Article

Improving the Shelf Life of Peeled Fresh Almond Kernels by Edible Coating with Mastic Gum

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Abstract: Coating, as a process in which fruits, vegetables, kernels, and nuts are covered with an edible layer, is an environmentally friendly alternative to plastic wrapping, which has been considered the most effective way to preserve them over the long term. On the other hand, prolonging the shelf life results in a reduction of spoilage and therefore achieving a goal that is very important nowadays—the reduction of food waste. The quality of preserved almonds kernels depends on factors such as grain moisture, storage temperature, relative humidity, oxygen level, packaging, and the shape of the stored nuts (along with being peeled, unpeeled, roasted, etc.). The commercial importance of the almond fruit is related to its kernel. Almonds that are peeled (without the thin brown skin) and stored have a shorter shelf life than unpeeled almonds since the reddish-brown skin, rich in antioxidants, may protect the kernels against oxidation. In this study, a bioactive edible coating has been tested, which may provide an effective barrier against oxygen permeation and moisture, thus preserving the quality of peeled fresh almonds by extending their shelf life. Mastic gum, as a natural coating agent, was used to coat the peeled fresh almond kernels in four different concentrations (0.5%, 1.0%, 1.5%, and 2.0% *w/v*). The effect of mastic gum coating on the quality parameters of the peeled fresh almonds (moisture uptake, oil oxidation, total yeast and mold growth, and *Aspergillus* species development) was studied during four months of storage. The results showed that mastic gum, as a coating agent, significantly ($p < 0.05$) reduced moisture absorption, peroxide and thiobarbituric acid indices, total yeast and mold growth, and *Aspergillus* species development in the peeled and coated fresh almonds, compared to the control, i.e., uncoated fresh almonds, during 4 months of storage, packed at room temperature (25–27 °C) inside a cabinet at 90% humidity. Therefore, mastic gum can be used as a great natural preservative coating candidate with antioxidant and antimicrobial effects.

Keywords: almond; mastic gum; natural edible coating; preservation; shelf life

1. Introduction

Currently, researchers are testing innovative protective layers that are supposed to keep the fruit, vegetables, and kernels fresher longer. The layers, also called edible coating, are colorless, odorless, tasteless, and harmless to health, and they can even be consumed without hesitation since they consist of natural or microbiological sources. The edible coating can reduce packaging waste, food waste, and greenhouse gases. It is sprayed or spread on fruit, vegetables, and kernels and creates a barrier that controls how much water

and carbon dioxide leak from the fruit, vegetables, and kernels, and how much oxygen enters from the outside [1–3].

Many foods processing have still a long way to go in terms of food safety, and almonds are no exception. Europe as a continent is far away from becoming a major region of food production. Almost every day, manufacturers recall foods because they contain contaminants. Even dry goods, which are considered safe due to their lack of water, are also regularly withdrawn from the market. This is because harmful microorganisms can settle on these foods during processing. According to the consumer protection center in Germany, as an example, the number of food recalls with almonds rapidly grew between 2015 and 2019. If the affected products endanger health, the manufacturer must take them off the market and inform the consumer [4,5].

Almond, with the scientific name of *Prunus amygdalus*, is one of the dark rose plants belonging to dicotyledons. Almond is a tree native to West Asia, the southern shore of the Mediterranean Sea, and one of the oldest dried fruit trees. The plant grows well in hot and dry climates; the main area of almond production in the world is the central plains of California, and the second-largest area of almond production includes European countries along the Mediterranean. The United States leads the global almond production with an approximate 80% share, followed by Asia, and Tunisia. Iran is one of the producers of almonds in Asia, due to its favorable climatic conditions for growing almonds. Almond kernels represent the commercial importance of almond fruit [6].

Almonds are used by many manufacturers around the world for a wide variety of products. Due to the desirable sensory properties, almond kernels are used as an ingredient in the preparation of many food products such as beverages, ice cream, chocolate, sweets, and breakfast cereals [6–9].

