strawberries are susceptible to rapid quality deterioration [15]. Water evaporation and substrate utilization during respiration likely contributed to reduced fruit weight [16].

Among the treatments, strawberries coated with 0.5% cinnamon extract exhibited the lowest weight loss, suggesting that this concentration effectively reduced moisture loss and respiration. The presence of antioxidant compounds in cinnamon extract may have contributed to maintaining fruit water balance [18]. In contrast, the control treatment showed higher weight loss due to the absence of protective components, while excessive extract concentration (1%) may have increased coating permeability, leading to greater water vapor transfer [19].

Moisture Content

Figure 2 indicates a gradual decline in moisture content of strawberries during storage. This reduction may be attributed to continued metabolic activities such as respiration and transpiration [20]. Strawberries coated with avocado seed starch containing cinnamon extract exhibited a slower decrease in moisture content compared to the control, suggesting improved water vapor barrier properties of the coating. Active compounds in cinnamon extract, such as cinnamaldehyde and eugenol, may limit water vapor transmission and reduce evaporation [21]. The 0.5% treatment retained moisture more effectively than the 1% treatment, which may indicate that excessive extract addition introduces soluble solids that interfere with water-binding capacity [12].

Fruit Firmness

As shown in Figure 3, strawberry firmness decreased during storage, likely due to water loss and enzymatic degradation of cell wall components [22]. Increased respiration may accelerate protopectin conversion into soluble pectin, weakening cell wall integrity and contributing to softening [19]. The control treatment (0%) showed the lowest hardness due to the absence of protective compounds that maintain water

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content. The control treatment exhibited the lowest firmness, while strawberries coated with 0.5% cinnamon extract maintained higher firmness. This suggests that bioactive compounds in cinnamon extract may inhibit enzymes involved in cell wall modification [18]. At a concentration of 1%, coating brittleness may have increased, promoting microcracks and water loss.

Total Soluble Solids

Figure 4 shows an increase in total soluble solids (TSS) during storage, which may reflect ripening processes and concentration effects due to water loss [23]. The control treatment exhibited the highest TSS values, while the 0.5% cinnamon extract treatment showed the lowest. This suggests that metabolic activity and respiration rate were better regulated at this concentration. Higher extract levels may interfere with fruit metabolism, potentially affecting TSS accumulation [24].

Color Analysis

Figure 5 illustrates a decrease in lightness (L*) values during storage, indicating fruit darkening. Strawberries treated with 0.5% cinnamon extract maintained higher brightness, suggesting delayed oxidation and browning processes [18]. At 0% concentration, the absence of antimicrobial protection may accelerate discoloration, while excessive extract concentration (1%) may disrupt pigment metabolism due to suboptimal coating structure [27]. These results indicate that 0.5% cinnamon extract provides the most effective balance between protection and coating integrity.

Total Microbial Test

Figure 6 shows an increase in microbial count during storage in all treatments, with the highest growth observed in the control. This trend may be associated with increased sugar availability during fruit ripening, which supports microbial proliferation [28]. Treatments containing cinnamon extract effectively suppressed microbial growth, particularly at 0.5% concentration. This suggests that antimicrobial compounds such as eugenol and cinnamaldehyde play a significant role in inhibiting microbial activity [12]. Based on BPOM (2019) standards, the 0.5% cinnamon extract treatment produced the most acceptable microbial count, indicating improved shelf-life and safety.

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5. Conclusions

Based on the findings of this study, the application of an edible coating formulated from avocado seed starch enriched with cinnamon extract was effective in maintaining strawberry fruit quality during storage. The edible coating significantly influenced weight loss, moisture content, firmness, total soluble solids, color, and total microbial count, while organoleptic attributes, including taste and aroma, were not significantly affected.

The optimal treatment was achieved using 0.5% (v/v) cinnamon extract, which effectively preserved strawberry quality for five days of storage at room temperature, resulting in a weight loss of 9.58%, moisture content of 88.67%, firmness of 6.05 $N \cdot cm^{-2}$, total soluble solids of 6.85 °Brix, lightness value (L) of 7.42*, and a total microbial count of 2.4×10^{10} $CFU \cdot mL^{-1}$.

These results indicate that an avocado seed starch–based edible coating containing 0.5% cinnamon extract has strong potential as a natural and sustainable approach for preserving strawberry fruit quality during short-term storage at ambient temperature.

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