**Journal of Food Science and Technology (Iran)**

**Homepage:www.fsct.modares.ir**

**Scientific Research**

# Effect of *Aloe vera* gel enriched with sesame oil, honey and *Zataria multiflora* Boiss essential oil on browning reduction of ber fruit

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**ARTICLE INFO**

**Article History:**

Received:2023/10/7
Accepted: 2023/11/25

**Keywords:**

Browning,
Edible coating,
Fruit Quality,
Phenolic compound,
Storage

**DOI: 10.22034/FSCT.21.146.180**

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**ABSTRACT**

Ber fruit (*Zizyphus mauritiana* Lamk) contains abundant polyphenols and is highly susceptible to enzymatic browning after harvest. In order to reduce browning and maintain fruit quality of ber fruit, a factorial experiment was conducted in a completely randomized design with four replications. Experimental treatments included control, *Zataria multiflora* essential oil (ZEO) (0.5%), ZEO (1%), *Aloe vera* gel-based (20%) enriched with sesame oil 1%, honey 1% (ASH), ASH + ZEO (0.5%), ASH + ZEO (1%) and storage time (0, 7, 14, 21 and 28 days) at 6 ± 1°C and relative humidity of 90±5%. The results showed that edible coating application had significant effect on the quality characteristics of the ber fruit during storage. The combination of ASH with ZEO (0.5%), as an edible coating, significantly alleviated enzymatic browning by reducing PPO and POD activities on fruit during 28 days of storage. Fruits treated with ASH with ZEO (0.5%) reduced browning index (70%) compared to the control; while increased total phenol content and antioxidant activity (18.14%, and 31.16%, respectively) compared to the control after 28 days of storage. Also, ASH in combination with ZEO (0.5%) treatment decreased electrolyte leakage and malondialdehyde (19.7%, and 17.8%, respectively) compared to the control after 28 days of storage. These results indicated that ASH edible coating in combination with ZEO (0.5%) can be a useful method for delaying ripening and senescence, extending the storage life of ber fruit.



[ DOI: 10.22034/FSCT.21.146.180 ]

## 1. Introduction

Ber fruit (*Ziziphus mauritiana* Lamk.) is considered a tropical or semi-tropical fruit, mostly eaten fresh. It is a rich source of phenolic compounds, ascorbic acid, essential minerals, and carbohydrates [1]. A commercial problem in ber fruit marketing is the limitation of the product's supply period. If kept in storage, the fruit can become more economic in value and have more supply opportunity [2]. Ber fruit, like most tropical fruits, is sensitive to cold. Keeping it in storage at a temperature close to zero can cause chilling injury to the fruit, and higher temperatures encourage fungal infestation and rotting [1, 3]. Fruit browning is an irreversible and undesirable process in fruit ripening and aging, which is associated with a series of physiological and biochemical changes. In addition to changes in fruit color, it causes changes in taste, texture and nutritional value, and ultimately decreases fruit quality [4]. Enzymatic browning is generally caused by the oxidation of phenolic compounds, which is catalyzed by polyphenol oxidase (PPO) activity and ultimately forms brown pigments in the fruit [5]. Enzymatic browning of ber fruit is one of the main causes of fruit rot in postharvest, due to the high content of polyphenols in the fruit and its high sensitivity to browning [6]. Edible coatings reportedly reduced the browning index of guava fruit [7], reduced decay, chilling damage, malondialdehyde content, and electrolyte leakage while increasing phenolic content in orange fruits [8] and improving guava fruit quality [7].

*Aloe vera* gel is an edible covering layer for fruits and vegetables. It is not merely beneficial for human health but also lacks undesirable odor and taste. It is a suitable option for increasing the shelf life of fruits [9], with antimicrobial properties and preventive properties. *Aloe vera* gel reportedly prevented the transfer of moisture and gaseous exchange [10]. Using *Aloe vera* gel as an edible coating offers biological safety and increases shelf life, delays aging, prevents moisture loss, and controls the respiration rate in various products such as papaya [11], cherry [9], and apple [12].

Natural honey has anti-browning effects for containing antioxidant compounds such as phenolic components, flavonoids, ascorbic acid, and alpha-tocopherol [13]. In previous research, a combined edible coating of 2% cassava starch, 1% sunflower oil, 2% rice bran, and 1% beeswax preserved pectin content, fruit firmness, texture, and quality. The treatment also reduced fruit browning and increased guava storability compared to the control [14]. Beeswax edible coating in combination with guava leaf extract resulted in more quality characteristics of guava fruit compared to the control [15]. Sesame seed oil contains unsaturated fatty acids and numerous non-acyl-glycerol compounds such as tocopherols, phytosterols, sesamin and sesamol, which have antioxidant properties [16]. Sesame oil also has antimicrobial properties [17] and edible coatings obtained from sesame and moringa oil reportedly improved the sensory quality of orange fruits [18].

Plant essential oils that have antioxidant compounds and antimicrobial properties can increase microbial immunity, maintain cell integrity and fruit firmness. Thus, they maintain fruit quality characteristics during fruit storage [19]. Shirazi thyme (*Zataria multiflora* Boiss) is a medicinal plant native to the Iranian plateau. It is characterized by effective antimicrobial properties and antioxidant activity [20]. Carvacrol, thymol, and eugenol are the main components in Shirazi thyme essential oil, and they constitute the majority of its antioxidant potential [21]. Adding Shirazi thyme essential oil to chitosan and carboxymethyl cellulose edible coatings reportedly increased antioxidant activity and increased fruit polyphenols [22]. Using thyme essential oil in edible coatings reportedly increased their phenolic compounds and antioxidant capacity while reducing the occurrence of mold in fresh pistachios [23]. Gum arabic edible coating in combination with Shirazi thyme essential oil reduced polyphenol oxidase activity and increased total phenol content in fresh pistachios [24].