To ensure the best possible quality, various steps are necessary in order to select the right processing and storage methods. Research has been carried out extensively to understand the effect of moisture on the quality and shelf life of almonds. This paves the way for developing tools and resources to maximize almonds' quality, from cultivation to storage and distribution [9–11]. Increased temperatures and humidity can lead to a significant loss of quality and reduced almond shelf life, besides accelerating the concealed damage. The concealed damage, a light-to-dark-brown discoloration in the almond kernel's interior, is called a "hidden defect," which is specific to almond kernels, resulting in a very bitter off-taste. Therefore, almonds should ideally be protected during storage [12,13].

Almond kernels are appreciated as high-calorie and rich foods. The core of fresh almonds (400–600 kcal/100 g) is rich in fat, total lipids (35–66% f.w. (fresh weight)), total protein (considering a conversion N factor of 5.18; 14–61% f.w.), fiber (11–14% f.w.), vitamins (E (antioxidant), B2, B9, B3, and B1), macronutrients (P, K, Ca, and Mg), micronutrients (Fe, Cu, Mn, and Zn), and carbohydrates (4–28% f.w.), of which soluble sugars comprise 2.5–12%. At the same time, they provide health-promoting bioactive phytochemical compounds (phytosterols, tocopherols, squalene, stanols, sphingolipids, phospholipids, chlorophylls, carotenoids, phenols, and volatile compounds). The proportion of these compounds changes according to the cultivars, the cultivation system, and the geographical origin [6,14–19].

Almonds contain 55–70% oil, with beneficial health effects but very sensitive to oxidation [20–22]. The almond oil is rich in monounsaturated fatty acids (MUFA, 60%) and polyunsaturated fatty acids (PUFA, 30%) [23–26].

Even by-products derived from the grinding of the pressing cake of almond oil extraction are of importance because they generate partially defatted flour. These flours have been reported to have promising uses in the culinary industry to enhance the nutritional properties of various products; such products aim to replace traditional meat-based products [27].

The oxidative process leads to unpleasant odors and tastes in almonds, and concealed damage. All these shorten their shelf life at ambient conditions and during storage; therefore, the resulting products lack the necessary quality for human nutrition [28,29].

Moreover, almonds that are peeled (skinless, without the thin brown skin) and stored have a shorter shelf life than unpeeled almonds since the reddish-brown skin, rich in antioxidants, may have a protective role against oxidation, but many food recipes call for skinless almonds [25,30]. Packaging and storing conditions are very important factors to prevent oxidation and maintain optimum flavor, avoiding, at the same time, concealed damage.

In order to extend the shelf life of nuts, including almonds, and retard lipid oxidation, research has been carried out extensively to study the use of bio-based edible coatings. The edible coating may provide an effective barrier against oxygen permeation and moisture, thus preserving the quality of nuts by extending their shelf life [31–34].

Due to the increasing demand for sources of bioactive biodegradable/edible films and coatings, there is a need to explore the novel and underutilized sources of raw materials with functional properties for preservation and shelf-life extension of foods [35]. Therefore, natural tree resins, excreted by trees or bushes when injured, and natural tree gums, may be promising alternatives for coating, as substitutes for materials from nonrenewable sources [36].

Mastic gum, a plant resin, is obtained from a special type of pistachio, a variety of *Pistacia lentiscus* (family: Anacardiaceae). The viscous resin emerges in tear shaped droplets from the bark of the mastic bush and therefore also called “tears”.

