horticulturae

MDPI

Article

Effect of Alginate-Based Edible Coating Containing Thyme Essential Oil on Quality and Microbial Safety of Fresh-Cut Potatoes

Sarengaowa [1], Ke Feng [2,*], Yuanzheng Li [3], Ya Long [4] and Wenzhong Hu [1,*]

1 School of Pharmacy and Food Science, Zhuhai College of Science and Technology, Zhuhai 519041, China; kuailexiaosa@sina.com
2 Faculty of Medicine, Macau University of Science and Technology, Macau 999078, China
3 Taiyuan Distillery Co., Ltd., Taiyuan 030000, China
4 Pharmaron Beijing Co., Ltd., Beijing 100000, China
* Correspondence: fengkesky@163.com (K.F.); hwz@dlnu.edu.cn (W.H.)

Abstract: Fresh-cut potatoes (*Solanum tuberosum* L.) are a favorite product on account of their freshness, convenience, and health benefits. However, cutting causes potatoes to lose their protective tissue and suffer mechanical damage, which greatly increases the quality deterioration and safety risk of potatoes. The background microorganism and foodborne pathogens on fresh-cut potatoes might rapidly grow during transportation, processing, and marketing, and cause high health risks for consumers. In this study, the quality and safety of fresh-cut potatoes coated with an alginate-based edible coating containing thyme essential oil (AEC-TEO) was evaluated during a storage period of 16 days at 4 °C. Samples were coated with AEC-TEO at different concentrations (0, 0.05, 0.35, and 0.65%, v/v). The quality characteristics of fresh-cut potatoes including color, weight loss, firmness, and sensory attributes were evaluated over 4 days. The viability of the background microorganism of fresh-cut potatoes and artificially inoculated bacteria involving *Listeria monocytogenes* (LM) was measured every 4 days. The research showed that treatment with AEC-TEO at a 0.05% concentration was the most beneficial for maintaining quality and inhibiting the microorganism of fresh-cut potatoes. The increase in L and firmness was 10.55 and 8.24 N, respectively, and the decrease in browning was 4.19 compared to that in the control. Sensory attributes represent an assessment between "indifferent" and "like a little". The reductions in total plate counts, total coliform counts, yeast and mold counts, and *Lactobacillus* counts were 2.41 log cfu/g, 1.37 log cfu/g, 1.21 log cfu/g, and 2 log cfu/g, and *Listeria monocytogenes* decreased by 3.63 log cfu/g on fresh-cut potatoes after 16 days. Therefore, AEC-TEO effectively improved the quality of fresh-cut potatoes and, to a certain extent, prolonged their shelf life. This represents a potential application prospect for the preservation of fresh-cut potatoes.

Keywords: background microorganisms; coating; *Listeria monocytogenes*; preservation; vegetables

check for updates

Citation: Sarengaowa; Feng, K.; Li, Y.; Long, Y.; Hu, W. Effect of Alginate-Based Edible Coating Containing Thyme Essential Oil on Quality and Microbial Safety of Fresh-Cut Potatoes. *Horticulturae* **2023**, *9*, 543. https://doi.org/10.3390/horticulturae9050543

Academic Editor: Othmane Merah

Received: 24 February 2023
Revised: 20 March 2023
Accepted: 27 April 2023
Published: 29 April 2023

1. Introduction

Potatoes (*Solanum tuberosum* L.) are economically important staple crop plants that produce high yields of nutritionally valuable food and are important in our daily lives [1]. Potatoes, as a main crop plant, play an important role in food provision all over the world. In China and across the world, potatoes rank as the fourth most common agricultural crop after rice, wheat, and corn. Potatoes are cultured in 79% of the world's countries, making this the largest vegetable crop [2]. Potato has been identified by the Food and Agriculture Organization of the United Nations (FAO) as a staple and sustainable food for the growing world population [3]. However, a large amount of soil attached to the surface of fresh potatoes needs to be removed, and potatoes need to be washed before cutting or cooking. The cleaning and processing of potatoes take more time before the end consumer is reached. Fresh-cut fruits and vegetables (FFVs) are peeled, cubed, trimmed, and sliced prior to sale and have the characteristics of freshness, nutrition, and convenience [4]. Such products are increasingly becoming popular with consumers. Potato is a kind of preprocessed vegetable that is suitable for cutting. However, the mechanical damage caused to potatoes by cutting ruptures the cells and tissues [5], causing texture softening, flavor loss, microbial growth, and other undesirable phenomena, making storage more difficult and impacting the commercial value [6]. Hence, it is important to develop preservation technology that can enhance the quality attributes of fresh-cut potatoes.

Edible coatings (ECs) can maintain freshness as a wrapping on FFVs by improving the tactile and visual properties of product surfaces [7]. FFVs have been preserved with various types of ECs, including alginates, pectin, starch, chitosan, gums, and carrageenan [8,9]. Among these, the alginate-based edible coating (AEC) has attracted widespread interest. Alginate is an anionic polysaccharide found in the outer cell wall of brown algae. In terms of its physical properties, sodium alginate itself is nontoxic and stable in the environment. It is able to gel, form films, and bind with numerous molecules [10]. Sodium alginate is classified as GRAS (generally regarded as safe) by the Food and Drug Administration (FDA) and can be used as an emulsifier, stabilizer, thickener, or gel [11]. Alginic acid and its salts are food additives approved by the European Commission [12]. The most common salt of alginate is sodium alginate [13]. Alginate can be used as an edible, biodegradable preservative for coating fruits and vegetables [14]. AEC affects fruits and vegetables by controlling the gas exchange, reducing the moisture transfer, and delaying the ripening process. Some reports have shown that AEC also has beneficial effects on the preservation of FFVs [15–17].

Essential oils (EOs), also known as volatile oils, can be obtained from all plant organs, i.e., flowers, seeds, leaves, roots, wood, twigs, fruits, and bark; they are stored in secretory cells, cavities, canals, epidermal cells, or glandular trichomes [18]. There is widespread recognition that essential oils have antibacterial, antifungal, antiparasitic, and antiviral properties [19]. In one of our previous reports, using in vitro experiments, we demonstrated that thyme essential oil (TEO) exhibited the strongest antibacterial activity against foodborne pathogens among many well-known EOs (thyme oil, cinnamon oil, oregano oil, lemongrass oil, mint oil, rosemary oil, clove oil, eucalyptus oil, lavender oil, tea tree oil, blumea oil, valerian oil, atractylodes oil, and zingiber oil) [20]. TEO is among the world's top ten essential oils and is noted for its antimicrobial, antimycotic, antioxidative, food preservative, antifungal, and mammalian-age-delaying properties [21]. Antimicrobial properties are attributed to the alcohols, phenols, terpenes, and ketones in EOs [22]. Researchers have demonstrated that the main component of TEO is thymol [23]. TEO can readily enhance antibacterial activity by volatilizing and inhibiting microbial growth on fresh collard greens and sweet basil leaves during storage [24,25]. However, the volatile odor of TEO can affect the quality, flavor, and sensory attributes of FFVs. Therefore, TEO might be combined with EC to reduce these negative impacts. The preservation effects of alginate EC with oregano essential oils, carboxymethyl chitosan-pullulan EC with galangal essential oil, EC with cinnamon essential oil, and alginate-based EC with thyme essential oil have all been evaluated on fruits and vegetables such as tomatoes, mangos, strawberries, and cantaloupes [26–29]. Moreover, the quality and safety of fresh-cut potatoes treated with alginate-based EC containing thyme essential oil have been not reported. The development of the preservative technology can provide a potential antibacterial agent for fresh-cut potatoes.

The objective of this study is to further evaluate the preservation effects of AEC-TEO on the quality and sensory attributes of fresh-cut potatoes, as well as its impact on background microorganisms and *Listeria monocytogenes*.

