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Development and Application of an Edible Coating from Avocado Seed Starch (*Persea americana* Mill.) and Vetiver Root Extract (*Vetiveria zizanioides* L.) for Food Quality Preservation

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ABSTRACT

The increasing use of non-degradable plastic packaging has raised serious environmental concerns, highlighting the need for biodegradable alternatives such as starch-based edible coatings. Avocado seed starch (*Persea americana* Mill.) represents a promising renewable raw material; however, starch-based coatings suffer from poor water resistance and susceptibility to microbial growth. Therefore, *Vetiveria zizanioides* L. was incorporated as a natural antimicrobial agent. This study contributed to characterize the physical properties of the edible coating and evaluate its performance when applied to strawberries and *dodol*. The methods included starch and extract preparation, coating formulation, physical characterization, and application tests. The edible coatings were fabricated using avocado seed starch with vetiver root extract at concentrations of 0%, 3%, 5%, and 7%. Subsequently, characterization tests were conducted, including thickness, solubility, and elasticity tests, as well as an application test on food products, which are strawberries and *dodol*. The results indicate that the edible coating containing 7% vetiver root extract had the highest film thickness and solubility, while the 5% vetiver root extract had the highest elasticity. Moreover, the application test of an edible coating containing 7% vetiver root extract on strawberries showed the highest effectiveness in preserving the physical condition for up to 7 days, while the application test on dodol showed the highest effectiveness in preserving the physical condition for up to 7 weeks. These findings indicate the potential of an edible coating made from avocado seed starch and vetiver root extract as an environmentally friendly food coating to preserve the quality of food products.

KEYWORDS

Avocado seed starch; *Dodol*; Edible coating; Strawberry; *Vetiveria zizanioides* L.

1. INTRODUCTION

Food is a fundamental human necessity crucial for fulfilling the nutritional requirements for body health. In general, food materials are perishable, meaning they have a relatively short shelf life. Food can be considered spoiled when changes occur that make it unacceptable to consumers. The deterioration of food products is a multifaceted process initiated by factors such as microbial activity, chemical degradation, and physical alterations. Among these, microbial contamination, predominantly from bacteria, yeasts, and molds, constitutes a major mechanism of spoilage [1], [2].

The process of food deterioration can be inhibited through packaging or by storing produce at specific temperatures. Packaging provides an optimal environment for food materials. This packaging can take the form of wraps or containers, with the primary objective of shielding the food from contamination and physical damage. Conventional packaging frequently utilizes plastic due to its numerous advantages, including flexibility, transparency, strength, shatter resistance, the potential for lamination with other materials, heat resistance, and stability. However, the persistent use of plastic presents significant

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environmental challenges and potential risks to human health. The migration of monomers into food can lead to adverse effects on consumers' digestive systems [3]. Consequently, there is a pressing need for environmentally friendly packaging alternatives, such as edible coatings. Edible coatings offer various advantages in preserving the color, flavor, microbial safety, appearance, nutritional value, and texture of the food [4], [5]. In general, various natural polymers have been investigated for the production of edible films and coatings, including starch, proteins, cellulose derivatives, alginates, pectins, and other polysaccharides [6], [7]. Along with the growing global effort to promote packaging materials derived from renewable resources, biodegradable films have attracted increasing attention for their environmental friendliness, renewability, and biodegradability [8]. Moreover, these films can serve multiple functions, such as carriers for antioxidants and antimicrobial agents, reducing packaging waste and weight, seed encapsulation, and protective coatings for fruits [2], [7].

Avocado seed waste is a byproduct produced by avocado plantations, processed avocado product factories, and fruit juice vendors across various regions of Indonesia. Avocado production in Indonesia is substantial, particularly in West Java, where it has consistently increased year after year. According to data from the Badan Pusat Statistik, Indonesia's avocado production reached 919,508 tons in 2024, up from 874,046 tons in 2023. This data suggests a positive correlation that higher avocado production yields greater quantities of avocado seed waste. Each avocado fruit can generate 15% seed waste [9]. Starch isolated from avocado seeds (*Persea americana* Mill) yielded 19.54% and exhibited favorable functional properties, including good water and oil absorption capacities, low water solubility, and high thermal stability up to 366 °C, with a relatively high amylose content (39.56%) [10]. The notably high starch content of avocado seeds suggests their potential as a raw material for edible coating production. Films from avocado seed starch exhibit good flexibility but low antibacterial activity; supplementation is needed to enhance the antibacterial activity of edible coatings [10].