Several studies on the biological properties of mastic gum have shown positive therapeutic effects in anticancer activity, improving the immune system, cardiovascular disease, inhibiting free radicals, inhibiting lipid peroxidation, and stimulating the activity of antioxidant enzymes. Ancient doctors recommended this sap to treat periodontal disease or pimples. The sap was also used for digestive problems, such as stomach pain, heartburn, and stomach ulcers, as well as for wound treatment or rheumatic complaints. It has been shown that mastic acts throughout the gastrointestinal system or that it lowers cholesterol, blood sugar, and blood pressure. New studies confirm its antibacterial effectiveness: germs that are responsible for the formation of caries and periodontitis can be successfully reduced with mastic. There are also studies on the effects on oral hygiene, for example, in the case of tooth decay, xerostomia (dry mouth or oral dryness), or gingivitis, and on the skin [37–41].

Due to the numerous positively proven bioactive properties, mastic gum received increasing attention, and the demand for it has increased in recent years. Moreover, in different areas such as food supplements, general cosmetic products, toothpaste or mouthwash products, industrial uses, animal nutrition, and for natural flavors in food, confectionery, and beverages, there is a need for bio-based materials, such as natural materials, as substitutes for materials from nonrenewable sources replacing traditional petroleum polymers in several industrial sectors, which provide additional properties, such as antimicrobial, antioxidant, anti-inflammatory effects. Almond kernels during storage are highly exposed to fungi contamination, resulting in the production of toxins (metabolites produced by *Aspergillus* species) and increased mold and yeast counts. However, most of the cases, contaminated almonds leave no visually visible wounds or discoloration, posing a risk to public health can lead in the seemingly defect-free final product [42].

A low temperature (around 4 °C), as an ideal storage parameter, seems to reduce aflatoxin levels and mold and yeast count for 3–6 months [43].

The aim of this study was to investigate the effect of bioactive edible coating of mastic gum on fresh almond kernels (variety Carmel cultivar from Artin Azma, Lorestan Province, Iran), and to evaluate the quality parameters (moisture uptake, oil oxidation, total yeast, and mold growth, and *Aspergillus* species development) during 4 months of the storage period, packed at room temperature (25–27 °C) inside a cabinet and at 90% humidity.

2. Materials and Methods

2.1. Materials

To conduct the present research, mastic gum (*Pistacia lentiscus*) was purchased from the medicinal plants' store city (Artin Azma, Lorestan Province, Iran), and the fresh almond

from cultivar Carmel was purchased from Lorestan Province, Iran. All chemicals needed and plate count agar (PCA) medium were purchased from Merck (Hamburg, Germany).

2.2. Methods

2.2.1. Edible Coating Preparation

In order to prepare mastic gum solutions with concentrations of 0.5%, 1%, 1.5%, and 2% (*w/v*), respectively, 5, 10, 15, and 20 g of mastic gum powder were added to one liter of distilled water, slowly and in several steps. The solution was then stirred with a glass stirrer. The solution was filtered afterward with Whatman grade 3 qualitative filter paper Ø 185 mm.

2.2.2. Covering, Packing, and Storage Study of Fresh Almond Kernels

First, after raw almonds were dehulled (separating the green skins), the whole fresh almond seeds were dried using a cabinet dryer (Artin Azma, Yavari st, Madani Ave, Resalat.Ave Tehran, Iran) at 43 °C until a moisture content of 5% (AOAC, 2005) was achieved [44]. Then, the almonds were crushed manually, to remove the shell, and peeled (skinless, without the thin brown skin), and healthy kernels were selected. The hull, shell, and skin are considered almond by-products [45]. The peeled fresh almond kernels were then weighed and placed in lattice containers.

Afterward, they were immersed in containers with the corresponding coating solution for 30 s and removed. After coating, to remove excess moisture, the almonds were left for the excess solution to drop off, and to dry off the excess moisture, they were dried in an oven at 40 °C for 4 h until they reached an average humidity of 2.5% [46,47].

Five treatments were prepared using fresh almonds skinless: uncoated fresh almonds (control sample), and coated fresh almonds with mastic gum in different concentrations, 0.5%, 1%, 1.5%, and 2% (*w/v*), respectively.