2. Materials and Methods

2.1. Bacterial Inoculum

Listeria monocytogenes (LM, CICC 21633) was purchased from the China Center of Industrial Culture Collection (CICC, Beijing, China). A tryptic soy broth containing yeast extract (TSB-YE) was used to culture LM at 37 °C for 12 h. The bacterium suspension was centrifuged at 5000 r/min for 5 min. Peptone water at 0.1% (*w*/*v*) was added to mix the LM for washing. Dilution was carried out using 0.1% (*w*/*v*) peptone water, in a ratio of 1:10, in order to reach the proper inoculum. The population of LM was expressed as log cfu/mL [30].

2.2. Fresh-Cut Potatoes

Fresh potatoes were obtained from a New-Mart in Dalian City (China). They were uniform in size, color, and the absence of defects. The experiment site is located at 38.9° N and 121.6° E. Fresh potatoes were stored at a low temperature (approximately 4 °C) before being processed. They were cleaned with fresh water to remove surface dirt and washed again with distilled water. The surface of the samples was sterilized using alcohol (75% *v*/*v*). A biosafety cabinet was used to air-dry samples for 10 min at 25 °C. The potatoes were then cut into cubes (1 cm × 1 cm × 1 cm) using a sterile knife.

2.3. Preparation of AEC-TEO

The preparation of AEC in this study was carried out in line with previous research [29]. A mixture of sodium alginate at 1.29% (*w*/*v*) and glycerol at 1.5% (*w*/*v*) was stirred in ultrapure water at 70 °C until the solution became transparent [31]. TEO at different concentrations (0.05%, 0.35%, and 0.65%, *v*/*v*) was added to the AEC and stirred for 3 min at 12,500 rpm using Ultra Turrax T25 mixer (IKA® WERKE, Staufen, Germany). To produce a cross-linking reaction necessary for gel formation, a 2% (*w*/*v*) calcium chloride solution (food grade) containing 1% (*w*/*v*) ascorbic acid (food grade) and 1% (*w*/*v*) citric acid (food grade) was prepared. To the calcium chloride solution, ascorbic acid and citric acid were added as antioxidants and color fixatives, respectively [32].

2.4. Fresh-Cut Potato Coating

Fresh-cut potatoes were soaked in the solution of sodium alginate containing TEO for 2 min. Samples were then placed in the calcium chloride solution for 2 min. Fresh-cut potatoes treated with AEC, AEC-TEO (0.05%), AEC-TEO (0.35%), and AEC-TEO (0.65%) were evaluated. Uncoated samples were used as controls. Fresh-cut potatoes (10 cubes) were placed on polystyrene trays as a group and wrapped with PVC films for the evaluation of quality and sensory attributes every 4 days, for a 16-day period, at 4 °C.

2.5. Evaluation of Fresh-Cut Potato Color, Weight Loss, and Firmness

Five group experiments were planned to measure the color of fresh-cut potatoes over 16 days (one test every 4 days). The surfaces of three fresh-cut potato cubes were randomly selected from one group (10 cubes) for each test. The color of the cut surfaces of the potato cubes was measured using a CR400/CR410 colorimeter (Minolta, Tokyo, Japan). The color parameters L^* (lightness), a^* (green chromaticity), and b^* (yellow chromaticity) were measured. Each measurement was carried out on potato cubes. The browning index (BI) was calculated using Equation (1), as follows:

$$\mathrm{BI} = [100(\mathrm{x} - 0.31)]/0.172 \tag{1}$$

where

$$\mathrm{x} = (a^* + 1.75\, L^*)/(5.645\, L^* + a^* - 3.012\, b^*) \tag{2}$$

Three group experiments were planned to measure the weight loss of fresh-cut potatoes over 16 days. Polystyrene trays containing the potato cubes were measured using a digital balance (PL-2002, METTLER TOLEDO, Greifensee, Switzerland) over a period of 16 days. The weight loss rate was calculated as follows:

$$\text{Weight loss rate (\%)} = [(\mathrm{m}_1 - \mathrm{m}_2)/\mathrm{m}_1] \times 100 \tag{3}$$

where m_1 is the initial weight (g) and m_2 is the weight at the specified time point (g).

Five group experiments were planned to measure the firmness of fresh-cut potatoes over 16 days (one test every 4 days). Three fresh-cut potato cubes were randomly selected from one group (10 cubes) for each test. The firmness of the fresh-cut potatoes was determined using a TA.XT texture analyzer (Stable Micro Systems Ltd., Godalming, UK). We measured the firmness of the fresh-cut potato cubes based on the force (N) exerted on the cubes using the P5 compression probe. Each experiment was carried out three times.

2.6. Sensory Attribute Analysis

The sensory characteristics of the potato cubes were evaluated after 8 days by regular consumers of potatoes. A total of twenty individuals, including students and staff, were recruited from the food science and technology faculty. Twenty group experiments (10 cubes in each group) were planned to evaluate the sensory attributes. Fresh-cut potatoes were randomly presented to assessors in different treatment groups. Testing was carried out in individual rooms for each candidate. The odor, color, texture, appearance, and acceptability of the fresh-cut potatoes were evaluated according to a 9-point hedonic scale test. The hedonic evaluation scale recorded degrees of appreciation using the following scoring system: 9 = like very much; 8 = like a lot; 7 = like moderately; 6 = like slightly; 5 = indifferent; 4 = dislike slightly; 3 = dislike moderately; 2 = dislike a lot; 1 = dislike very much [33,34]. The assessors recorded their responses on paper scorecards. Panelists were advised to sip water between the evaluations of two different samples.

2.7. Analysis of Background Microorganisms

Fresh-cut potatoes coated with AEC and AEC-TEO of different concentrations (0.05%, 0.35%, and 0.65%, *v*/*v*) were stored at 4 °C for 16 days. Samples without the coating served as the control. Samples were taken to measure the background microorganism at an interval of 4 days during storage time. Samples were homogenized with 0.1% peptone water (1:10) in a sterile blender. Suspensions of 0.1 mL were taken from the homogenate and cultured on plate count agar (PCA) at 37 °C for 24 h to measure the total plate counts; on potato dextrose agar (PDA) at 28 °C for 48 h to measure yeast and mold counts; on violet red bile dextrose agar (VRBDA) at 37 °C for 24 h to measure total coliform counts; and on Lactobacilli MRS agar at 37 °C for 24 h to measure *Lactobacillus* counts [35,36].

2.8. Analysis of Listeria monocytogenes (LM)

Fresh-cut potato cubes (10 g) were placed in sterile Petri dishes. For the challenges, the potato cube surfaces were inoculated with LM suspensions (8–9 log CFU/mL, 500 µL). Samples were air-dried in a biosafety cabinet at 25 °C for 1 h. As described previously, samples were treated with AEC and AEC-TEO at different concentrations. Untreated fresh-cut potatoes were used as a control. During the 16-day storage period, fresh-cut potato cubes were put in a sterile blender bag and stored at 4 °C. The population of LM on the fresh-cut potatoes was measured at 4-day intervals during the 16-day storage period. Each experiment was conducted three times. The suspension of LM was taken and cultured on an Oxford agar base at 37 °C to determine the bacterial count, which was expressed as log cfu/g.

2.9. Statistical Analysis

Experiments were conducted in triplicate and the mean + standard deviation values were obtained for each experiment. The data were analyzed using SPSS software (Version 14.0; SPSS, Chicago, IL, USA). The significance of differences between variables was tested using a one-way ANOVA (between groups) and a repeated-measures ANOVA (within groups). Duncan's multiple range test was used to compare the means. The statistical significance was determined at $p < 0.05$.

