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Scientific Research

Evaluation of the effect of edible coating based on *Lepidium sativum* seed mucilage in combination with *Cinnamomum zeylanicum* essential oil on increasing the shelf life of strawberries

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ABSTRACT

Strawberry is a non-climacteric fruit, but its high post-harvest respiration rate results in a rapid spoilage at room temperature. The aim of this study was to evaluate the application of biodegradable coating based on *Lepidium sativum* seed mucilage in combination with *Cinnamomum zeylanicum* essential oil in post-harvest protection of strawberry fruit at 4 °C. Strawberry coating treatments included control sample, mucilage without essential oil, mucilage containing 0.5% essential oil, mucilage containing 0.75% essential oil, and mucilage containing 1% essential oil. Physicochemical (total soluble solids, pH, acidity, and hardness), microbial (mold and yeast), and sensory (color, odor, texture, and overall acceptance) properties of the fruits were studied on days 1, 4, 7 and 10 of storage. The treatments containing essential oil had a positive effect on post-harvest quality of strawberries. Although the quality of samples decreased by storage time, compared with the control sample, mucilage coating containing 1% essential oil prevented severe changes in acidity, pH, hardness, fungi count, and sensory properties of the samples during the storage period and it was selected as the best treatment. In general, samples coated with *L. sativum* seed mucilage containing *C. zeylanicum* essential oil showed the highest overall acceptance compared to the control sample due to low microbial load and preservation of texture and flavor compounds. Therefore, the edible coating based on *L. sativum* seed mucilage and *C. zeylanicum* essential oil can be used to increase the shelf life of other food products.

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1. Introduction

Strawberries are highly appreciated all over the world not only for their unique flavor and distinctive taste, but also for their health benefits. Strawberries contain typical nutrients such as minerals and vitamins and a diverse range of anthocyanins, flavonoids and phenolic acids with biological properties such as antioxidant, anti-cancer and anti-inflammatory activity. Phytochemical composition is affected by genotype, environmental conditions and factors before and after harvest [1-3].

However, strawberry has a short postharvest life with rapid spoilage, which indicates high susceptibility to mechanical damage, excessive tissue softening, physiological disturbances, and infection by several pathogens during transportation, storage, and processing [4]. Several studies have shown that the postharvest life of strawberries can be extended by various storage methods, such as chilling, synthetic chemical fungicides, modified atmosphere packaging, osmotic treatments, heat treatment, and edible coating [5-8]. In recent years, edible coatings have been widely studied for the preservation of fruits and vegetables. Edible coating with semipermeable layers may increase the postharvest life of strawberries by reducing moisture, gas exchange, respiration, and oxidative reaction rates [7, 9].

Cress (*Identification tag*) commonly known as garden cress and its seeds contain about 6.5 to 15% mucilage with good biodegradable, hydrophilic and rheological properties along with low production cost. These properties make watercress mucilage an interesting alternative to conventional synthetic plastic-based materials in the manufacture of edible films and coatings [10]. However, polysaccharide-based coatings rarely have antimicrobial or antioxidant effects, and therefore additives, such as antioxidant and antimicrobial compounds, are usually included in edible coatings to improve their technological performance [11, 12].

Essential oils are classified by the Food and Drug Administration as safe ingredients for use in food, and interest in their use for treating fruits and vegetables and in the post-harvest period has increased. Therefore, the search for new food preservation alternatives that are mostly efficient and easy to obtain is a growing research field [13]. cloves (*Aromatic syzygium* L.) a medium-sized tree (8-12 meters) from the Myrtaceae family (*Mirtaceae*) is native to eastern Indonesia. Clove is one of the main plant sources of phenolic compounds such as flavonoids, hydroxybenzoic acids, hydroxycinnamic acids and hydroxyphenylpropene. Eugenol is the main bioactive compound of cloves, which is found in concentrations of 9381 to 14650 mg per 100 grams of fresh plant material. Regarding phenolic acids such as gallic, caffeic, ferulic, ellagic and salicylic acids and flavonoids such as kaempferol, quercetin and its derivatives (glycosylated) are also found in cloves. A concentration of up to 18% essential oil can be found in clove buds. Approximately 89% of clove essential oil consists of eugenol and 5-15% of eugenol acetate and β-caryophyllin [14]. The antioxidant, antibacterial and antifungal effects of eugenol have been reported in scientific sources [15, 16]. Therefore, in this study, the effect of edible coating treatment based on watercress seed mucilage in combination with clove essential oil on strawberry fruit was evaluated based on changes in physicochemical and sensory characteristics during cold storage after harvest.