Almonds were completely randomly divided into 50 g units using a digital scale (A&D Co, LTD, Lorestan, Japan) with an accuracy of 0/001 and packed in commercial plastic bags with dimensions of 6 cm × 20 cm. Packed almonds were stored for 4 months at room temperature (25–27 °C) inside a cabinet and at 90% humidity.

The percentage of moisture was calculated according to the following equation:

$$\% \text{ moisture} = (m_w / m_{\text{sample}}) \times 100, \quad (1)$$

where,

m_w = mass of the water;

m_{sample} = mass of the sample.

2.2.3. Chemical Analysis

Chemical Decomposition of Almond Kernels

Measurements of moisture, ash, fat, fiber, protein, and carbohydrates of fresh almond kernels were performed using AOAC (2007) standard methods at 926-12, 923-03, 992-23, and 948-22, respectively [43]. The percentage of carbohydrates was determined according to AOAC (2007) [48]. The percentage of fiber was calculated according to the AACC standard (2000) number 1–33 (AACC, 2000) [49]. Total moisture, ash, fat, fiber, protein, and carbohydrates were subtracted from 100 g fresh almonds.

Assessment of Oxidation

Measurement of Peroxide Index (PI)

Almond kernel oil was extracted under room temperature (25–27 °C) condition in a dark place using normal hexane solvent [50], and peroxide index, as an indicator of primary oxidation product, was measured by an iodometric method in accordance with the standard of the American Oil Chemists' Society (AOCS, 2003) [51].

Measurement of Thiobarbituric Acid Index (TBA)

Thiobarbituric acid index, as an indicator of secondary oxidative aldehyde products, was measured according to the American Oil Chemists' Society (AOCS, 2004) [51–53].

2.2.4. Total Yeast and Mold Counts (TYMC)

To perform the total yeast and mold counts, 10 g of each uncoated and coated almonds were pounded with a sterile mortar under the flame and the microbial hood (Karen Pouya Noavar, Tehran, North Kargar St Boulevard Saman, Tower Iran). Almonds powder, along with 90 mL of 0.9% sterilized sodium chloride solution, was transferred to a stomacher bag and mixed thoroughly in the stomacher device (Stomacher Bag Mixer 400 SW Interscience, Artin Azma, Iran). Dilutions 10^{-2} and 10^{-3} were obtained from dilutions of 10^{-1} . A total of 0.1 mL of each dilution was added to the PCA solid culture medium using a sampler and completely spread on the culture medium using a special glass rod (Arian Company, Artin Azma, Iran).

After a few minutes, the plates were heated upside down at 20 to 25 °C. After 5 days, the number of grown mold and yeast were counted and reported in cfu/gr unit.

2.2.5. Antifungal Characteristic of Mastic Gum against the Growth of *Aspergillus* Species

For this purpose, 10 g of almond kernels from each of the coated and uncoated samples were placed in large glass plates containing wet filter paper and all of which were sterilized and then incubated at 25 °C. After 5 days, the number of plates infected with fungi was counted, and the rate of fungi development was determined based on the percentage in each sample (coated almond kernels), compared to the control sample (uncoated almond kernels).

If necessary, the fungi grown on almond kernels were cultured on a culture slide, and the growth of *Aspergillus* species was ensured under an electronic microscope.

All measurements were measured at intervals of 1 month to 4 months in three replications.

2.3. Statistical Analysis

The experiments were performed in three replications in a completely randomized design, and the obtained data were statistically analyzed. After analysis of variance, the means were compared using Duncan's multiple range test at the level of 0.05 by SAS (Statistical Analysis System) software (version 9.2). Word Excel 2013 software was used to draw the graphs.

3. Results

3.1. Fresh Skinless Almond Kernels' Nutritional Chemical Composition

The nutritional composition of fresh almond kernels used in the current study, before the coating, is shown in Table 1. Almond kernels composition is of great interest from the nutritional points of view and therefore very important for commercial and industrial applications. It seems that the almond kernels used in this study present compounds in concentrations reported already with high nutritional value [14–19].