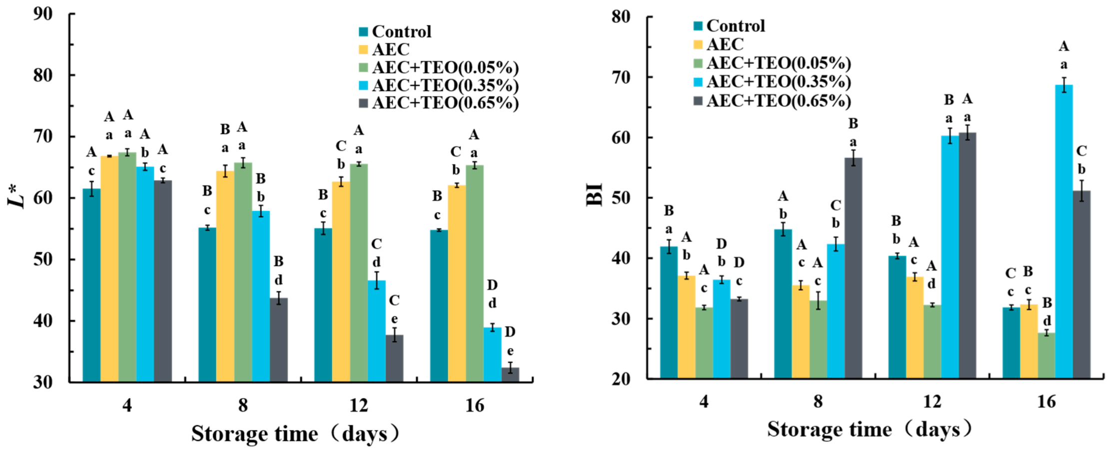
3. Results

3.1. Effects of AEC-TEO on the Quality of Fresh-Cut Potatoes

3.1.1. Color

Color is a critical factor in consumer acceptance of fruit and vegetables. Enzymatic browning is an important process that compromises the color of fresh-cut potatoes. In this study, *L** (lightness) indicates the brightening or darkening of fresh-cut potatoes and BI indicates enzymatic browning during the storage period.

Figure 1a shows changes in the *L** of fresh-cut potatoes treated with AEC with or without TEO. The *L** of fresh-cut potatoes decreased significantly in the control and AEC treatment during the storage period ($p < 0.05$). The *L** in AEC-TEO (0.05%) was higher than that in other groups after 12 days. Decreases were more dramatic in fresh-cut potatoes treated with AEC-TEO (0.35% and 0.65%) than in other treatment groups after 12 days.



(**a**) (**b**)

Figure 1. The effect of alginate-based EC with thyme essential oil on color of fresh-cut potatoes at 4 °C. (**a**) *L** (lightness); (**b**) BI (Browning index). Control: Uncoated; AEC: Alginate-based edible coatings; TEO: Thyme essential oil. The different lowercase letters indicate significant differences across different treatments. The different uppercase letters indicate significant differences across different storage times ($p < 0.05$).

Figure 1b shows changes in the BI of fresh-cut potatoes treated with AEC and AEC-TEO. The BI of fresh-cut potatoes in the control was higher than that of the other groups on the fourth day and then decreased more significantly during the storage period. The BI in AEC was lower than that of the control group after 12 days. The BI of fresh-cut potatoes treated with AEC-TEO (0.05%) also decreased significantly during the storage period, reaching the lowest value among all groups on the 16th day. The BI of fresh-cut potatoes treated with AEC-TEO (0.35% and 0.65%) increased significantly during the storage period, more dramatically than in other groups after 4 days.

3.1.2. Weight Loss

It was important to assess the quality of the fresh-cut potatoes in terms of weight loss during the 16-day storage period (Figure 2). The measured weight loss values of the fresh-cut potatoes increased significantly during storage times ($p < 0.05$). There were no significant differences in the control, AEC, and AEC-TEO (0.05%) during storage time ($p \geq 0.05$). The weight loss in AEC-TEO (0.35% and 0.65%) groups was significantly higher than that in the other treatment groups during storage times ($p < 0.05$).

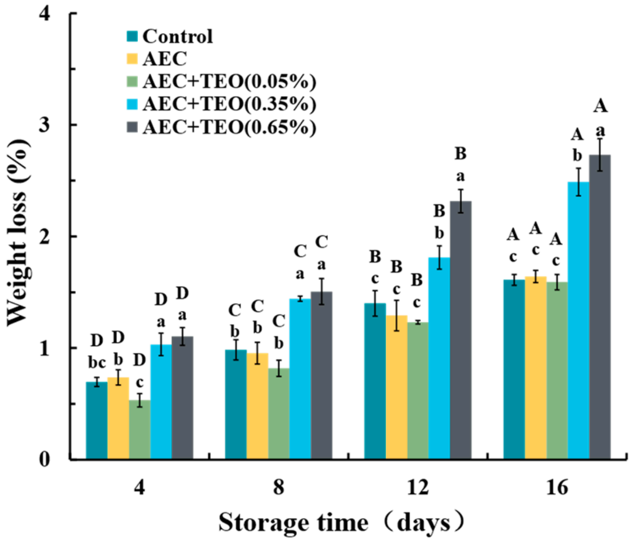


Figure 2. The effect of alginate-based EC with thyme essential oil on weight loss of fresh-cut potatoes at 4 °C. Control: Uncoated; AEC: Alginate-based edible coatings; TEO: Thyme essential oil. The different lowercase letters indicate significant differences across different treatments. The different uppercase letters indicate significant differences across different storage times ($p < 0.05$).

3.1.3. Firmness

The firmness of fruits and vegetables depends on the composition of the cells and the structure of the cell wall. The softening of fruit occurs during ripening and postharvest storage and affects the quality, shelf life, and commercial value of the fruit. The process of softening involves the hydrolysis of starch into sugars and pectin degradation in the cell wall of the fruit. Figure 3 shows changes in the firmness of fresh-cut potatoes treated with AEC with or without TEO. The firmness in the control group showed the lowest value among all treatment groups on the 16th day ($p < 0.05$). The firmness in the AEC and AEC-TEO (0.05%, 0.35%, and 0.65%) was higher than that in the control on the 16th day ($p < 0.05$). There was no significant difference between AEC and AEC-TEO (0.05%, 0.35%, and 0.65%) on the 16th day ($p \geq 0.05$).

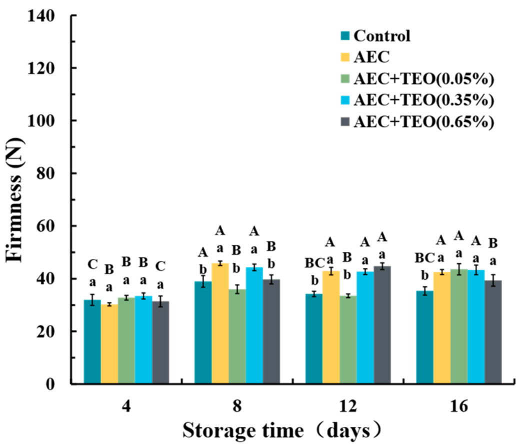


Figure 3. The effect of alginate-based EC with thyme essential oil on firmness of fresh-cut potatoes at 4 °C. Control: Uncoated; AEC: Alginate-based edible coatings; TEO: Thyme essential oil. The different lowercase letters indicate significant differences across different treatments. The different uppercase letters indicate significant differences across different storage times ($p < 0.05$).

3.1.4. Sensory Analysis of Fresh-Cut Potatoes

EOs are known to have strong odors and flavors that might affect the organoleptic characteristics of fruits. The sensory evaluation of fresh-cut potatoes in the AEC and AEC-

TEO (0.05%, 0.35%, and 0.65%) treatments after 8 days is presented in Figure 4. Hedonic data analysis revealed score ranges of 1.55–5.05 for color, 1.5–5 for appearance, 3.3–5.1 for odor, 2.65–5.6 for texture, and 1.75–5.15 for acceptability. In terms of acceptability, the score of the fresh-cut potatoes in the AEC-TEO (0.05%) treatment represented an assessment between "indifferent" and "like a little". The score for fresh-cut potatoes in the control, AEC, and AEC-TEO (0.35%) groups represented an assessment between "dislike moderately" and "dislike a little". For samples in the AEC-TEO (0.65%) treatment, the acceptability score represented an assessment between "dislike very much" and "dislike a lot." Therefore, fresh-cut potatoes in AEC-TEO (0.05%) obtained significantly higher scores than those in the control and the AEC-TEO (0.35% and 0.65%) treatments ($p < 0.05$), and their sensory attributes might be acceptable for further commercialization. A visualization diagram of the fresh-cut potatoes during storage times is shown in Figure 5. This shows that fresh-cut potatoes in the AEC-TEO (0.05%) treatment group were more acceptable visually than those in other treatment groups during the storage period.