Ber fruit is an economically important fruit in many regions of the Middle East. There has been limited research on its maintenance and horticultural approaches that may increase its marketing potential. Since browning and limited postharvest storability are major problems in the marketability of this product, the present research aimed to control enzymatic





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browning and increase the storability of ber fruits. Using edible coatings of several natural substances, Shirazi thyme essential oil was added to the coating formula to optimize the efficiency of fruit quality maintenance during the storage period.

## 2- Materials and Methods

Ber fruits were harvested in mature green stage from a commercial orchard in Minab, Hormozgan province, 2022. They were immediately transferred to a postharvest physiology laboratory at Hormozgan University. First, healthy and uniform fruits were selected in terms of color and size. Then, the fruits were disinfected by 0.5% sodium hypochlorite for one minute, washed with distilled water, and air-dried.

### 2-1- Preparation of edible coating

First, mature leaves of *Aloe vera* plants from a commercial greenhouse were washed with water in the laboratory and then disinfected with sodium hypochlorite 0.5% for one minute. The *Aloe vera* gel was manually separated from the parenchyma tissue and homogenized in a blender for 5 minutes. The obtained mixture was filtered to remove fibers [8]. The resulting gel was diluted with distilled water at a ratio of 20: 80 (v/v). Then, we added natural honey 1% (v/v), sesame oil 1% (v/v), and 1.5% (v/v) glycerol as a plasticizer. The mixture was homogenized for 5 minutes. Finally, in the combined treatments, different concentrations of Shirazi thyme essential oil (0.5 and 1%) were added to the edible coating mixture [24]. The concentrations of *Aloe vera* gel, sesame, and honey were optimized after preliminary tests.

### 2-2- Treatment and measurement indicators

According to the type of treatment, the fruits were immersed in the edible coating for 2 minutes [25]. After drying at ambient temperature, 10 fruits for each experimental unit were stored in a cold room (6 ± 1 °C) at a relative humidity of 90 ± 5. The storage period lasted for 0, 7, 14, 21 and 28 days. Then, the quality indicators of the fruits were evaluated on a weekly basis.

### 2-3- Total phenol content

Total phenol content was measured by grinding 0.5 g of fruit flesh, followed by homogenization with 3 ml of methanol (85%) using a pestle and mortar. The samples were centrifuged at 10,000 rpm for 15 minutes. Then, 300 µl of the supernatant was mixed with 1500 µl of 10% Folin-Ciocalteu and after 3 minutes, 1200 µl of 7% sodium carbonate was added. The samples were kept in the dark for 30 minutes at room temperature. The absorbance value of each sample was read using a microplate reader (Epoch, Bio-Tek, USA) at a wavelength of 750 nm. The total phenol content was measured based on the standard absorption curve of gallic acid and was reported as mg of gallic acid per 100 grams of fresh weight [26].

### 2-4- Total antioxidants

To determine the antioxidant capacity, 0.5 g of fruit flesh was ground and homogenized with three ml of 85% methanol using a pestle and mortar. The samples were placed in a centrifuge at 10,000 rpm for 15 minutes. Then, 30 µl of the supernatant was mixed with 270 µl of 2,2-diphenyl-1-picrylhydrazyl (DPPH) (0.1 mM) and was placed in a dark room for 30 minutes. Then, the samples were read for absorbance values using a microplate reader at a wavelength of 517 nm. Total antioxidant activity was calculated using the equation (1) below [24].

Antioxidant activity (%) = (absorbance of control/absorbance of sample - 1) × 100 (1)

### 2-5- Electrolyte leakage (EL)

To measure the amount of electrolyte leakage, 0.1 g of fresh peel tissue was placed in 10 ml of distilled water. Then, the tubes were placed in a hot water bath (40 °C) for 30 minutes. After cooling, the initial electrolytic conductivity of the samples was measured using an EC meter (Weilheim, Germany). Again, the samples were placed in a hot water bath (100 °C) for 15 minutes and the secondary electrolytic conductivity was measured. The ion leakage percentage was calculated using equation (2) [27].

EL (%) = (secondary electrolytic conductivity / primary electrolytic conductivity) x 100 (2)

### 2-6- Malondialdehyde (MDA)



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Peroxidation of lipids was done by measuring the concentration of malondialdehyde [26]. For this purpose, 0.5 grams of fruit peel tissue was ground with liquid nitrogen in a mortar and one ml of phosphate buffer was added. The resulting extract was centrifuged for 15 minutes at 14,000 rpm (4 °C). After that, 500 µl of the supernatant solution was removed, and 500 µl of 20% trichloroacetic acid solution (0.5% tri butyric acid) was added. The resulting mixture was placed in a hot water bath (95 °C) for 30 minutes and cooled on ice immediately. Then, the samples were centrifuged again at 10000 rpm for five minutes. Finally, the absorbance of the samples was measured at 532 and 600 nm by a microplate reader. Malondialdehyde concentration was calculated as nM per gram of fresh weight according to equation (3).