2- Materials and methods

1-2- Preparation of clove essential oil

The essential oil of clove plant was obtained according to the extraction method of distillation with water and was kept at 4°C until the time of analysis [17].

2-2- Preparation of edible coating of royal mucilage

Cress seed mucilage was extracted from plant seeds according to the method of Barzegar et al. [10]. The extraction process was carried out at a water-to-seed ratio of 30:1 at a pH of 10 and a temperature of 35°C for 15 minutes. The mucilage was separated from the seed surfaces and then filtered and dried at 60°C for 12 hours. The obtained mucilage was finally milled, packed and stored at ambient temperature. To prepare the edible coating, 2 g of mucilage and 0.1 g of Tween 80 were dissolved in 100 ml of distilled water for 2 hours. Then, clove essential oil (0, 0.5, 0.75, and 1% v/v) was added to the hydrocolloid solution to prepare bioactive edible coating.

3-2- Covering strawberry fruit

800 strawberry fruits were randomly divided into 5 groups, each group containing 160 strawberries: coating solution without essential oil; coating solution containing 0.5% essential oil; coating solution containing 0.75% essential oil; coating solution containing 1% essential oil; Sterile distilled water as control. Each group of strawberries was immersed in the appropriate preparation solution for 5 minutes and then transferred to the storage environment with a temperature of 20°C and a relative humidity of 70 ± 5% [18].

3-2- Physicochemical tests

Total dissolved solids (Brix) and pH of strawberry juice were determined using refractometer and digital pH meter, respectively. Total acidity content was determined after titration of 10 ml of juice with 0.1 M solution and the results were expressed as grams of citric acid per liter [19].

Firmness was measured on the opposite sides of 15 fruits using a texture tester with a probe with a diameter of 5 mm, and the average value was expressed in Newtons. The test conditions used for measurement included the penetration speed of the probe equal to 5 mm/s for before and after the test and 1 mm/s during the test with a penetration distance of 5 mm into the fruit [19].

4-2- Microbial test

Microbial growth in the samples was tested as follows. Random samples of 30 grams of strawberry homogenate were diluted with sterile saline peptone solution (containing 1 gram per liter of peptone and 8.5 grams per liter of sodium chloride). The number of yeast and mold was determined on potato dextrose agar and after being kept in a greenhouse at 29°C for 2 and 5 days. Microbial counts were reported as colony forming units per gram of sample (Log CFU/g) [18].

5-2- Sensory evaluation

Sensory evaluation of strawberry during shelf life was done by 40 evaluators in the age range of 20 to 45 years. The order of the samples was random for each consumer and the strawberries were stored after 1, 4, 7 and 10 days in Refrigerators were evaluated visually by the same consumers according to a 9-point hedonic scale (1 = strongly dislike, 5 = neither like nor dislike, and 9 = like very much). Sensory attributes analyzed included color, smell, texture and overall acceptability [20].

6-2- Statistical analysis

The data was analyzed using SPSS software (version 26) and using one-way analysis of variance, and the difference between the average data was determined with the help of Duncan's test ($p < 0.05$). All experiments were repeated in three steps.

1- Results and discussion

Changes in pH and acidity of strawberry samples as a function of the type of edible coating and storage time are shown in Figure 1. Storage time and the type of food coating did not show a significant effect on the pH of the samples ($p > 0.05$). However, the pH level increased with increasing storage time and the coated samples, especially the types coated with mucilage containing clove essential oil, showed a lower pH level than the control sample ($p > 0.05$). Increasing the storage time from 1 to 10 days decreased the acidity in the samples and this decrease was significant in the control sample. In general, increasing the concentration of essential oil in the edible coating caused an increase in the acidity of the sample; So, on the 10th day of storage, a significant difference was observed between the acidity of the control sample and the sample coated with mucilage containing 1% clove essential oil. It has been reported that the acidity of strawberry fruit decreases due to enzymatic activity during the storage period [21]; In this regard, the significant decrease in acidity in the control sample during the storage period may be due to the extensive decomposition of acids and organic compounds. In addition, researchers have reported that the use of edible coating controls breathing and subsequently acidity and pH in the product during the storage period [21, 22], which is in line with the findings of this research.