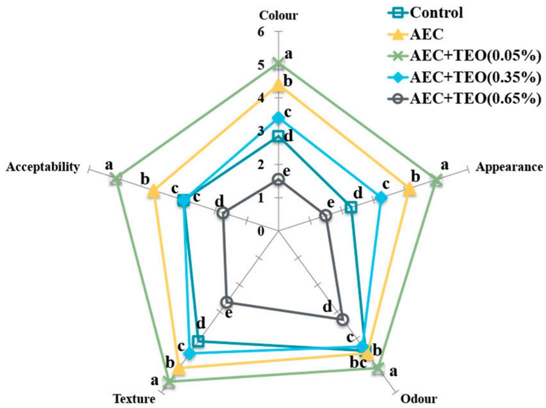


Figure 4. Effect of alginate-based EC with thyme essential oil on sensory attribute of fresh-cut potatoes after 8 days of storage at 4 °C. Control: Uncoated; AEC: Alginate-based edible coatings; TEO: Thyme essential oil. The hedonic evaluation scale used a 9-point scale as follows: 9 represented like very much and 1 represented dislike very much. For each sample, the means designated by different letters are significantly different ($p < 0.05$).

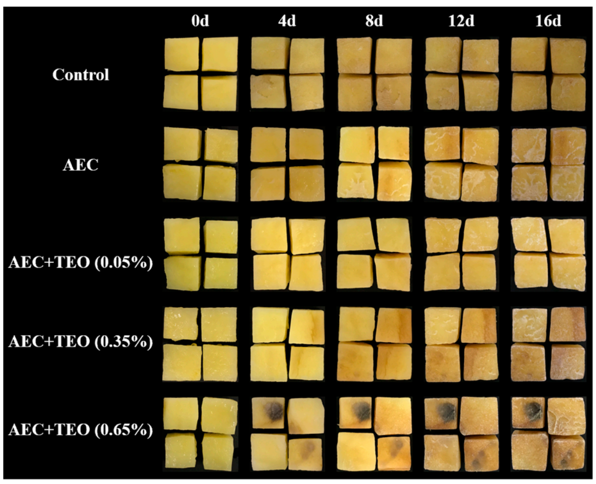


Figure 5. The effect of alginate-based EC with thyme essential oil on appearance of fresh-cut potatoes at 4 °C. Control: Uncoated; AEC: Alginate-based edible coatings; TEO: Thyme essential oil.

3.2. Background Microorganisms

Populations of background microorganisms on fresh-cut potatoes in the AEC treatment with or without TEO were measured (Figure 6). The results showed considerable increases for fresh-cut potatoes in the control, AEC, and AEC-TEO groups ($p < 0.05$). Total plate counts, total coliform counts, yeast and mold counts, and lactic acid bacteria counts in the AEC and AEC-TEO treatments were all lower than those of fresh-cut potatoes in the control over 16 days ($p < 0.05$). The total plate counts, total coliform counts, yeast and mold counts, and lactic acid bacteria counts were much lower in the AEC-TEO treatment than in the AEC treatment ($p < 0.05$). The addition of TEO to AEC caused the population of the background microorganisms to decrease compared with that of fresh-cut potatoes treated with AEC alone. The total plate counts and total coliform counts of fresh-cut potatoes in the AEC-TEO (0.05%) treatment group were lower than those in the AEC treatment group after 12 days. The yeast and mold counts and *Lactobacillus* counts of fresh-cut potatoes in the AEC-TEO (0.05%) treatment were lower than those of potatoes treated with AEC alone after 16 days. The total plate counts in the AEC-TEO (0.35% and 0.65%) treatments were higher than those in the AEC-TEO (0.05%) treatment after 12 days. The yeast and mold counts and total coliform counts in the AEC-TEO (0.35% and 0.65%) treatment were higher than those in the AEC-TEO (0.05%) treatment after 16 days. There were no significant differences in the *Lactobacillus* counts among fresh-cut potatoes in the AEC-TEO (0.05%) and AEC-TEO (0.35%) at 16 days. Interestingly, the values for total plate counts and total coliform counts recorded in the AEC-TEO (0.05%) treatment increased significantly after 12 days. The counts for yeast and mold and for *Lactobacillus* bacteria were also obtained for fresh-cut potatoes treated with AEC-TEO (0.05%) after 16 days.

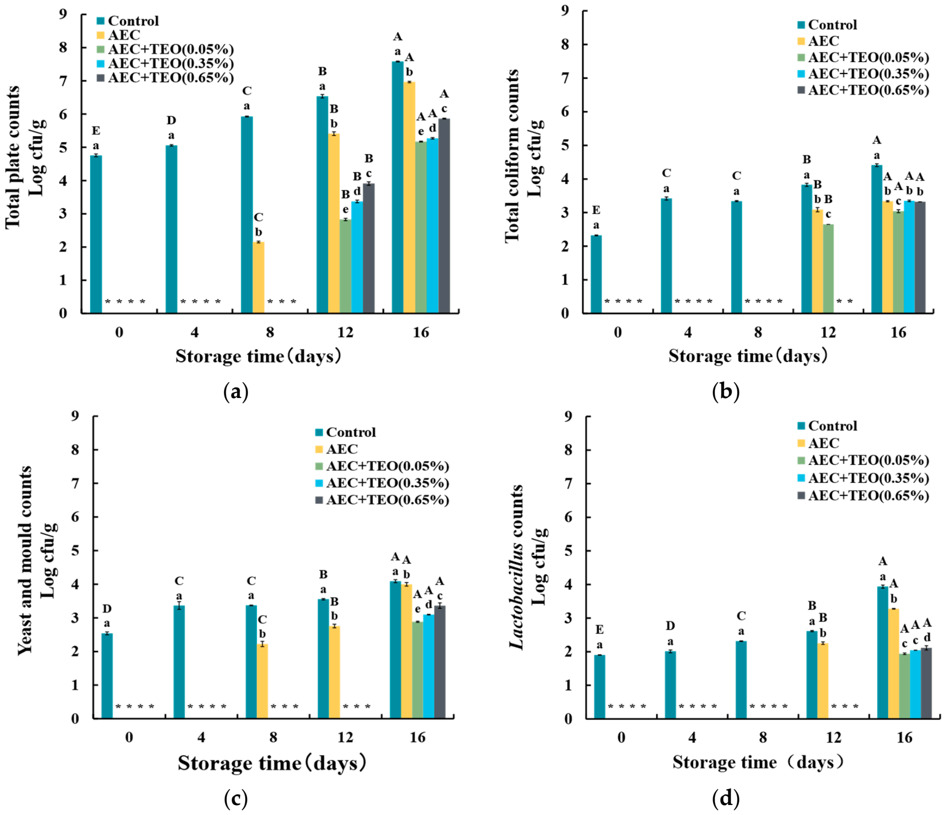


Figure 6. The effect of alginate-based EC with thyme essential oil on background microorganisms on fresh-cut potatoes at 4 °C. (**a**) Total plate counts; (**b**) total coliform counts; (**c**) yeast and mold counts; (**d**) lactobacillus counts. Control: Uncoated; AEC: Alginate-based edible coatings; TEO: Thyme essential oil. Asterisk indicate microorganisms were not detected. The different lowercase letters indicate significant differences across different treatments. The different uppercase letters indicate significant differences across different storage times ($p < 0.05$).