Table 1. Nutritional content of uncoated fresh almond kernels.

Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Fiber (%)	Carbohydrate (%)
5.13 ± 0.25	16.13 ± 0.65	62.01 ± 0.06	3.13 ± 0.11	4.06 ± 0.14	13.6 ± 0.11

According to Table 1, the fresh almond kernels are very fatty, with- 62.0% ± 01.06% of fat, and if their storage conditions are unsuitable, this aspect makes them susceptible to lipid oxidation, rancidity development, and concealed damage. This may influence shelf life, resulting in a very bitter off-flavor and a low acceptance rate among consumers [9–11,22–30].

3.2. The Effect of Coating with Mastic Gum

3.2.1. On Moisture Content

Humidity is one of the important factors in maintaining the quality of kernels. The rate of moisture transfer between food and the surrounding atmosphere is reduced by completely covering the food with film or by coating [54].

Figure 1 shows the changes in the moisture content (%) of fresh almond kernels uncoated and coated with different mastic gum concentrations over a 4-month storage period conditions. As can be observed, although the average amount of moisture absorption in all samples during the storage period is associated with an increasing trend, the coating with mastic gum significantly reduced moisture absorption, compared to uncoated samples, during the storage period.

Figure 1. Changes in the moisture content (%) of uncoated (control) and coated almond kernels during 4 months of storage. Different lowercase letters indicate a statistically significant differences ($p < 0.05$) between the samples during each month; share a lowercase letter are not statistically different, while different letters denote for statistical differences at least 95% confidence.

3.2.2. On Peroxide Index

Peroxide index (PI) is the most common sign of oxidative spoilage in kernels [55]. Oxidation of lipids in food is one of the most important factors in food degradation during processing, storage, and distribution and leads to adverse effects on aroma, color, nutritional value, and the production of toxic compounds [56].

The presence of unsaturated fatty acids makes almond oil susceptible to oxidation, as previously mentioned. The effect of coating with mastic gum in different concentrations on the trend of changes in almond kernel peroxide index during four months of storage period and conditions, based on mill equivalents of oxygen per kg of almond oil, is presented in Table 2. The results show that the trend of changes in the peroxide index of all samples increased significantly during the storage period. The PI of fresh almond kernel uncoated (control) was 0.24 mill equivalents of oxygen per kilogram, and after 4 months under storage conditions, PI reached 1.12 mill equivalents of oxygen per kilogram of oil.

Table 2. Changes in the peroxide value of uncoated (control) and coated almonds during 4 months of storage in mill equivalents of oxygen per kilogram of oil.

Sample	Time (Months)				
	0	1	2	3	4
Control	0.24 ± 0.001 Ea	0.41 ± 0.001 Da	0.57 ± 0.003 Ca	0.88 ± 0.002 Ba	1.12 ± 0.011 Aa
Coating with 0.5% (<i>w/v</i>)	0.24 ± 0.001 Ea	0.36 ± 0.002 Dab	0.48 ± 0.002 Cb	0.78 ± 0.001 Bb	1.07 ± 0.001 Ab
Coating with 1% (<i>w/v</i>)	0.24 ± 0.001 Ea	0.33 ± 0.001 Db	0.41 ± 0.001 Cc	0.66 ± 0.002 Bc	0.96 ± 0.002 Ac
Coating with 1.5% (<i>w/v</i>)	0.24 ± 0.001 Ea	0.27 ± 0.001 Dc	0.37 ± 0.001 Cd	0.56 ± 0.01 Bd	0.86 ± 0.013 Ad
Coating with 2% (<i>w/v</i>)	0.24 ± 0.001 Da	0.27 ± 0.002 Dc	0.35 ± 0.001 Cd	0.53 ± 0.001 Bd	0.82 ± 0.011 Ad

Different capital letters in each row indicate a statistically significant difference in each sample during different months at the level of 5%; Different lowercase letters in each column indicate a statistically significant difference between the samples during each month at the level of 5%.