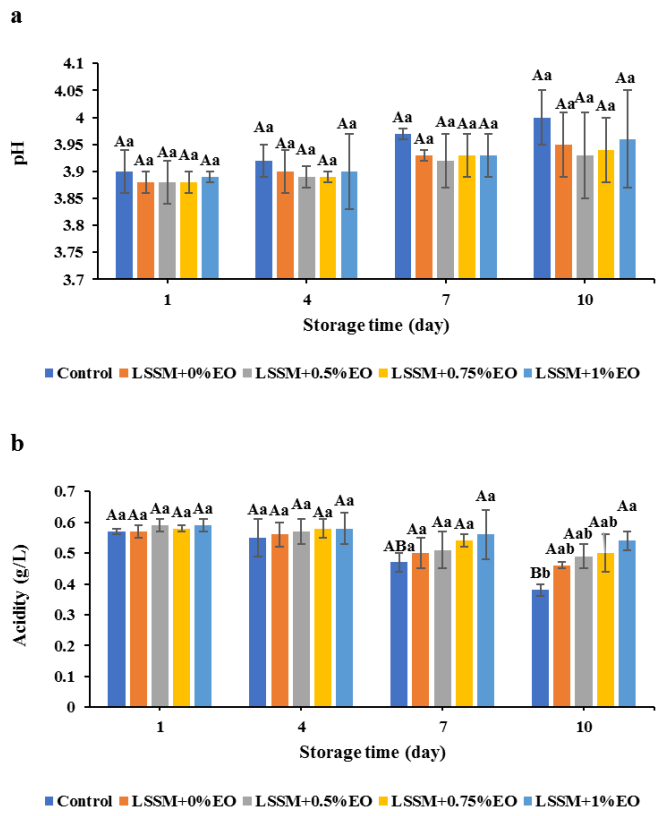

Figure 1. Changes in pH and acidity of strawberries coated with *Identification tag* seed mucilage (LSSM) containing *Cinnamomum zeylanicum* essential oil (EO) during storage period at 4 °C. Significant small and capital letters indicate the effect of coating type and storage time on the response, respectively ($p < 0.05$).

Decomposing carbohydrates and converting acid into sugar during respiration leads to an increase in the amount of soluble solids during fruit storage [23]. Figure 2 shows the amount of dissolved solids of strawberry samples. The amount of dissolved solids of the samples increased significantly with increasing storage time from 1 to 10 days. The type of food coating also showed a significant effect on the changes in the dissolved solids of the samples. The control strawberry samples, covered with mucilage without clove essential oil, covered

with mucilage containing concentrations of 0.5, 0.75 and 1% of clove essential oil, respectively, suffered an increase of 1.74, 1.54, 1.37, and 19. 1 and 1.17 times in the amount of dissolved solids were maintained during the period. The lower changes of dissolved solids in the coated samples may be related to the lower respiration of these samples. Similar results were reported by Mali and Grossman [24]. These researchers stated that compared to the control sample, the soluble solids of strawberry fruit coated with starch-based edible coating increased to a lesser extent during the storage period. It was also reported that the use of edible coating based on chitosan preserves the solids of strawberry solution during the storage period [25].

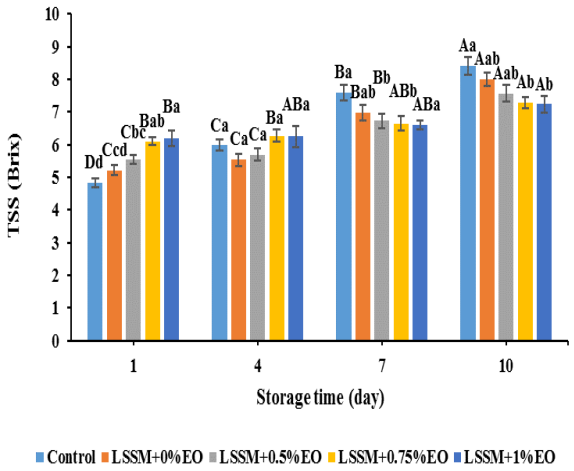

Figure 2. Changes in total soluble solids of strawberries coated with *Identification tag* seed mucilage (LSSM) containing *Cinnamomum zeylanicum* essential oil (EO) during storage period at 4 °C. Significant small and capital letters indicate the effect of coating type and storage time on the response, respectively ($p < 0.05$).