To enhance the quality of the edible coating, the incorporation of an antibacterial additive is essential. One potential material for this purpose is vetiver root. Vetiver root (*Vetiveria zizanioides* L.) contains various phytochemical compounds. The ethanolic extract of vetiver is reported to contain flavonoids and terpenoids [11]. It also has a high percentage of oil and sesquiterpenoids [12]. Vetiver is commonly used as an antimicrobial agent with antibacterial activity against *Staphylococcus aureus, Bacillus sublitis, Pseudomonas aeruginosa*, and *Escherichia coli* [13]. This extract demonstrates antibacterial activity against *B. cereus*, a common foodborne pathogen [14]. Moreover, *V. zizanioides* is traditionally used as gastrointestinal relief for indigestion and bloating, making it suitable for application in edible coatings for food product [15].

Therefore, the addition of vetiver root extract to the edible coating is predicted to be highly beneficial, serving as a natural preservative in food applications. Despite growing interest in starch-based edible coatings and plant-derived bioactive additives, the specific combination of avocado seed starch and vetiver root extract has not yet been explored. This research contribution is to characterize the physical properties of edible coating films based on avocado seed starch and vetiver root extract, including thickness, solubility, and elasticity. As well as evaluate the performance of the developed coatings when applied to food products such as strawberries and *dodol* in delaying quality deterioration and mold growth during storage.

2. MATERIALS AND METHODS

2.1. Materials

The materials used in this research include avocado seed (*Persea americana* Mill.), vetiver root (*Vetiveria zizanoides* L.), glycerol, acetic acid, and distilled water. These materials were procured from local markets and suppliers in Bogor. The tools used in this study were beaker glass (pyrex), measuring cylinder, erlenmeyer flask (pyrex), an OEM laboratory thermometer, Mettler Teledo, an OEM grinder, a Tyler 60 sieve, a vacuum filter, Whatman No. 41 filter paper with a diameter of 11 cm and 20 μm holes, and a non-vacuum hood desiccator and microwave.

2.2. Preparation of Avocado Seed Starch

The preparation of avocado seed starch was conducted according to Martin et al., (2022) [10] with modification. The avocado seeds were peeled and then washed until clean. The clean seeds were cut into small pieces and subsequently crushed using a blender. After being pulverized, the avocado seed paste was placed into a container and separated from the pulp using a filtering cloth. This filtration process aims to separate the avocado seed starch. The starch slurry was placed into the filtering cloth and squeezed while being filtered simultaneously, so that the pulp remained in the cloth and the water mixed with starch passed through. The remaining pulp was mixed with water again, as described above, and then filtered again. This process was repeated until the filtrate appeared clear. This indicates that the starch had been completely extracted. The liquid resulting from squeezing, which was a suspension, was left to stand and sediment for approximately 12 hours in a container to obtain the starch.

2.3. Preparation of Vetiver Root Extract

The extraction of vetiver root was carried out using a modified method based on previously reported procedures [16]. Fresh vetiver roots were first washed thoroughly with running water to remove adhering dirt and impurities. The cleaned roots were then cut into small pieces and mechanically ground using a blender until a homogeneous pulp was obtained. The resulting slurry was subsequently filtered and pressed using a muslin cloth to separate the liquid extract from the solid residue. The obtained filtrate was used directly as vetiver root extract for further formulation.

2.4. Preparation of Edible Coating from Avocado Starch and Vetiver Extract

The edible coating based on avocado seed starch was prepared with the addition of vetiver root extract across four different treatments. The preparation method was conducted as described by Charles et al. (2022) [17] with modifications. The formulation consisted of 100 g of avocado seed starch, 15 mL of glycerol, and 5 mL of acetic acid, with vetiver root extract concentrations of 0%, 3%, 5%, and 7% (w/w).

2.5. Film Thickness Measurement

Film thickness was measured using a micrometer (Digimatic Micrometer Mitutoyo, Japan). The method involved placing the film between the micrometer's jaws. The thickness was measured at seven different points for each sample shape (circle, square, and other dimensions), and the average value was then calculated [18].