MDA = [155 / (absorbance at wavelength 600 - absorbance at wavelength 532)] ×100 (3)

**2-7- Browning index**

Browning index was measured by the spread of the brown surface on the fruit. Browning index was described with four separate intensities, 1- no damage, 2- weak (more than zero and less than 25% damage), 3- moderate (25 to less than 50% damage), and 4- severe (more than 50% damage) [28]. The browning index was calculated with equation (4).

Browning index (%) = [Σ (browning degree × number of fruit in each degree)/ 4 × total number of fruit in each treatment] × 100. (4)

**2-8- Peroxidase activity (POD)**

To measure the peroxidase enzyme activity, 0.2 grams of fruit tissue was homogenized with 2 ml of 50 mM phosphate buffer (pH=7) on liquid nitrogen and homogenized (4 °C) for 15 minutes at 1000 rpm. Then, the supernatant solution was used as a crude enzyme extract to measure the activity of the tested enzymes. To measure peroxidase activity, 20 µl of enzyme extract was added at 25 °C to the reaction mixture, comprising 0.1 M guaiacol, 50 mM phosphate buffer, and 0.3% hydrogen peroxide. The absorbance value of tetragaiacol was read at 470 nm in the beginning of the reaction by adding the enzyme extract and repeatedly reading the absorbance after one minute. The extinction coefficient of tetragaiacol was 25.5 $nmol^{-1}cm^{-1}$. This volume of tetragaiacol was equivalent to the activity of one peroxidase enzyme unit [26].

**9-2- Polyphenol oxidase (PPO) enzyme activity**

To measure polyphenol oxidase enzyme activity, 100 µl of enzyme extract was mixed with 2.5 ml of 50 mM phosphate buffer (pH=7) and then 200 µl of 0.02 M pyrogallol was added as a precursor of the enzyme to start the reaction. After 3 minutes, the absorbance value of each sample was read at 420 nm [29].

**2-10- Experimental design and data analysis**

The experiments were conducted as a factorial in a completely randomized design with four replications and 10 fruits in each replicate. Data analysis was done using SAS software version 9.1. Figures were illustrated using Microsoft Excel.

**3- Results and Discussion**

Based on the results of data variance analysis, the simple effect of time and treatment in all traits was significant (P≤0.01). Also, the interaction effect of treatment with time was significant on several traits such as total phenol content, ion leakage, total antioxidants, polyphenol oxidase activity, and browning index (P≤0.01) (Table 1).

**Table 1. Analysis of variance of quality traits of ber fruits**

| | Source of variation (Mean of squares) | | | | |
|---|---|---|---|---|---|
| Attributes | Time (A) D.F=4 | Treatment (B) D.F=5 | AB D.F=20 | Error D.F=90 | C.V% |
| Total Phenol | 24732.01** | 11038.72** | 867.69** | 32.73 | 1.00 |
| Antioxidant activity | 1812.71** | 272.73** | 24.54** | 1.18 | 1.59 |
| Electrolyte leakage | 3917.56** | 254.36** | 27.15** | 2.11 | 2.88 |
| Malondialdehyde | 4.30** | 2.81** | $0.43^{ns}$ | 0.34 | 14.75 |
| Browning index | 307.24** | 53.29** | 12.17** | 0.14 | 12.99 |
| POD activity | 205.61** | 53.16** | $6.08^{ns}$ | 6.54 | 16.44 |



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| | | | | | |
|---|---|---|---|---|---|
| PPO activity | 0.0** | 0.0** | 0.0** | 0.0 | 20.52 |

ns, *, ** Not-significant, significant at 5% and 1% levels of probability, respectively.

### 3-1- Total phenol content

The total phenol content of ber fruit increased in the control treatment until the 7th day and in the other treatments until the 14th day, but decreased thereafter in most of the treatment groups. Among the experimental treatments, the lowest amount of total phenol was observed in the control treatment. In the majority of the storage periods, the highest increase in total phenol was observed in response to *Aloe vera* enriched with sesame oil, honey, and 0.5% Shirazi thyme EO. After 28 days of storage, the *Aloe vera* enriched with sesame oil, honey, and 0.5% Shirazi thyme EO increased the total phenol content by 18.2% in jujube fruits, compared to the control (Fig. 1).

A decrease in total fruit phenol during the storage period in untreated samples can be due to the rapid oxidation of phenolic compounds entering direct contact with oxygen. The enzymatic oxidation of phenolic compounds associate with polyphenol oxidase activity, causing the browning of fruit tissue. On the other hand, a higher amount of phenolic compounds in the treated samples resulted from a decrease in respiration rate in these treatments, thereby decelerating the decomposition of these compounds [26]. By reducing the permeability of gases (oxygen, carbon dioxide), edible coatings change the micro-atmosphere around fruits. By reducing the oxygen available to phenol-decomposing enzymes, such as polyphenol oxidase, they prevent the destruction of phenolic compounds [7]. Adding essential oil to the food coating, in addition to increasing the antioxidant and antimicrobial properties, can change the physical characteristics of the food coating. Adding essential oils to edible coatings can be likened to adding simple lipids (such as oleic acid), resulting in the formation of a complex polymer matrix and the optimization of bioactive coatings [24]. The antioxidant effects of essential oils added to edible coatings have been mentioned numerously in the available literature [7]. Essential oils act through unique antioxidant activity when spread on the surface of an edible product. Another mode of action includes an increase in the barrier capacity against oxygen diffusion due to its function as a radical oxygen scavenger [30]. Chitosan coating enriched with Shirazi thyme EO affected phenolic content in shiitake mushrooms and showed that phenolic compounds decreased in this product during the storage period. This edible coating preserved higher amounts of phenolic compounds [31]. Also, increasing the Shirazi thyme EO concentration in a zein protein film matrix increased the total phenol content [32].