The initial number of mold in strawberry samples was in the range of 2.84-2.3 log CFU/g (Figure 3) and increased during storage. The number of fungi in the control sample increased from 2.3 log CFU/g on the first day to 1.4 log CFU/g on the 10th day ($p < 0.05$). However, the increase in the number of fungi in coated samples was not significant. In general, the highest and lowest number of fungi on the 10th day of storage were observed in the control sample and the sample covered with cress seed mucilage containing 1% clove essential oil, respectively. Previous studies have reported similar results in strawberries coated with edible coatings [18, 25]. The lower rate of fungal growth in samples coated with mucilage containing clove essential oil may be attributed to the antifungal activity of the essential oil (Figures 4 and 5) and the low permeability of the edible coating to oxygen [26, 27]. Considering that fungal species are aerobic and have the ability to grow on the surface of the product, therefore, the low permeability of the food coating to oxygen reduces the access of the fungus to oxygen and, as a result, the growth of fungal strains is lower [12].

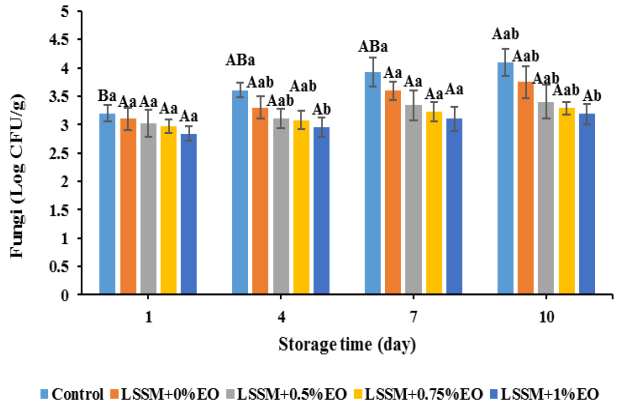

Figure 3. Changes in fungi counts of strawberries coated with *Identification tag* seed mucilage (LSSM) containing *Cinnamomum zeylanicum* essential oil

(EO) during storage period at 4 °C. Significant small and capital letters indicate the effect of coating type and storage time on the response, respectively ($p < 0.05$).

Strawberry firmness decreased during storage regardless of treatment, but coated strawberries suffered slower tissue degradation (Figure 4). The hardness of the control strawberry sample decreased from 3.52 N on the first day to 2.28 N on the 10th day ($p < 0.05$), while no significant difference was observed between the hardness values of the coated strawberry samples during the storage period. The lowest and highest levels of stiffness were observed in the control and coated samples with mucilage containing 1% clove essential oil, respectively. The decrease in strawberry firmness is mainly attributed to the degradation of pectin and other cell wall components under the influence of extracellular pectolytic enzymes [28]. The antimicrobial activity of clove essential oil can indirectly reduce the amount of pectolytic enzymes by inhibiting microbial growth [29]. In addition, the effective ability of edible coating to prevent the entry of oxygen reduces the metabolic activity of strawberries, which is useful for maintaining firmness [30]. The findings of this research are consistent with the results of other researchers [18, 27].