2.6. Solubility Test

The solubility test was conducted as follows: the sample was cut into 2 x 2 cm pieces. The sample, along with the filter paper, was dried at 105 °C for 24 hours. The filter paper and the sample were weighed separately to determine their initial weight (W1). The sample was then placed in 50 mL of water containing 0.02% NaCl. The addition of the NaCl solution was intended to prevent microbial growth. The immersion lasted for 24 hours with periodic gentle agitation. Filtration was then performed, and the filter paper, along with the undissolved film, was dried at 105 °C for 24 hours. Afterward, the sample was weighed (W2) [17]. The solubility was calculated using equation (1).

$$\%\text{Solubility} = \frac{\text{W1-W2}}{\text{W1}} \times 100\% \tag{1}$$

2.7. Elasticity Test

The elasticity of the edible coating films was evaluated using a static load elongation test in accordance with the general principles of ASTM [19]. The film samples were cut into rectangular strips with dimensions of 5 × 2 cm. The thickness of each sample was measured at several points using a micrometer screw gauge, and the average value was used to calculate the film's cross-sectional area by multiplying the width and thickness. Each sample was clamped vertically on a support stand, and a 10 g load was attached to the lower end of the film. The initial length of the sample (L_0) was recorded before loading, and the final length (L) after loading was measured. The elongation was calculated and expressed as a percentage using the equation (2).

$$\%\text{Elasticity} = \frac{L - L0}{L0} \times 100\% \tag{2}$$

The applied stress was calculated by dividing the applied force by the sample's initial cross-sectional area. Each treatment was performed in triplicate, and the results were reported as mean values [18].

2.8. Edible Coating Application Test on Strawberries and *Dodol*

The application test of the edible coating on strawberries and *dodol* was carried out by observing changes in the physical condition of the *dodol* and strawberries that were coated with the edible coating made from avocado seed waste with the addition of vetiver root extract. Data on these changes were recorded by comparing their physical condition each week over time, with observations made once a week [20].

3. RESULTS AND DISCUSSION

3.1. Thickness

Thickness is an important parameter that influences the formation of the edible film. The film's thickness was measured at 7 different points, and the results were then averaged. Based on micrometer measurements, the average thickness ranged from 0.126 mm to 0.142 mm. The measurement result is shown in Table 1.

Table 1. The thickness of the edible film.

Extract concentration (%)	Thickness (mm)	Notes
0	0.139	-
3	0.128	-
5	0.126	Lowest result
7	0.142	Highest result

The thickness of the edible film decreased with increasing concentrations of vetiver root extract. Higher extract concentrations produced a more concentrated solution, which in turn yielded a thicker coating. At 7% concentration, the solution viscosity increased, resulting in a notably thicker film compared to other treatments. However, the anomaly was observed at 3% and 5% vetiver root extract concentrations, resulting in a thinner film than at 0%. The anomaly in film thickness is possibly because of the film preparation method, with the solution pouring method, which has the disadvantage of a great challenge in thickness uniformity [7]. Avocado seed starch has been reported to exhibit strong viscoelastic properties and structural stability over a wide temperature range, maintaining high G′ values (850–1000 Pa) even at elevated temperatures [21]. In this context, the incorporation of vetiver root extract may modify the intermolecular interactions within the starch network, thereby influencing the rheological behavior of the coating solution. This suggests that the interaction between starch and the extract may affect solution rheology and warrants further investigation. Other methods that can be used to improve coating thickness include extrusion blow molding, electrospinning, casting process, and 3D printing technology [7].

3.2. Solubility

The results of the solubility test on the edible film showed that solubility increased with increasing film thickness. This indicates that the film's weight dissolved during the solubility test in NaCl was directly proportional to its thickness (Figure 1). The edible coating in this study was prepared using a physical blending approach, in which the components were combined by mechanical mixing without forming or breaking chemical bonds. The interactions among the components were mainly governed by weak intermolecular forces, such as hydrogen bonding and van der Waals interactions [7]. Glycerol was incorporated into the formulation as a plasticizer to improve the flexibility of the film matrix [22]. The presence of plasticizer is known to increase the mobility of polymer chains, and an increase in plasticizer concentration generally leads to higher water solubility of the resulting film [23].

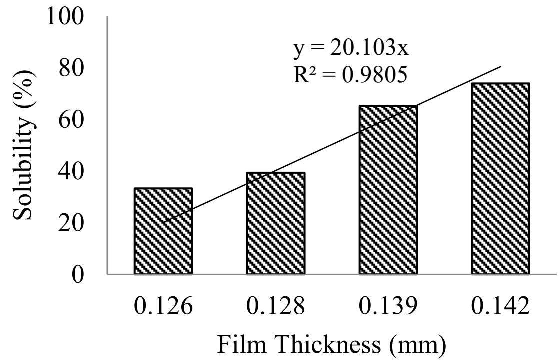

Figure 1. Solubility test result.