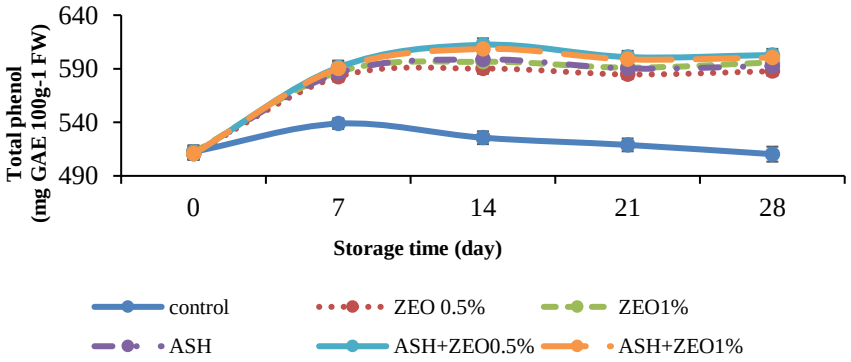


Figure 1. Effect of *Aloe vera* gel edible coating in combination with sesame oil and honey (ASH) and *Zataria multiflora* essential oil (ZEO) treatments and storage time on total phenol of ber fruit.

### 3-2- Total antioxidants

The interaction of treatments and storage time showed that total antioxidants in all treatments increased until the seventh day of storage and then decreased until the last day of storage. After 28 days of storage, the most significant decrease in total antioxidants occurred in the control treatment. The least amount of decrease occurred in response to *Aloe vera*. The lowest decrease in total antioxidants from day 0 to day





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28 occurred in response to *Aloe vera* coating. After 4 weeks of storage, *Aloe vera* gel enriched with sesame oil, honey, without Shirazi thyme EO and in combination with 0.5% Shirazi thyme EO increased the total antioxidants in fruits by 35.02% and 31.16%, respectively, compared to the control (Fig. 2). Several reports have shown that using *Aloe vera* edible coating on fruits, grapes [33], cherries, nectarines and peaches [34] maintained organoleptic properties in fruits, delayed their aging and ripening, and preserved the antioxidants in fruits. In another study, the highest antioxidant activity reportedly occurred in response to gum arabic edible coating enriched with 1% oleic acid and 1% cinnamon EO during storage [7]. Edible coating treatments preserved phenolic compounds and antioxidant capacity on the green surface of pistachio nuts, which possibly stimulated phenylalanine ammonia-lyase enzyme activity and caused phenolic compound production, thus increasing pistachio antioxidant capacity [35].

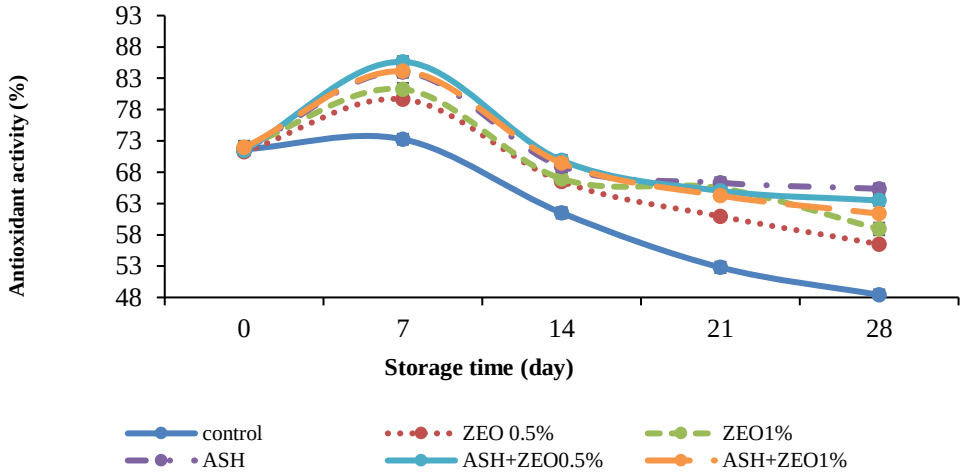


Figure 2. Effect of *Aloe vera* gel edible coating in combination with sesame oil and honey (ASH) and *Zataria multiflora* essential oil (ZEO) treatments and storage time on antioxidant activity of ber fruit.

### 3-3- Ion leakage

The interaction of time and treatment showed that the amount of ion leakage in all treatments increased gradually during the storage time. This increase was slow until the 14th day but faster thereafter. The highest amount of ion leakage occurred in the control and in response to 0.5% Shirazi thyme EO. The treatment containing aloe vera enriched with honey, sesame oil, and 1% Shirazi thyme EO had the lowest increase in ion leakage during the storage time. *Aloe vera* slowed down ion leakage in the fruits, so that after 28 days of storage, the edible coating enriched with honey, sesame oil, and 1% thyme EO decreased the ion leakage by 28.82% compared to the control (Fig. 3).