3.3. *Listeria monocytogenes* Analysis

Changes in the populations of *L. monocytogenes* inoculated on the fresh-cut potatoes in the AEC treatment with and without TEO were also measured (Figure 7). The population of *L. monocytogenes* on fresh-cut potatoes in the AEC, AEC-TEO (0.05%, 0.35%, and 0.65%) treatments decreased significantly during the storage period. The populations of *L. monocytogenes* in the AEC were lower than those in the control during the storage period, and the populations of *L. monocytogenes* in the AEC-TEO were lower than those treated with AEC alone. The populations of *L. monocytogenes* decreased as the concentration of the essential oil increased. After 16 days, the *L. monocytogenes* population was lowest on fresh-cut potatoes with the highest tested concentration of TEO (0.65%).

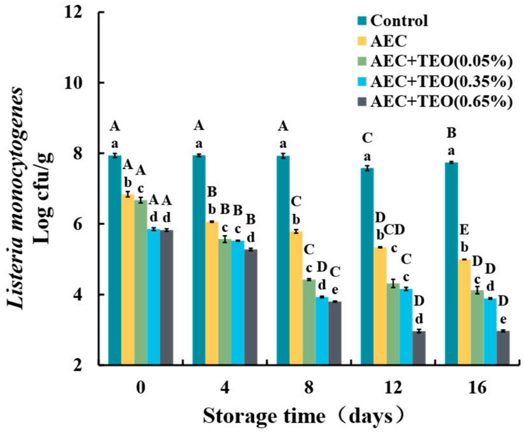


Figure 7. The effect of alginate-based EC with thyme essential oil on *Listeria monocytogenes* on fresh-cut potatoes at 4 °C. Control: Uncoated; AEC: Alginate-based edible coatings; TEO: Thyme essential oil. The different lowercase letters indicate significant differences across different treatments. The different uppercase letters indicate significant differences across different storage times ($p < 0.05$).

4. Discussion

Potatoes are suitable for processing into fresh-cut vegetables as a type of important food material. Fresh-cut potatoes were one of the earliest FFV products in the catering and retail industries. However, mechanical cutting damages the integrity of the potato tissue structure and causes physiological and biochemical changes such as enzymatic browning, water loss, and tissue softening. In particular, the nutrient composition of potatoes provides ideal growth and reproduction conditions for microorganisms [37]. The combination of EC and essential oils as preservative agents can inhibit the growth of microorganisms while maintaining the quality of fresh-cut potatoes. Essential oils are natural and safe and exhibit antibacterial and antioxidant properties. Other research indicated that perillaldehyde, anethole, carvacrol, cinnamaldehyde, eugenol, thymol, and anethole essential oils have a positive effect on enhancing the antioxidant capacities of raspberries, strawberries, and blueberries [38,39]. However, the volatility of essential oils affects their antibacterial activity. EC is an excellent preservative for FFVs. It can reduce weight loss, delay tissue softening, inhibit enzymatic browning, and prevent microbial infection [40]. The volatility of essential oils might be delayed by mixing with EC and maintaining the flavor and texture of fruit and vegetables. In addition, EC can also be used as a carrier of active ingredients such as antioxidants (ascorbic acid, citric acid, and oxalic acid) and nutrients (Vitamin E), which can increase the nutritional value of FFVs [41].

Color has a significant impact on the quality and appearance of FFVs. In this study, *L** and BI were used to evaluate the color of fresh-cut potatoes. *L** (lightness) indicates the brightening or darkening of fresh-cut potatoes, and BI indicates enzymatic browning during the storage period. Lower *L** and higher BI values indicate more serious browning. *L** significantly decreased and BI significantly increased during the storage period ($p < 0.05$). This may be due to the cutting and peeling stimulating signal molecular transmission in fruits and vegetables, activating the phenylalanine ammonia lyase, and synthesizing phenols. The substrate for enzymatic browning is phenols, which are oxidized to quinones under catalysis [42]. During the 4–12-day period, *L** values in the AEC and AEC-TEO (0.05%) treatments were higher, while BI values were lower, compared with the control group. These results indicate that AEC inhibited the browning of fresh-cut potatoes by reducing the reaction between oxygen and PPO. Another study demonstrated that the combination of an edible coating and cinnamon essential oil reduced phenolic content and the browning index compared to uncoated fresh-cut apples after 25 days [43]. The addition of ascorbic acid and citric acid to AEC can also contribute to anti-browning and color protection [44]. Several studies have reported similar results. For example, fresh-cut potatoes soaked in ascorbic acid (1%) maintained good coloration for 6 days [45]. A combination of ascorbic acid (1%) and aloe vera gel (50%) significantly reduced the browning of fresh-cut lotus root [46]. The combination of lginate-CaCl2 and an acetylate monoglyceride coating reduced BI compared with the control fresh-cut apples [47]. However, in the current study, the *L** values in the AEC-TEO (0.35% and 0.65%) treatments significantly decreased as concentrations of TEO increased, while the BI values significantly increased, indicating that TEO in a high concentration seriously affected the appearance of fresh-cut potatoes. This may be because a high concentration of TEO damages the potato tissues. The polyphenol oxidase and substrates in potato tissues lose their separation, and this accelerates enzymatic browning [48]. In another study, fresh-cut potatoes experienced serious browning when exposed to high concentrations of cinnamon essential oil [49]. In this study, we demonstrated that adding a higher concentration of TEO affected the sensory quality of fresh-cut potatoes. This observation is in line with the findings of other studies. For example, the study found that adding thyme essential oil reduced appearance scores to acceptable levels compared with chitosan films for fresh collard greens after 8 days [24]. Fresh-cut vegetables treated with coriander, marjoram, and origanum essential oil show lower odor and taste scores, which reduced the acceptability of the samples [50]. The addition of 0.5% (v/v) lemongrass essential oil significantly affected the sensory properties of fresh-cut pineapple, leading to flavor scores of less than five, and high concentrations of essential oil accelerated the softening of fresh-cut samples [31].

Weight loss is a crucial index to evaluate the quality of FFVs. In this study, weight loss in fresh-cut potatoes in the control, AEC, and AEC-TEO groups increased significantly during the storage period. Because fresh-cut products lose their integrity when peeled, cut, sliced, or shredded, they are more likely to lose water than uncut fruit and vegetable products. Fresh-cut potatoes in the AEC and AEC-TEO (0.05%) treatment showed lower weight loss among all treatment groups during the storage period. Related research has demonstrated that the edible coating can affect weight loss in fresh-cut papaya. The authors of [51] found that a combination of alginate and pectin in an edible coating significantly reduced weight loss in fresh-cut papaya and also reduced juice loss at the end of storage times. However, in the current study, when the TEO concentration increased to 0.35% and 0.65%, the weight loss of the fresh-cut potato samples increased significantly. Indeed, high concentrations of essential oil are toxic to FFVs, causing the destruction of the tissue structure and increased weight loss [52], as demonstrated by previous authors who found that higher concentrations of TEO damaged the tissue of fresh-cut apple, resulting in juice loss, increased respiration, and weight loss [20].

Softening is a serious problem that affects FFVs during storage periods. Starch and pectin function to hydrolyze during fruit softening [53]. This limits the shelf life of FFVs and is an important factor affecting the acceptability of consumers. In this study, the AEC and AEC-TEO maintained the firmness of the fresh-cut potatoes compared with those in the control. The components used in coating solutions might help fresh-cut potatoes to maintain their firmness, and the presence of $CaCl_2$ in the EC may be important in this regard. Ca^{2+} can bind with pectin to stabilize the cell wall, reduce the activity of cell wall hydrolase, and slow down the softening rate [54].