The highest and lowest PI values, after 4 months of storage, were related to the control sample (uncoated almonds) and the sample of almonds coated with 2% (*w/v*) mastic gum, respectively. The PI values of the almond samples coated with 1.5% and 2% (*w/v*) of mastic gum were not significantly different, as can be seen; concluding that coating with 1.5% mastic gum offers good almonds protection as well.

3.2.3. On Thiobarbituric Acid Index (TBA)

Measurement of TBA index is a method for detecting by-products of fat oxidation in fatty food products [57]. By-products change the taste of the product, cause food spoilage, and have adverse effects on the nutritional value of the product, which makes it difficult to use kernels in other products [58]. The changes in the value of the TBA index in the tested uncoated and coated almonds samples are shown in Table 3.

Table 3. Changes in the peroxide value of uncoated (control) and coated almonds during 4 months storage in mill equivalents of oxygen per kilogram of oil.

Sample	Time (Months)				
	0	1	2	3	4
Control	0.014 ± 0.0001 Ea	0.023 ± 0.0011 Da	0.039 ± 0.0002 Ca	0.048 ± 0.0003 Ba	0.059 ± 0.0011 Aa
Coating with 0.5% (<i>w/v</i>)	0.014 ± 0.0011 Ea	0.021 ± 0.0013 Db	0.035 ± 0.0003 Cb	0.042 ± 0.0006 Bb	0.053 ± 0.0011 Ab
Coating with 1% (<i>w/v</i>)	0.014 ± 0.0001 Ea	0.021 ± 0.0016 Db	0.032 ± 0.0002 Cc	0.039 ± 0.0011 Bc	0.045 ± 0.0003 Ac
Coating with 1.5% (<i>w/v</i>)	0.014 ± 0.0002 Ea	0.019 ± 0.0012 Dbc	0.030 ± 0.0011 Ccd	0.034 ± 0.0011 Bd	0.042 ± 0.0002 Ad
Coating with 2% (<i>w/v</i>)	0.014 ± 0.0011 Ca	0.018 ± 0.0002 Bc	0.028 ± 0.0001 ABd	0.033 ± 0.0012 ABd	0.040 ± 0.0003 Ad

Different capital letters in each row indicate a statistically significant difference in each sample during different months at the level of 5%; Different lowercase letters in each column indicate a statistically significant difference between the samples during each month at the level of 5%.

As can be observed in Table 3, the TBA index increased significantly during the storage period in uncoated almonds samples, compared to almonds coated with 1%, 1.5%, and 2% (*w/v*) mastic gum. There is no significant difference between control and coating with 0.5% mastic gum, thus providing slight protection.

3.2.4. Microbiological Analysis Results

Total Yeast and Mold Counts (TYMC)

The results of the TYMC in almond kernels uncoated (control) and coated with different concentrations of mastic gum during the 4-month storage period are shown in Figure 2. According to the results obtained during the storage period, the growth rate of mold and yeast in the control sample increased significantly, while coated almonds with mastic gum significantly reduced the overall mold and yeast, compared to the control sample, at each stage of sampling during the storage period. In the middle of the storage period (day 105), differences in the mean values among treatments began to appear.

Figure 2. Changes in TYMC load of uncoated (control) and coated almonds with mastic gum in different concentrations during 4 months storage. Different lowercase letters indicate a statistically significant differences ($p < 0.05$) between the samples during each month; share a lowercase letter are not statistically different, while different letters denote for statistical differences at least 95% confidence.

The total number of mold and yeast increased from 1150 to 11,700 cfu/gr after 4 months of storage in the control sample, while the total number of mold and yeast in the samples coated with 2% (w/v) mastic gum decreased from 11,700 to 3700 cfu/gr, compared to the uncoated sample.