Membrane damage and electrolyte leakage are closely related and associated with membrane damage. Cold stress and freezing temperatures can generate large amounts of reactive oxygen species and lead to lipid oxidation, resulting in membrane damage [36]. In line with the results of this research, using chitosan and cinnamon EO on guava fruits caused a slower increase in ion leakage and led to a lower level of ion leakage at the end of storage [7]. Chitosan coating with thyme EO led to a lower ion leakage compared to untreated samples in shiitake mushrooms [31]. Chitosan coating enriched with cinnamon essential oil reduced membrane peroxidation and ion leakage in grapefruit [37]. The current research is comparable to previous studies on the effects of edible *Aloe vera* gel coatings on oranges [8] and chitosan coatings on bell peppers [38], which showed membrane damage over time in storage, although edible coating treatments decreased the level of damage compared to the control.



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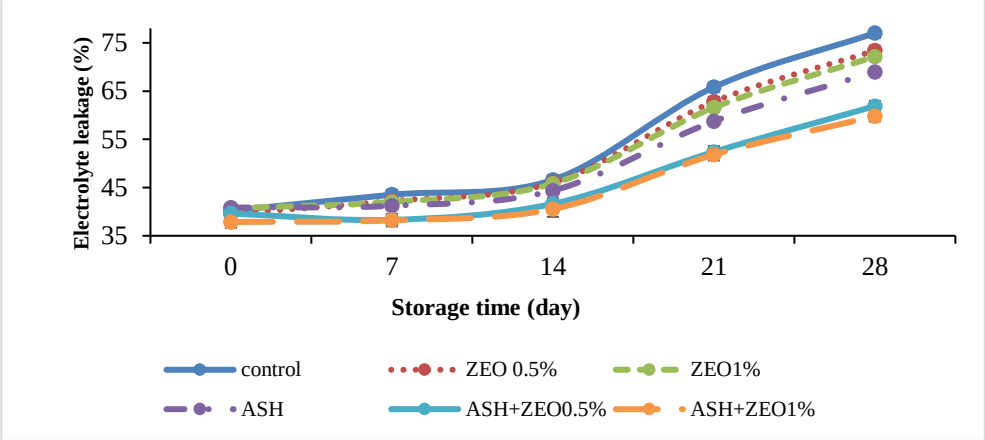


Figure 3. Effect of *Aloe vera* gel edible coating in combination with sesame oil and honey (ASH) and *Zataria multiflora* essential oil (ZEO) treatments and storage time on electrolyte leakage of ber fruit.

### 3-4- Malondialdehyde (MDA)

The simple effect of time on the malondialdehyde index was significant. Through storage time, the malondialdehyde content increased significantly. The lowest MDA content at the beginning of the experiment (3.4 nM/g of fresh weight) was significantly different from the highest amount at the end of storage (4.5 nM/g of fresh weight). However, no significant difference was observed between the 21st and 28th days of storage (Fig. 4). The comparison of the simple effects of treatments showed that the treatments, except for the enriched *Aloe vera*, significantly reduced the MDA content, and no significant statistical difference was observed between them. The highest amount occurred in the control (4.5 nM/g fresh weight) (Fig. 5).

MDA is an indicator of membrane integrity in response to oxidative stress during storage. The deoxygenation of unsaturated fatty acids causes the production of toxic hydroperoxy fatty acids, which cause membrane damage to the tissue [39]. While oxygen causes lipid peroxidation, food coatings maintain membrane integrity by becoming a barrier to oxygen. In line with the current results, cinnamon essential oil and chitosan in guava fruit caused a slower increase in malondialdehyde [7]. Also, the MDA content in guava fruits increased during the storage period while chitosan coating decreased its amount compared to the control [28], thereby confirming the findings of the current research.

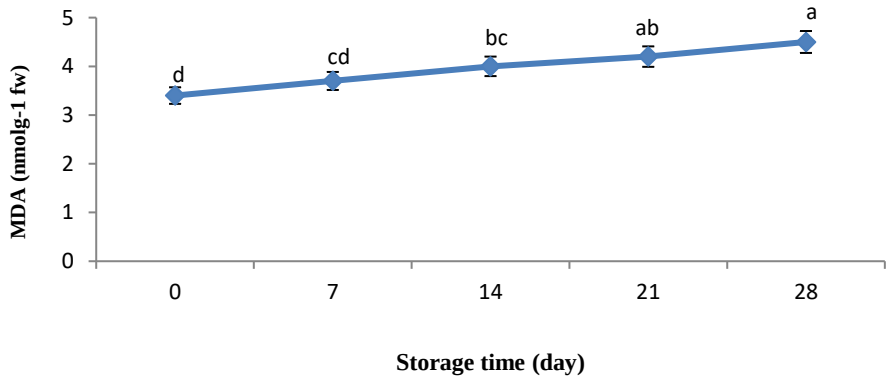


Figure 4. Effect of storage time on malondialdehyde of ber fruit. Similar small letters indicate non-significant difference at 1% level of probability using LSD test.