This study reveals that background microorganisms and *Listeria monocytogenes* are able to survive and grow on fresh-cut potatoes during storage periods. Fresh-cut potatoes may provide ideal survival conditions for microorganisms due to the nutrients released after cutting. Pathogens and spoilage microorganisms have also been reported to grow on different types of potato products [55,56]. In the current study, background microorganisms of fresh-cut potatoes in the AEC-TEO treatments were lower than those in the control, and it is reasonable to suggest that TEO exhibits antibacterial activity and that the coating process itself might wash away some microorganisms. Other research showed that an edible coating containing cinnamon oil inhibited yeast and mold on strawberries [28]. An alginate edible coating with thyme oil reduced mold and yeast growth compared to the control and alginate without thyme oil [57]. Bacterial counts were significantly reduced in fruits that were coated with edible coatings with ethanolic essential oil [58]. This study also demonstrated that the populations of background microorganisms and LM on fresh-cut potatoes in the AEC-TEO treatments significantly decreased during the storage period, and antibacterial activity was enhanced with increased concentrations of essential oil. In a previous study, TEO was found to be effective in inhibiting *Listeria monocytogenes*, *Salmonella typhimurium*, *Staphylococcus aureus*, and *E. coli* O157:H7 [20]. TEO exhibits strong antibacterial activity due to its own volatile components. It is well-known that the chemical composition of EOs plays an important role in inhibiting microorganisms [59]. TEO is primarily composed of thymol and carvacrol, and these have biological properties including anti-inflammatory and liver-protecting effects [60]. Other studies have found that thymol can effectively inhibit Gram-positive bacteria by interfering with cell membrane lipids, and proteins, causing an increase in membrane permeability [61]. However, in the current study, high concentrations of TEO did not significantly inhibit the decline of background microorganisms on fresh-cut potatoes after 16 days. The chemical structure of fresh-cut potatoes may be damaged by TEO at concentrations of 0.35% to 0.65%. The juice and nutrition composition provides rich growth conditions for microorganism growth [62]. Therefore, fresh-cut potatoes in the AEC-TEO (0.35% and 0.65%) treatments were prone to microorganism growth. In addition, background microorganisms of 6 log cfu/g are considered an acceptable limit for the shelf life of a fruit product according to the standard of the Institute of Food Science and Technology (IFST) [63]. In this study, therefore, the shelf life of fresh-cut potatoes in the AEC-TEO (0.05%) treatment was extended to 16 days.

5. Conclusions

In this study, the AEC-TEO (0.05%) treatment effectively enhanced the *L*, firmness, and sensory attributes and reduced the weight loss and browning index regarding the quality of fresh-cut potatoes after 16 days. In addition, AEC-TEO exhibited increasing antibacterial activity against background microorganisms and LM on fresh-cut potatoes with increasing concentrations of TEO. Therefore, the AEC-TEO preservation agent can effectively control the infection of LM and maintain the sensory quality of fresh-cut potatoes during the process of packaging, storage, logistics, and sales. The development of AEC-TEO can ensure the wholesomeness and safety of consumers to meet the present-day growing consumer demands for fresh-cut potatoes.

Author Contributions: Conceptualization, K.F. and W.H.; methodology, S. and K.F.; software, S. and K.F.; validation, W.H.; investigation, Y.L. (Yuanzheng Li), resources, W.H.; data curation, Y.L. (Yuanzheng Li) and Y.L. (Ya Long); writing—original draft preparation S.; writing—review and editing, K.F. and W.H.; project administration, K.F. and W.H.; funding acquisition, S. All authors have read and agreed to the published version of the manuscript.

Funding: This study was supported by the Guangdong Basic and Applied Basic Research Foundation (Grant No. 2023A1515011473) and the Doctor Promotion Program of Zhuhai College of Science and Technology.

Data Availability Statement: The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Li, Y.; Zhao, D. Transcriptome analysis of scions grafted to potato rootstock for improving late blight resistance. *BMC Plant Biol.* **2021**, *21*, 272. [CrossRef]
2. Batool, T.; Ali, S.; Seleiman, M.F.; Naveed, N.H.; Ali, A.; Ahmed, K.; Abid, M.; Rizwan, M.; Shahid, M.R.; Alotaibi, M.; et al. Plant growth promoting rhizobacteria alleviates drought stress in potato in response to suppressive oxidative stress and antioxidant enzymes activities. *Sci. Rep.* **2020**, *10*, 16975. [CrossRef] [PubMed]
3. Ciccone, M.; Chambers, D.; Iv, E.C.; Talavera, M. Determining which cooking method provides the best sensory differentiation of potatoes. *Foods* **2020**, *9*, 451. [CrossRef] [PubMed]
4. Van Haute, S.; Sampers, I.; Holvoet, K.; Uyttendaele, M. Physicochemical quality and chemical safety of chlorine as a reconditioning agent and wash water disinfectant for fresh-cut lettuce washing. *Appl. Environ. Microbiol.* **2013**, *79*, 2850–2861. [CrossRef]
5. Kang, W.; Robitaille, M.C.; Merrill, M.; Teferra, K.; Kim, C.; Raphael, M.P. Mechanisms of cell damage due to mechanical impact: An in vitro investigation. *Sci. Rep.* **2020**, *10*, 12009. [CrossRef] [PubMed]
6. Agriopoulou, S.; Stamatelopoulou, E.; Sachadyn-Król, M.; Varzakas, T. Lactic acid bacteria as antibacterial agents to extend the shelf life of fresh and minimally processed fruits and vegetables: Quality and safety aspects. *Microorganisms* **2020**, *8*, 952. [CrossRef]
7. Valencia-Chamorro, S.A.; Palou, L.; Del Río, M.A.; Pérez-Gago, M.B. Antimicrobial edible films and coatings for fresh and minimally processed fruits and vegetables: A review. *Crit. Rev. Food Sci.* **2011**, *51*, 872–900. [CrossRef]
8. Chen, G.; Zhang, B.; Zhao, J. Dispersion process and effect of oleic acid on properties of cellulose sulfate-oleic acid composite film. *Materials* **2015**, *8*, 2346–2360. [CrossRef]
9. Duan, C.; Meng, X.; Meng, J.; Khan, M.I.H.; Dai, L.; Khan, A.; An, X.; Zhang, J.; Huq, T.; Ni, Y. Chitosan as a preservative for fruits and vegetables: A review on chemistry and antimicrobial properties. *J. Bioresour. Bioprod.* **2019**, *4*, 11–21. [CrossRef]
10. Hu, Q.; Nie, Y.; Xiang, J.; Xie, J.; Si, H.; Li, D.; Zhang, S.; Li, M.; Huang, S. Injectable sodium alginate hydrogel loaded with plant polyphenol-functionalized silver nanoparticles for bacteria-infected wound healing. *Int. J. Biol. Macromol.* **2023**, *234*, 123691. [CrossRef]
11. U.S. Food & Drug Administration. Code for Federal Regulations Title 21 Part 184—Direct Food Substances Affirmed as Generally Recognized as Safe. Available online: https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfcfr/CFRSearch.cfm?fr=184.1724 (accessed on 5 April 2018).
12. Younes, M.; Aggett, P.; Aguilar, F.; Crebelli, R.; Filipic, M.; Jose Frutos, M.; Galtier, P.; Gott, D.; Gundert-Remy, U.; Georg Kuhnle, G.; et al. Re-evaluation of alginic acid and its sodium, potassium, ammonium and calcium salts (e 400–e 404) as food additives. *EFSA J.* **2017**, *15*, 5049.
13. Yoo, S.; Krochta, J.M. Whey protein–polysaccharide blended edible film formation and barrier, tensile, thermal and transparency properties. *J. Sci. Food Agric.* **2011**, *91*, 2628–2636. [CrossRef] [PubMed]
14. Chit, C.S.; Olawuyi, I.F.; Park, J.J.; Lee, W.Y. Effect of composite chitosan/sodium alginate gel coatings on the quality of fresh-cut purple-flesh sweet potato. *Gels* **2022**, *8*, 747. [CrossRef]
15. Malvano, F.; Corona, O.; Pham, P.L.; Cinquanta, L.; Pollon, M.; Bambina, P.; Farina, V.; Albanese, D. Effect of alginate-based coating charged with hydroxyapatite and quercetin on colour, firmness, sugars and volatile compounds of fresh cut papaya during cold storage. *Eur. Food Res. Technol.* **2022**, *248*, 2833–2842. [CrossRef]
16. Glicerina, V.; Siroli, L.; Betoret, E.; Canali, G.; Dalla, R.M.; Lanciotti, R.; Romani, S. Characterization and evaluation of the influence of an alginate, cocoa and a bilayer alginate-cocoa coating on the quality of fresh-cut oranges during storage. *J. Sci. Food Agric.* **2022**, *102*, 4454–4461. [CrossRef] [PubMed]
17. Huang, D.; Wang, C.; Zhu, S.; Anwar, R.; Hussain, Z.; Khadija, F. Combination of sodium alginate and nitric oxide reduces browning and retains the quality of fresh-cut peach during cold storage. *Food Sci. Technol. Int.* **2022**, *28*, 735–743. [CrossRef]
18. Patrignani, F.; Siroli, L.; Serrazanetti, D.I.; Gardini, F.; Lanciotti, R. Innovative strategies based on the use of essential oils and their components to improve safety, shelf-life and quality of minimally processed fruits and vegetables. *Trends Food Sci. Technol.* **2015**, *46*, 311–319. [CrossRef]
19. Zhang, Y.; Ma, Q.; Critzer, F.; Davidson, P.M.; Zhong, Q. Organic thyme oil emulsion as an alternative washing solution to enhance the microbial safety of organic cantaloupes. *Food Control* **2016**, *67*, 31–38. [CrossRef]
20. Sarengaowa; Hu, W.Z.; Jiang, A.L.; Xiu, Z.L.; Feng, K. Effect of thyme oil–alginate-based coating on quality and microbial safety of fresh-cut apples. *J. Sci. Food Agric.* **2018**, *98*, 2302–2311. [CrossRef]
21. Fatma, G.; Mouna, B.F.; Mondher, M.; Ahmed, L. In-vitro assessment of antioxidant and antimicrobial activities of methanol extracts and essential oil of *Thymus hirtus* sp. *algeriensis*. *Lipids Health Dis.* **2014**, *13*, 114. [CrossRef]
22. Abers, M.; Schroeder, S.; Goelz, L.; Sulser, A.; St. Rose, T.; Puchalski, K.; Langland, J. Antimicrobial activity of the volatile substances from essential oils. *BMC Complement. Med. Ther.* **2021**, *21*, 124. [CrossRef]
23. Ibrahim, D.; Abdelfattah-Hassan, A.; Badawi, M.; Ismail, T.A.; Bendary, M.M.; Abdelaziz, A.M.; Mosbah, R.A.; Mohamed, D.I.; Arisha, A.H.; El-Hamid, M.I.A. Thymol nanoemulsion promoted broiler chicken's growth, gastrointestinal barrier and bacterial community and conferred protection against Salmonella Typhimurium. *Sci. Rep.* **2021**, *11*, 7742. [CrossRef] [PubMed]