3.3. Elasticity

The elasticity values of the films in this study, which ranged from 1.33% to 3.66%, indicate that the mechanical flexibility of the avocado seed starch-based edible coating was influenced by the incorporation of vetiver root extract. The highest elasticity observed at 5% addition of vetiver root extract suggests an optimal composition between avocado seed starch and the bioactive additive for improving film flexibility (Figure 2). A similar concentration-dependent effect has been reported in bioactive starch-based films incorporated with ozonated lignin, where increasing lignin content up to 10% significantly enhanced film ductility, while further increasing to 20% lignin content reversed this effect and deteriorated the mechanical properties [24]. At low to moderate concentrations, the extract may act as a plasticizing or compatibilizing agent, promoting better chain mobility and flexibility of the starch network, while at higher concentrations it may interfere with starch-starch interactions and weaken the film structure.

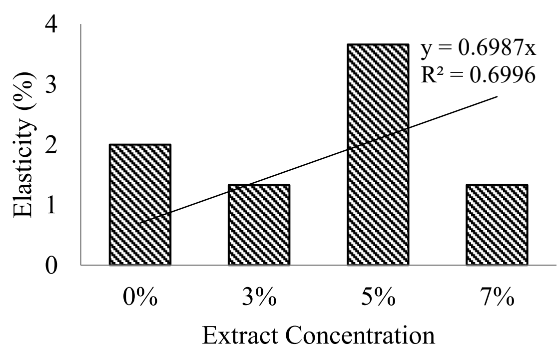

Figure 2. Elasticity test result.

Another study reported that the film flexibility has been reported to improve with the addition of soybean polysaccharides into amylopectin-based composite films [25]. Moreover, the addition of basil seed mucilage in antibacterial edible films has been shown to enhance their mechanical properties compared to previous formulations [26].

3.4. Food Physical Condition Observation

Based on observations of physical changes in strawberries coated with an edible coating containing avocado seed waste and vetiver root extract, the following data were obtained (Table 2). The physical condition of the strawberries was rated using a numerical scale, (1) unchanged from the initial state, (2) texture began to soften, (3) mold appeared, and (4) mold appeared and an unpleasant odour developed.

Table 2. Physical appearance observation of a strawberry coated with edible film.

Treatment	Days						
	1	2	3	4	5	6	7
Control +	1	1	2	3	3	4	4
Control -	1	1	1	2	3	4	4
0%	1	1	1	2	3	4	4
3%	1	1	1	2	2	3	4
5%	1	1	1	2	2	3	3
7%	1	1	1	1	2	2	3

The data from the table were plotted on a graph illustrating the physical changes in the strawberries. All data were compiled into a single graph to facilitate a direct comparison between the different treatments. This comparative data is presented in Figure 3.

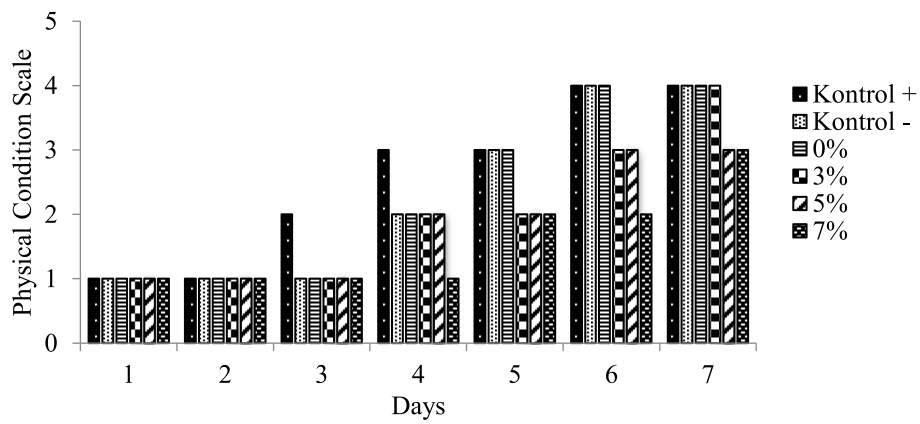

Figure 3. Physical condition changes over days on the strawberry.