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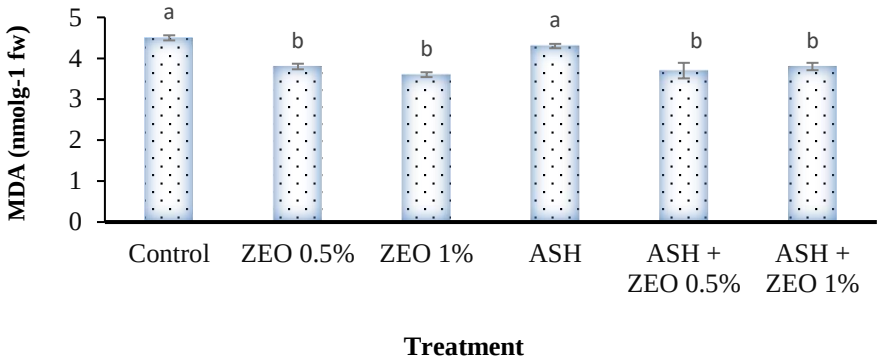


Figure 5. Effect of *Aloe vera* gel edible coating in combination with sesame oil and honey (ASH) and *Zataria multiflora* essential oil (ZEO) treatments on malonaldialdehyde of ber fruit. Similar small letters indicate non-significant difference at 1% level of probability using LSD test.

### 3-5- Browning index

The browning index of ber fruit gradually increased during the storage period. Fruit browning accelerated more in the control treatment. In most of the treatment groups, except for the combined edible coating treatments containing *Aloe vera* enriched with Shirazi thyme EO, fruit browning began from the seventh day of storage. In treatments containing *Aloe vera* enriched with honey, sesame oil and Shirazi thyme EO, fruit browning was delayed for a week and began on the fourteenth day of storage. After 4 weeks of storage, the lowest amount of browning index was observed in fruits coated with *Aloe vera* and honey, sesame oil, and 0.5% Shirazi thyme EO. The highest rate of fruit browning occurred in the control treatment (Fig. 6).

According to the results of this research, the browning index was reduced by applying *Aloe vera* gel and orange peel EO on edible mushrooms [40]. The presence of oxygen affected the oxidation of phenols, the growth of microorganisms, the activity of enzymes related to browning and the reduction of vitamin C in food products [41]. A decrease in shelf life resulted from the oxidation of proteins, lipids, and pigments that caused unpleasant odors, fruit discoloration, and nutrient loss [42]. Films made of protein and carbohydrates are excellent barriers to oxygen transfer due to the compactness and network structure of hydrogen bonds [43]. Films and coatings that contain antioxidant agents reduce the activity of polyphenol oxidase enzymes and reduce the presence of oxygen in fruits. In other words, they reduce phenolic oxidation and limit the conversion of phenolic compounds to brown pigments [7]. Films combined with essential oils appear to be more efficient barriers to gaseous exchange, but there is scanty information in this regard.

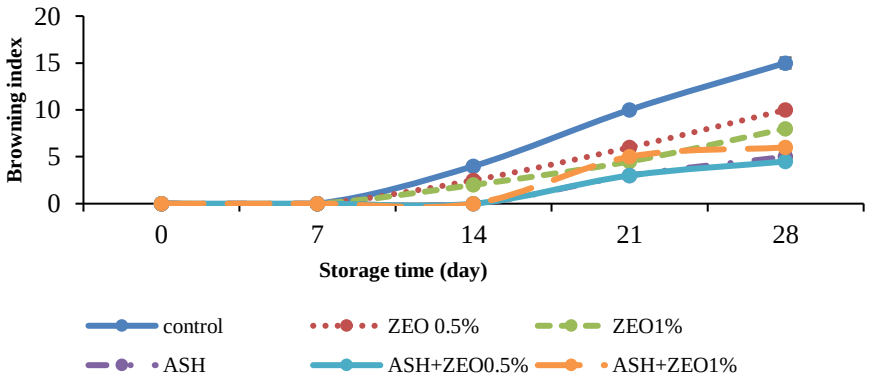


Figure 6. Effect of *Aloe vera* gel edible coating in combination with sesame oil and honey (ASH) and *Zataria multiflora* essential oil (ZEO) treatments and storage time on browning index of ber fruit.

### 3-6- Peroxidase (POD)





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POD activity in fruits increased during the storage time. It was 11.1 units per gram of fresh weight per minute at the beginning of the experiment and reached 18.6 units per gram of fresh weight per minute at the end of storage (Fig. 7). The comparison of mean values on the simple effect of treatments showed a significant difference between the combined edible coating treatment and the control. In the *Aloe vera* treatment enriched with honey, sesame oil, and Shirazi thyme EO (0.5 and 1%) the POD activity reached 14 and 14.1 units per gram of fresh weight per minute, i.e., the lowest peroxidase activity, which had no significant difference compared to each other. However, both treatment groups were significantly different from the control group. In the control treatment, the highest POD activity (18.4) occurred (Fig. 8).

During fruit ripening and aging, enzyme activity usually leads to changes in color, taste, and firmness of fruit texture. Enzymatic browning in fruits and vegetables is often caused by the activity of two polyphenol oxidase and peroxidase enzymes, which, in addition to browning and changing the color of the product, reduce the taste and quality of the fruit. Considering the role of oxygen in the activity of these two enzymes, antioxidant compounds can inhibit the activity of these enzymes [26]. The results of similar research on grapes showed that *Aloe vera* gel reduced the POD activity in the presence of oxygen [44]. By combining with ambient oxygen, essential oils prevent the enzymatic browning reaction and control the POD activity [45], thus confirming the findings of this research. Increasing the EO concentration significantly increased the POD activity in 'Golden Delicious' apples while the opposite occurred when using clove EO. Increasing the clove EO concentration had a higher inhibitory effect on POD activity [46].