Antifungal Characteristic of Mastic Gum Coating against the Growth of *Aspergillus* Species

Aflatoxins may occur in contaminated almonds, and, in general, in contaminated foods, with fungi from *Aspergillus* species as carcinogenic secondary metabolites. Factors such as environmental conditions (e.g., temperature, relative humidity) affect mold growth and aflatoxin production [59].

The contamination with *Aspergillus* spp. of almonds, as in other nuts (such as peanut, hazelnut, walnut), occurs generally during harvest, processing, and storage. It is very important to prevent the postharvest mold contamination and growth of the susceptible almonds, and nuts [1,42].

The results of the present study regarding *Aspergillus* spp. mold development on fresh almond kernels uncoated and coated with different mastic gum concentrations during the 4 months of storage period are shown in Figure 3. As can be seen in the figure, mastic gum coating significantly reduced the growth rate of *Aspergillus* spp. Mold, compared to control samples.

Figure 3. Percentage of the growth of *Aspergillus* species on almond uncoated (control) and coated with different concentrations of mastic gum during 4 months of storage. Different lowercase letters indicate a statistically significant differences ($p < 0.05$) between the samples during each month; share a lowercase letter are not statistically different, while different letters denote for statistical differences at least 95% confidence.

The contamination with aflatoxins produced by *Aspergillus* spp. represents a major public health concern and, in addition to the possible contamination with other kinds of mold and yeast, causes food spoilage. Investigations on minimizing or eliminating such contaminants are an ongoing research topic, and the results of the present study contribute with new results to this area of research.

4. Discussion

Plant-based foods that are consumed raw are susceptible to changes in quality during processing. They can be contaminated with germs and thus represent a source of food infections. Dry foods such as almonds, nuts, dried fruits, spices, milk powder, or dried teas are not excluded. Almond kernels are very fatty, rich in oleic (main monounsaturated fatty acids) and linoleic acids (polyunsaturated fatty acids). The ratio of these two fatty acids is at a higher level than in the various common nut oils, vegetable oils (e.g., soybean), and seed (e.g., pomegranate, grape, date, and sesame) oils [28,60].

Moreover, the high content of these fatty acids in almonds, contributing to shorter shelf life, compared to other nuts, in addition to the presence of riboflavin as a photosensitizer in almonds, makes almonds susceptible to auto-oxidation, which is the main cause of off-flavor development in almonds, both in wild or domestic species of almonds. Environmental factors (e.g., storage temperature, packaging techniques, moisture, and light) play an active role in influencing lipid oxidation [28,61].

Several suitable packaging materials and techniques (e.g., modified atmosphere packaging or vacuum packaging) and storage temperatures have been tested and proposed to extend the shelf-life period of various types of nuts and almond kernel products [28,62–66]. Major challenges during storage and limitations for usage, for example, as snack mix nuts and almond products, may be considered.

The quality of almonds and other nuts can be affected by moisture, another important factor to be taken into consideration. When moisture is too high, it influences the deterio-

rative reactions, and therefore, mold growth occurs. However, too low levels of moisture have another kind of influence on the kernel shrivel [67].

Recently the application of edible coating based on bio-based antimicrobial and bioactive materials, such as natural plant materials or from different renewable resources, as substitutes for materials from nonrenewable sources, has received attention, contributing to extending the shelf life of natural perishable products while developing healthy and natural foods. The use of edible films (e.g., polysaccharides and proteins) for extending the shelf life of different nuts, including almonds, has been studied, and research is still ongoing [1,31–34,52,68–70].

The main objective of the present study was to enhance the durability of stored fresh almond kernels without becoming spoiled by pathogens and affected by moisture, which are the routes that cause food spoilage. Almond kernels, as the main commercial importance of almond fruit, are widely used in different food products; lately, snack mix nuts and almonds are the top products preferred. Even athletes appreciate almond kernels for their plant-based proteins and their essential amino acids. Moreover, recent studies have explored the effect of other nutritional compounds of almonds such as fiber on gut microbiota or the antioxidant capacity of the protein fraction [71–75].