Based on physical observations, the strawberries showed no changes during the first two days, regardless of treatment. On the third day, the positive control strawberries (uncoated) began to show texture degradation. This was due to the absence of a protective coating. In the following days, strawberries from all treatments continued to experience physical decay. This occurs during the respiratory process. Strawberries have a relatively high respiration rate of 25–50 mL CO_2/kg/h at 10 °C. With a high respiration rate, the fruit loses weight, texture, total solids, and even acid, which is converted into sugar [27]. The slowest physical deterioration was observed in strawberries coated with edible film containing 7% vetiver root extract. This is likely due to its superior antibacterial properties compared to other coating formulations [28]. The presence of antimicrobial substances in edible films can inhibit the transfer of oxygen from the environment into food products, thereby inhibiting the growth of aerobic bacteria [29]. Furthermore, edible coatings can suppress respiration, thereby reducing strawberry shrinkage. The thicker the edible coating, the less weight loss the fruit will experience because the fruit's pores are completely closed, slowing respiration [20]. Another function of edible coating is that it completely coats strawberries, making them permeable to gases, water, and even air, thereby preventing direct contact between the strawberries and the air and extending the fruit's shelf life.

The edible film coating treatment for strawberries showed that coatings with 3% and 5% vetiver extract maintained the fruit's physical condition for 3 days, while a 7% concentration extended shelf life to 4 days. Previous studies have demonstrated that the effectiveness of edible coatings in preserving strawberries strongly depends on both the functional materials used and their underlying preservation mechanisms. For instance, a chitosan-based composite coating incorporating ascorbic acid and curcumin was reported to act through a dual mechanism: the chitosan matrix provided a physical barrier against moisture and oxygen transfer, while the incorporated antioxidants suppressed oxidative stress by scavenging reactive oxygen species and reducing lipid peroxidation. This synergistic system significantly delayed fruit softening and quality deterioration, allowing strawberries to be preserved for up to 15 days under cold storage conditions [30]. In another study, guar gum-based edible coatings enriched with wheat bran extract were shown to improve strawberry storage stability by reducing weight loss, decay incidence, and oxidative degradation, while also controlling microbial growth. It successfully extended strawberry shelf life to approximately 9 days at room temperature (25 °C) [31]. Similarly, coatings based on gum arabic and guar gum modified with organic acids (citric, malic, and tartaric acids) have been reported to exhibit improved structural and thermal properties, thereby maintaining fruit freshness for up to 16 days of storage [32].

Based on observations of physical changes in *dodol* coated with an edible coating containing avocado seed waste and vetiver root extract, the following data were obtained (Table 3). The physical condition of the *dodol* was rated using a numerical scale, (1) Unchanged from the initial state, (2) Texture began to soften, (3) Mold appeared, and (4) Mold appeared and an unpleasant odour developed.

Table 3. Physical appearance observation of *dodol* coated with edible film.

Treatment	Weeks						
	1	2	3	4	5	6	7
Control +	1	1	1	2	2	3	4
Control -	1	1	1	1	2	2	3
0%	1	1	1	1	2	2	3
3%	1	1	1	1	1	2	3
5%	1	1	1	1	1	2	3
7%	1	1	1	1	1	2	2

The data from the table were plotted in a graph showing the physical changes in *dodol*. All data were compiled into a single graph to facilitate a direct comparison between the different treatments. This comparative data is presented in Figure 4.

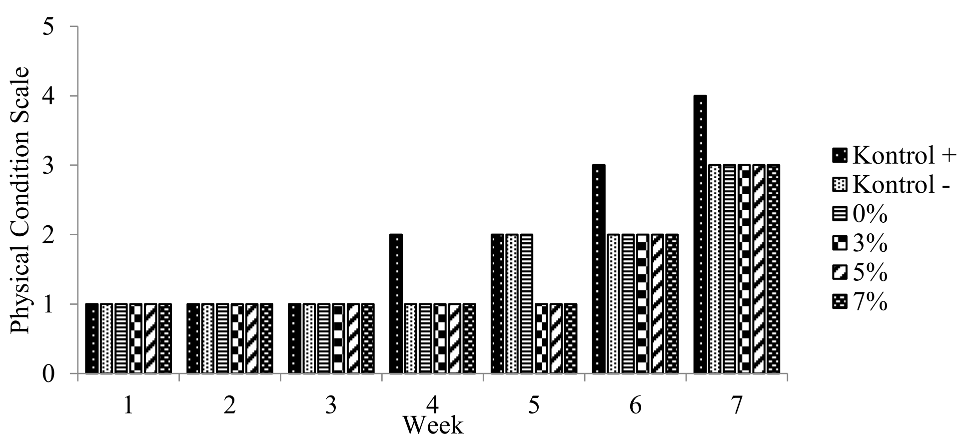

Figure 4. Physical condition changes over weeks on *dodol*.