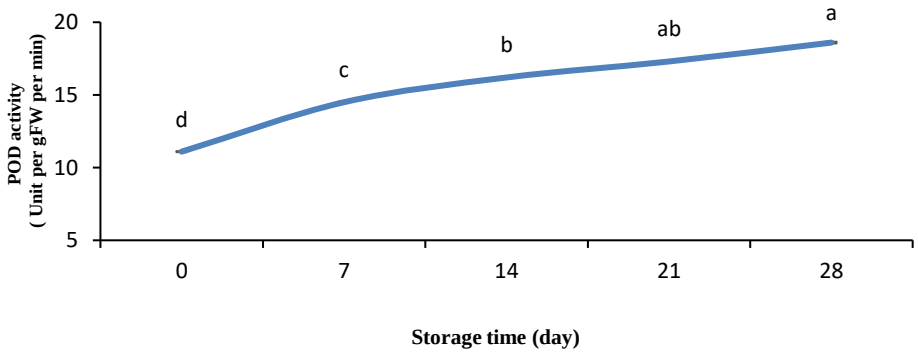


Figure 7. Comparison of the effect of storage time on POD activity of ber fruit

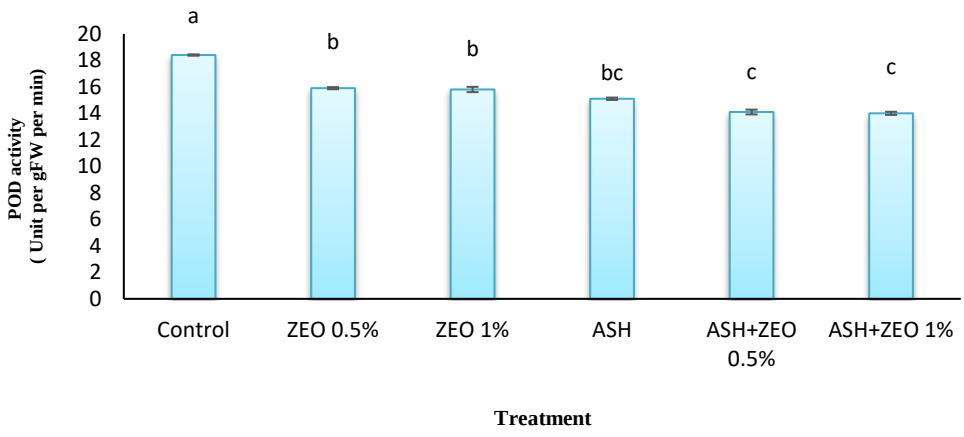


Figure 8. Effect of *Aloe vera* gel edible coating in combination with sesame oil and honey (ASH) and *Zataria multiflora* essential oil (ZEO) treatments and storage time on POD activity of ber fruit.

**3-7- Polyphenol oxidase (PPO)**





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The PPO activity in ber fruits increased gradually through the storage period. PPO activity increased more in the control treatment. After 28 days of storage, the lowest PPO activity was observed in fruits coated with *Aloe vera*, honey, sesame oil, and Shirazi thyme EO 1% (Fig. 9).

A series of enzymes called polyphenol oxidases cause fruit browning. These enzymes can oxidize phenolic compounds to orthoquinones [47]. Quinone compounds create colored compounds under the influence of secondary reactions in the vicinity of each other or with other substances such as proteins, causing plant tissue browning [48]. These enzymes are found in almost all plant tissues. The precursor of polyphenol oxidase is phenolic compounds found in plant tissues and mainly flavonoids [49]. Enzymatic browning can be reduced by low amounts of oxygen. Therefore, methods that reduce the amount of available oxygen can reduce PPO activity, thus reducing fruit tissue browning. In this regard, using cinnamon EO on guava fruit [7] and cinnamaldehyde and thyme on edible mushrooms [50] decreased PPO activity. In the present study, the edible coating acted as a barrier to gaseous exchange, especially oxygen, and reduced PPO activity. It reduced the oxidation of phenolic compounds and ultimately limited jujube fruit browning. Its effects may also be due to the antifungal and antioxidant properties of Shirazi thyme EO that reduced the occurrence of brown pigments on the fruit surface.

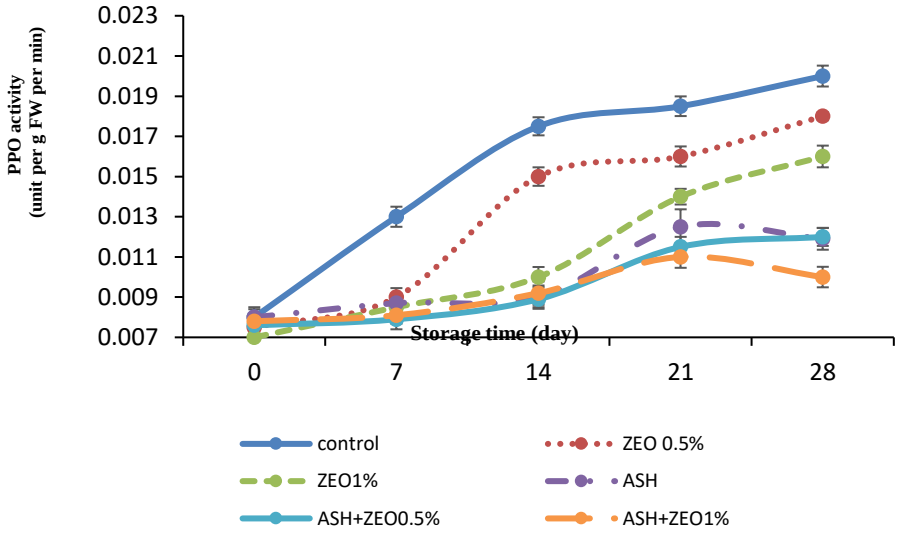


Figure 9. Effect of *Aloe vera* gel edible coating in combination with sesame oil and honey (ASH) and *Zataria multiflora* essential oil



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(ZEO) treatments and storage time on the PPO of ber fruit.