24. Zehra, A.; Wani, S.M.; Jan, N.; Bhat, T.A.; Rather, S.A.; Malik, A.R.; Hussain, S.Z. Development of chitosan-based biodegradable films enriched with thyme essential oil and additives for potential applications in packaging of fresh collard greens. *Sci. Rep.* **2022**, *12*, 16923. [CrossRef] [PubMed]
25. Hassan, F.A.S.; Ali, E.F.; Mostafa, N.Y.; Mazrou, R. Shelf-life extension of sweet basil leaves by edible coating with thyme volatile oil encapsulated chitosan nanoparticles. *Int. J. Biol. Macromol.* **2021**, *177*, 517–525. [CrossRef]
26. Pirozzi, A.; Del Grosso, V.; Ferrari, G.; Donsì, F. Edible coatings containing oregano essential oil nanoemulsion for improving postharvest quality and shelf life of tomatoes. *Foods* **2020**, *9*, 1605. [CrossRef]
27. Zhou, W.; He, Y.; Liu, F.; Liao, L.; Huang, X.; Li, R.; Zou, Y.; Zhou, L.; Zou, L.; Liu, Y.; et al. Carboxymethyl chitosan-pullulan edible films enriched with galangal essential oil: Characterization and application in mango preservation. *Carbohydr. Polym.* **2021**, *256*, 117579. [CrossRef]
28. Piechowiak, T.; Skóra, B. Edible coating enriched with cinnamon oil reduces the oxidative stress and improves the quality of strawberry fruit stored at room temperature. *J. Sci. Food Agric.* **2023**, *103*, 2389–2400. [CrossRef] [PubMed]
29. Sarengaowa; Hu, W.; Feng, K.; Xiu, Z.; Jiang, A.; Lao, Y. Thyme oil alginate-based edible coatings inhibit growth of pathogenic microorganisms spoiling fresh-cut cantaloupe. *Food Biosci.* **2019**, *32*, 100467. [CrossRef]
30. Joshua, P.V.; Di, L.; Linda, J.H.; Donald, W.S.; Michelle, D.D. Fate of *Escherichia coli* O157:H7, *Listeria monocytogenes*, and *Salmonella* on fresh-cut celery. *Food Microbiol.* **2013**, *34*, 151–157.
31. Azarakhsh, N.; Osman, A.; Ghazali, H.M.; Tan, C.P.; Adzahan, N.M. Lemongrass essential oil incorporated into alginate-based edible coating for shelf-life extension and quality retention of fresh-cut pineapple. *Postharvest Biol. Technol.* **2014**, *88*, 1–7. [CrossRef]
32. Bhat, T.A.; Rather, A.H.; Hussain, S.Z.; Naseer, B.; Qadri, T.; Nazir, N. Efficacy of ascorbic acid, citric acid, ethylenediaminetetraacetic acid, and 4-hexylresorcinol as inhibitors of enzymatic browning in osmo-dehydrated fresh cut kiwis. *J. Food Meas. Charact.* **2021**, *15*, 4354–4370. [CrossRef]
33. Peryam, D.R.; Pilgrim, F.J. Hedonic scale method of measuring food preferences. *Food Technol.* **1957**, *11*, 9–14.
34. Harich, M.; Maherani, B.; Salmieri, S.; Lacroix, M. Evaluation of antibacterial activity of two natural bio-preservatives formulations on freshness and sensory quality of ready to eat (RTE) foods. *Food Control* **2018**, *85*, 29–41. [CrossRef]
35. Gómez, P.L.; Salvatori, D.M. Pulsed light treatment of cut apple: Dose effect on color, structure, and microbiological stability. *Food Bioprocess Technol.* **2012**, *5*, 2311–2322. [CrossRef]
36. Siroli, L.; Patrignani, F.; Serrazanetti, D.I.; Tabanelli, G.; Montanari, C.; Gardini, F.; Lanciotti, R. Lactic acid bacteria and natural antimicrobials to improve the safety and shelf-life of minimally processed sliced apples and lamb's lettuce. *Food Microbiol.* **2015**, *47*, 74–84. [CrossRef]
37. Chen, C.; Hu, W.; He, Y.; Jiang, A.L.; Zhang, R.D. Effect of citric acid combined with UV-C on the quality of fresh-cut apples. *Postharvest Biol. Technol.* **2016**, *111*, 126–131. [CrossRef]
38. Jin, P.; Wang, S.Y.; Gao, H.; Chen, H.; Zheng, Y.; Wang, C.Y. Effect of cultural system and essential oil treatment on antioxidant capacity in raspberries. *Food Chem.* **2012**, *132*, 399–405. [CrossRef]
39. Wang, S.Y.; Chen, C.T.; Sciarappa, W.; Wang, C.Y.; Camp, M.J. Fruit quality, antioxidant capacity, and flavonoid content of organically and conventionally grown blueberries. *J. Agric. Food Chem.* **2008**, *56*, 5788–5794. [CrossRef]
40. Guerreiro, A.C.; Gago, C.M.L.; Faleiro, M.L.; Miguel, M.G.C.; Antunes, M.D.C. The effect of edible coatings on the nutritional quality of 'Bravo de Esmolfe' fresh-cut apple through shelf-life. *LWT-Food Sci. Technol.* **2017**, *75*, 210–219. [CrossRef]
41. Arnon-Rips, H.; Porat, R.; Poverenov, E. Enhancement of agricultural produce quality and storability using citral-based edible coatings; the valuable effect of nano-emulsification in a solid-state delivery on fresh-cut melons model. *Food Chem.* **2019**, *277*, 205–212. [CrossRef]
42. Cofelice, M.; Lopez, F.; Cuomo, F. Quality control of fresh-cut apples after coating application. *Foods* **2019**, *8*, 189. [CrossRef] [PubMed]
43. Solís-Contreras, G.A.; Rodríguez-Guillermo, M.C.; de la Luz Reyes-Vega, M.; Aguilar, C.N.; Rebolloso-Padilla, O.N.; Corona-Flores, J.; de Abril Alexandra Soriano-Melgar, L.; Ruelas-Chacon, X. Extending shelf-life and quality of minimally processed golden delicious apples with three bioactive coatings combined with cinnamon essential oil. *Foods* **2021**, *10*, 597. [CrossRef] [PubMed]
44. Rizzo, V.; Lombardo, S.; Pandino, G.; Barbagallo, R.N.; Mazzaglia, A.; Restuccia, C.; Mauromicale, G.; Muratore, G. Shelf-life study of ready-to-cook slices of globe artichoke 'Spinoso sardo': Effects of anti-browning solutions and edible coating enriched with Foeniculum vulgare essential oil. *J. Sci. Food Agric.* **2019**, *99*, 5219–5228. [CrossRef] [PubMed]
45. Gong, W.; Shi, B.; Zeng, F.K.; Dong, N.; Lei, Z.; Liu, J. Evaluation of cooking, nutritional, and quality characteristics of fresh-cut potato slice pretreated with acetic acid. *J. Food Sci.* **2022**, *87*, 427–437. [CrossRef]
46. Ali, S.; Anjum, M.A.; Nawaz, A.; Naz, S.; Hussain, S.; Ejaz, S.; Sardar, H. Effect of pre-storage ascorbic acid and Aloe vera gel coating application on enzymatic browning and quality of lotus root slices. *J. Food Biochem.* **2020**, *44*, e13136. [CrossRef]
47. Salvia-Trujillo, L.; Rojas-Graü, M.; Soliva-Fortuny, R.; Martín-Belloso, O. Use of antimicrobial nanoemulsions as edible coatings: Impact on safety and quality attributes of fresh-cut Fuji apples. *Postharvest Biol. Technol.* **2015**, *105*, 8–16. [CrossRef]
48. Bøjer Rasmussen, C.; Enghild, J.J.; Scavenius, C. Identification of polyphenol oxidases in potato tuber (*Solanum tuberosum*) and purification and characterization of the major polyphenol oxidases. *Food Chem.* **2021**, *365*, 130454. [CrossRef]