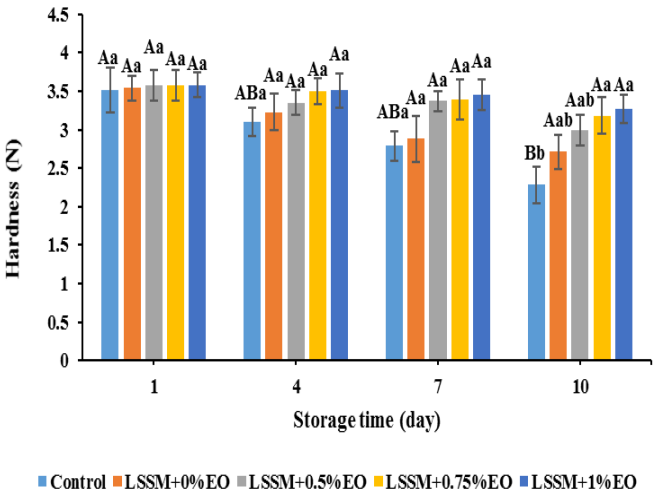

Figure 4. Changes in hardness of strawberries coated with *Identification tag* seed mucilage (LSSM) containing *Cinnamomum zeylanicum* essential oil (EO) during storage period at 4 °C. Significant small and capital letters indicate the effect of coating type and storage time on the response, respectively ($p < 0.05$).

Sensory characteristics of strawberry samples during the storage period are given in Figure 5. All the samples suffered a significant decrease in the color and smell sensory scores during the storage period, but this change was less in the samples covered with mucilage containing high concentrations of essential oil. So that the lowest and highest sensory scores at the end of the storage time were related to the control sample and the one covered with mucilage containing 1% clove essential oil, respectively.

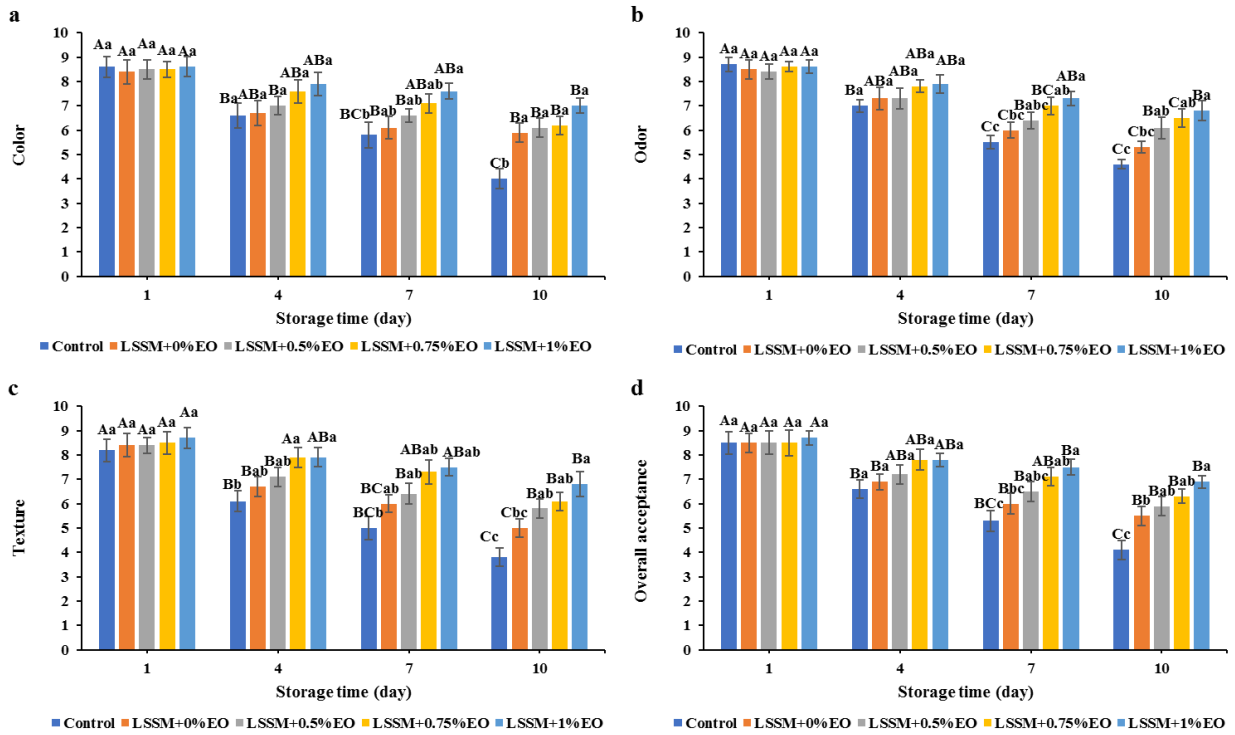

Figure 5. Sensory properties of strawberries coated with *Identification tag* seed mucilage (LSSM) containing *Cinnamomum zeylanicum* essential oil (EO) during storage period at 4 °C. Significant small and capital letters indicate the effect of coating type and storage time on the response, respectively ($p < 0.05$).