## 4 - Conclusion

This research revealed that *Aloe vera* gel, honey, sesame oil, and Shirazi thyme EO reduced enzymatic browning and preserved quality characteristics in ber fruits during 28 days of storage. Bioactive compounds, including total phenol content, were preserved better when using enriched *Aloe vera* compared to the control, which increased the antioxidant capacity of the whole fruit. A decrease occurred in ion leakage, malondialdehyde, polyphenol oxidase and peroxidase enzyme activity in fruits treated with Shirazi thyme EO. These effects were observed when using the thyme EO either alone or in combination with *Aloe vera*, compared to the control, thus decreasing the browning index. The combination of these treatments maintained fruit quality in storage. The combined coating of *Aloe vera* gel, honey, sesame oil, and 0.5% Shirazi thyme EO maintained jujube fruit quality in storage.

## 5- Acknowledgements

The authors would like to thank the Hormozgan Science and Technology Park and University of Hormozgan for their support.

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[ DOI: 10.22034/FSCT.21.146.180 ]

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# اثر ژل آلوئه ورا غنی‌شده با روغن کنجد، عسل و اسانس آویشن شیرازی بر کاهش قهوه‌ای شدن میوه کنارهندی

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**اطلاعات مقاله**

**تاریخ های مقاله :**

**تاریخ دریافت: ۱٤۰۲/۷/۱۵**

**تاریخ پذیرش: ۱٤۰۲/۹/٤**

**کلمات کلیدی:**

انبارمانی،

پوشش خوراکی،

کیفیت میوه،

قهوه‌ای شدن،

ترکیبات فنلی.

**DOI: 10.22034/FSCT.21.146.180**

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**چکیده**

میوه کنارهندی (*Ziziphus mauritiana* Lamk) حاوی ترکیبات فنلی فراوان است و پس از برداشت به قهوه‌ای شدن آنزیمی بسیار حساس است. به‌منظور کاهش قهوه‌ای شدن و حفظ کیفیت میوه کنارهندی آزمایشی به‌صورت فاکتوریل در قالب طرح کاملا تصادفی و با چهار تکرار انجام شد. تیمارهای آزمایش شامل: شاهد (آب مقطر)، اسانس آویشن شیرازی نیم درصد، اسانس آویشن شیرازی یک درصد، ژل آلوئه ورا (۲۰٪) غنی‌شده با روغن کنجد (۱٪) و عسل (۱٪)، ژل آلوئه ورا (۲۰٪) غنی‌شده با روغن کنجد (۱٪)، عسل (۱٪) + اسانس آویشن شیرازی نیم درصد، ژل آلوئه ورا (۲۰٪) غنی‌شده با روغن کنجد (۱٪)، عسل (۱٪) + اسانس آویشن شیرازی یک درصد و زمان نگه‌داری ( صفر، ۷، ۱٤، ۲۱ و ۲۸ روز) در دمای ۱ ± ٦ درجه سلسیوس و رطوبت نسبی ۵ ±۹۰ درصد بودند. نتایج نشان داد که کاربرد پوشش خوراکی اثر معنی‌داری بر ویژگی‌های کیفی میوه کنارهندی در زمان انبارمانی داشت. ترکیب ژل آلوئه ورا با روغن کنجد، عسل و اسانس آویشن شیرازی، به‌عنوان یک پوشش خوراکی، طی ۲۸ روز نگه‌داری، با کاهش فعالیت پلی‌فنل اکسیداز و پراکسیداز، به‌طور قابل توجهی قهوه‌ای شدن آنزیمی را در میوه کاهش دادند. پس از ۲۸ روز انبارمانی، میوه‌های تیمار شده با پوشش خوراکی و اسانس ۰/۵ درصد نسبت به شاهد، شاخص قهوه‌ای شدن (۷۰٪) را کاهش دادند، اما نسبت به شاهد، محتوای فنل کل و فعالیت آنتی‌اکسیدانی (به‌ترتیب ۱۸/۱٤ و ۳۱/۱٦ درصد) را افزایش دادند. همچنین استفاده از اسانس آویشن شیرازی ۰/۵ درصد در پوشش خوراکی موجب کاهش نشت الکترولیت و پراکسیداسیون لیپید (به‌ترتیب ۱۹/۷ و ۱۷/۸ درصد) در مقایسه با شاهد پس از ۲۸ روز نگه‌داری شد. این نتایج نشان داد که تیمار پوشش خوراکی و اسانس آویشن شیرازی ۰/۵ درصد می‌تواند یک روش مفید برای به‌تاخیر انداختن فرآیند رسیدن و پیری، افزایش انبارمانی و حفظ کیفیت میوه کنارهندی باشد.



[ DOI: 10.22034/FSCT.21.146.180 ]