49. Sarengaowa; Wang, L.; Liu, Y.; Yang, C.; Feng, K.; Hu, W. Screening of Essential Oils and Effect of a chitosan-based edible coating containing cinnamon oil on the quality and microbial safety of fresh-cut potatoes. *Coatings* **2022**, *12*, 1492. [CrossRef]
50. Kraśniewska, K.; Kosakowska, O.; Pobiega, K.; Gniewosz, M. The influence of two-component mixtures from spanish origanum oil with spanish marjoram oil or coriander oil on antilisterial activity and sensory quality of a fresh cut vegetable mixture. *Foods* **2020**, *9*, 1740. [CrossRef]
51. Brasil, I.M.; Gomes, C.; Puerta-Gomez, A.; Castell-Perez, M.E.; Moreira, R.G. Polysaccharide-based multilayered anti-microbial edible coating enhances quality of fresh-cut papaya. *LWT-Food Sci. Technol.* **2012**, *47*, 39–45. [CrossRef]
52. Sánche ez-González, L.; Vargas, M.; González-Martínez, C.; Chiralt, A.; Cháfer, M. Use of essential oils in bioactive edible coatings: A review. *Food Eng. Rev.* **2011**, *3*, 1–16. [CrossRef]
53. Fagundes, C.; Moraes, K.; Pérez-Gago, M.B.; Palou, L.; Maraschin, M.; Monteiro, A.R. Effect of active modified atmosphere and cold storage on the postharvest quality of cherry tomatoes. *Postharvest Biol. Technol.* **2015**, *109*, 73–81. [CrossRef]
54. Chong, J.; Lai, S.; Yang, H. Chitosan combined with calcium chloride impacts fresh-cut honeydew melon by stabilising nanostructures of sodium-carbonate-soluble pectin. *Food Control* **2015**, *53*, 195–205. [CrossRef]
55. Tamminga, S.K.; Beumer, R.R.; Keijbets, M.J.H.; Kampelmacher, E.M. Microbial spoilage and development of food poisoning bacteria in peeled, completely or partly cooked vacuum-packed potatoes. *Arch. Lemensmittelhyg.* **1976**, *29*, 215–219.
56. Rashid, M.H.; Khan, M.R.; Roobab, U.; Rajoka, M.S.R.; Inam-ur-Raheem, M.; Anwar, R.; Ahmed, W.; Jahan, M.; Ijaz, M.R.A.; Asghar, M.M.; et al. Enhancing the shelf stability of fresh-cut potatoes via chemical and nonthermal treatments. *J. Food Process Pres.* **2021**, *45*, e15582. [CrossRef]
57. Hashemi, M.; Dastjerdi, A.M.; Shakerardekani, A.; Mirdehghan, S.H. Effect of alginate coating enriched with Shirazi thyme essential oil on quality of the fresh pistachio (*Pistacia vera* L.). *J. Food Sci. Technol.* **2021**, *58*, 34–43. [CrossRef]
58. Naeem, A.; Abbas, T.; Ali, T.M.; Hasnain, A. Effect of guar gum coatings containing essential oils on shelf life and nutritional quality of green-unripe mangoes during low temperature storage. *Int. J. Biol. Macromol.* **2018**, *113.*, 403–410. [CrossRef] [PubMed]
59. Inouye, S.; Takizawa, T.; Yamaguchi, H. Antibacterial activity of essential oils and their major constituents against respiratory tract pathogens by gaseous contact. *J. Antimicrol. Chemoth.* **2001**, *47*, 565–573. [CrossRef]
60. Vaclav, V.; Jana, V. Essential oils from thyme (*Thymus vulgaris*): Chemical composition and biological effects in mouse model. *J. Med. Food* **2016**, *19*, 1180–1187.
61. Burt, S. Essential oils: Their antibacterial properties and potential applications in foods-a review. *Int. J. Food Microb.* **2004**, *94*, 223–253. [CrossRef]
62. Feng, K.; Hu, W.Z.; Jiang, A.L.; Sarengaowa; Xu, Y.P.; Ji, Y.R.; Shao, W.J. Growth of *Salmonella* spp. and *Escherichia coli* O157:H7 on fresh-cut fruits stored at different temperatures. *Foodborne Pathog. Dis.* **2017**, *14*, 510–517. [CrossRef] [PubMed]
63. IFST. *Development and Use of Microbiological Criteria for Foods*; Institute of Food Science and Technology: London, UK, 1999; p. 76.