A similar trend was observed regarding the texture index of the samples. Increasing the storage time caused a significant decrease in the texture index of the samples, but the presence of edible coating containing essential oil caused a better preservation of this index during the storage period, which is consistent with the results of the histometry test.

The changes in the sensory index of general acceptance were also similar, and increasing the storage time caused a significant decrease in this index. The type of cover also showed a significant effect on the overall acceptance index; Thus, the highest severity of overall acceptance drop was observed in the control sample and the lowest drop in the coated samples, especially the types containing clove essential oil. Although the increase in the rate of respiration and enzyme activity during the storage period leads to a decrease in the appearance and edible quality of the fruit, the samples coated with cress seed mucilage containing clove essential oil, due to the low microbial load, preserve the texture, reduce respiration, and preserve the aroma and flavor producing compounds. , showed the highest overall acceptance compared to the control sample. In line with the results of this research, it has been reported that the use of bioactive food coatings preserves the sensory characteristics of strawberry samples during the storage period [9, 31, 32].

2- total resulting

The use of clove essential oil with significant antioxidant and anti-fungal activity in the edible coating based on cress seed mucilage increased the protection after harvesting strawberry fruit and prevented the growth of yeasts and molds in it, and the sensory characteristics of the fruit at the end of 10 days of storage under the conditions Cold, improve. The use of edible coating containing clove essential oil can be a potential alternative to synthetic fungicides to control post-harvest fungal diseases in strawberry. Therefore, it is suggested that edible coating based on cress seed mucilage and clove essential oil be used to prevent microbial growth and control oxidation of various horticultural and food products.

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چکیده

توت فرنگی میوه‌ای نافرازگرا است، اما سرعت تنفس پس از برداشت بالایی دارد که منجر به فساد سریع آن در دمای اتاق می‌شود. این مطالعه با هدف ارزیابی کاربرد پوشش زیست تخریب پذیر مبتنی بر موسیلاژ بذر شاهی و اسانس میخک در حفاظت پس از برداشت میوه توت فرنگی در دمای ۴ درجه سانتی‌گراد صورت گرفت. تیمارهای پوشش دهی توت فرنگی شامل نمونه کنترل، موسیلاژ بدون اسانس، موسیلاژ حاوی ۰/۵ درصد اسانس، موسیلاژ حاوی ۰/۷۵ درصد اسانس و موسیلاژ حاوی ۱ درصد اسانس بودند. ویژگی‌های فیزیکوشیمیایی (مواد جامد محلول، pH، اسیدیته، سفتی)، میکروبی (کپک و مخمر) و حسی (رنگ، بو، بافت و پذیرش کلی) میوه‌ها در روزهای ۱، ۴، ۷ و ۱۰ نگهداری بررسی گردید. تیمارهای حاوی اسانس بر کیفیت پس از برداشت توت فرنگی تأثیر مثبت نشان دادند. اگرچه افزایش زمان نگهداری سبب کاهش کیفیت نمونه‌ها شد، اما در مقایسه با نمونه کنترل، پوشش موسیلاژ حاوی ۱ درصد اسانس سبب جلوگیری از تغییرات شدید اسیدیته، pH، سفتی، تعداد قارچ‌ها و ویژگی‌های حسی نمونه‌ها طی دوره نگهداری شد و بعنوان بهترین تیمار انتخاب گردید. بطورکلی، نمونه‌های پوشش داده شده با موسیلاژ بذر شاهی حاوی اسانس میخک به دلیل بار میکروبی پایین و حفظ بافت و ترکیبات مولد عطر و طعم، بالاترین پذیرش کلی را نسبت به نمونه کنترل نشان دادند. بنابراین، پوشش خوراکی مبتنی بر موسیلاژ بذر شاهی و اسانس میخک می‌تواند جهت افزایش عمر نگهداری سایر محصولات غذایی استفاده گردد.