The physical condition of the *dodol* samples was observed weekly because of their lower moisture content, which slowed physical decay compared with that of the strawberry samples. The results showed no physical changes in the first three weeks. In the fourth week, the positive control sample (uncoated *dodol*) began to show changes in texture due to the absence of a protective layer. In the following weeks, *dodol* with various treatments experienced slight physical changes. *Dodol* coated with edible film containing vetiver root extract performed superiorly, maintaining its physical condition until the fifth week. This was due to the enhanced antibacterial properties provided by the vetiver root extract.

The shelf life of *dodol* is generally quite short, ranging from 2 weeks to 1 month. The relatively high water content in *dodol* products shortens their shelf life, which ranges from 4 to 5 days. However, several types of *dodol* on the Indonesian market have quite varied shelf lives. For example, mangosteen *dodol* has a shelf life of 30 days at room temperature [33]. The shelf life of Garut Picnic *dodol* is up to 3 months. While red bean *dodol* has a shelf life of 14-16 days at room temperature [34]. This shelf life is greatly influenced by the loss of quality and damage to the *dodol* caused by microbial growth.

For *dodol*, all coating concentrations (3%, 5%, and 7%) were equally effective, maintaining the *dodol*'s physical condition for 5 weeks. A direct correlation was observed between vetiver extract concentration and its effectiveness in preserving strawberries. Higher concentrations result in longer preservation times due to the extract's strong antibacterial properties [28]. However, this concentration-dependent effect was not clearly observed in *dodol*, as all formulations exhibited similarly good preservation performance. This can be attributed to the inherently low water activity of *dodol* (9.16%), as reported by Nasaruddin et al., (2012) [35], which serves as the primary limiting factor for microbial growth. Under such conditions, microbial proliferation is already strongly suppressed, making the contribution of the antibacterial edible coating less critical than in high-moisture products such as strawberries.

The application of bioactive edible films for the preservation of *dodol* has previously been reported with promising results. An agar-based antimicrobial edible film incorporated with *Caulerpa racemosa* extract was shown to act as a moisture and oxygen barrier while providing antimicrobial protection, thereby slowing chemical deterioration and extending the shelf life of seaweed *dodol* by approximately two days compared to uncoated and coated controls during a six-day storage period [36]. In another study, starch-based edible films enriched with *Chlorella vulgaris* extract utilized the microalgal extract's antioxidant activity to reduce lipid oxidation and improve the storage stability of *dodol*, as indicated by lower peroxide values and better sensory quality compared to films without the extract [37].

4. CONCLUSION

This study demonstrated that the physical properties of avocado seed starch-based edible coating films, including thickness, solubility, and elasticity, were influenced by the concentration of vetiver root extract (0%, 3%, 5%, and 7%). The application of the coatings delayed quality deterioration and mold growth in both strawberries and *dodol*, although complete spoilage prevention was not achieved. The coating effectively maintained strawberry quality for up to 7 days and extended the shelf life of *dodol* for up to 7 weeks. Among the tested formulations, the coating containing 7% vetiver root extract exhibited the best overall performance.

However, this study is limited to evaluating basic physical properties and visual quality changes during storage, without detailed microbiological analysis or comprehensive mechanical characterization of the films. Future studies are therefore recommended to include microbial inhibition assays, tensile strength and barrier property measurements, and broader application tests across different food matrices to further validate the functional performance and practical applicability of this edible coating system. Overall, these findings indicate that an avocado seed waste-based edible coating supplemented with vetiver root extract has strong potential as an environmentally friendly, functional food coating to improve food storage stability.

AUTHOR CONTRIBUTION

All author contributed equally to the main contributor to this paper. All authors read and approved the final paper. **Gempur Irawan Supena Putra**: Writing (review & editing), writing (original draft), formal analysis, investigation. **Syahidah Asma Amanina**: Writing (review & editing), writing (original draft), and formal analysis. **Iis Tentia Agustin**: Investigation, writing (review & editing), supervision,

conceptualization, and funding acquisition. **Nurlia Damayani**: Investigation, writing (review & editing), supervision, conceptualization, and funding acquisition.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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