In the present study, mastic gum was analyzed to be used as an alternative for fresh almonds coating for preservation, against contamination with molds, yeast, and fungi during storage over 4 months. Many countries determined the toxin limits for some foods such as pistachio, almonds, peanut, walnut, and hazelnut. Additionally, most importantly is that EU imports of different Iranian nuts decreased due to the increasing contamination risk incidents originated from Iran [76,77]. If contaminated almonds enter the production facilities after harvest, they can also contaminate other batches.

Evaluation of the sample's moisture content during the storage period showed a statistically significant difference ($p < 0.05$) between the samples with mastic gum coating and the control sample. By increasing the concentration of mastic gum, the moisture content of almond kernels during the storage period was decreased.

These results indicate that the mastic gum coating, as a barrier, reduces the transfer of moisture to the almond kernel tissue and increases its inhibitory effect by increasing the thickness of the coating. Similar results were achieved on the effect of coating almonds or other nuts kernels with different kinds of edible coating materials, and with increasing the thickness of the coating, its inhibitory effect increases [68–70,78–81].

Moreover, the oxidation potential is increased, and the fats have a longer shelf life, i.e., the almonds do not go rancid as quickly [82].

It can be stated that the surface coating of the product reduces the passage of water molecules and improves the durability of the product. It is believed that the bioactive phytochemical compounds (phytosterols, tocopherols, squalene, stanols, sphingolipids, phospholipids, chlorophylls, carotenoids, phenols, and volatile compounds) are present as active antioxidant compounds in the composition of mastic gum [14–19]. The decrease in peroxide and thiobarbituric acid index can be attributed to the presence of triterpenics. The simultaneous presence of antioxidant compounds may create a boosting state and increase total antioxidant activity.

On the other hand, studies have confirmed its efficacy as a functional food for gastrointestinal disturbances or several modern lifestyle-related diseases of consumers who have been using mastic daily for many years in the form of chewing gum for oral health, or in powder or capsule [83–85].

Therefore, using mastic gum as a coating material could have double benefits, extending the shelf-life of a food product and, at the same time, promoting health benefits associated with its compounds. This could lead to a decrease in their nutritional content because the products with a protective layer can be stored longer.

5. Conclusions

The results of the present study indicated that mastic gum coating used in four different concentrations (0.5%, 1%, 1.5%, and 2% *w/v*) containing different bioactive compounds was effective significantly ($p < 0.05$) against moisture absorption and oxidative reactions, total yeast and mold growth, and *Aspergillus* species development in peeled and coated fresh almonds, compared to uncoated fresh almonds as the control sample, during 4 months of storage, packed at room temperature (25–27 °C) inside a cabinet at 90% humidity. By increasing the concentration of mastic gum, the protection against environmental factors during the storage period increased.

It could be concluded that mastic gum coatings could be effectively utilized to extend the shelf life of peeled fresh almonds and other nuts (containing high fatty acids content), on the one hand, and promoting health benefits, on the other hand, due to its valuable bioactive components. To our knowledge, there is no information in the literature on the use of mastic gum neither as edible coating nor on coating fresh almonds using mastic gum as edible coating to maintain the quality of the product during storage.

Due to the increase in the oxidation potential of fats, it is of potential interest for those with increased sensitivity to oxidation.

In addition, existing products in the market with coatings are around twice as expensive as those without, and so far, the consumer has paid for these additional costs, not the supermarket. Therefore, an edible coating such as natural mastic gum will open new perspectives.

Mastic gum belongs to the next generation of bio-based materials, such as natural plant materials, as substitutes for materials from nonrenewable sources, replacing traditional petroleum polymers in several industrial sectors.

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