Italian Journal of Food Science, 2025; 37 (2): 149–163

The role of sodium alginate and gelatin coatings in the preservation of mulberry pestil

Şeyda Öztürk

Department of Food Processing, Zile Vocational School, Gaziosmanpasa University, 60400, Tokat, Turkey

Corresponding Author: Şeyda Öztürk, Department of Food Processing, Zile Vocational School, Gaziosmanpasa University, 60400, Tokat, Türkiye. Email: drrseydaozturk@gmail.com

Academic Editor: Prof. Marco Dalla Rosa—University of Bologna, Italy

Received: 19 August 2024; Accepted: 2 February 2025; Published: 1 April 2025

ORIGINAL ARTICLE

Abstract

In this study, sodium alginate and gelatin-based edible coatings were applied to preserve the physicochemical quality of pestil (mulberry fruit pulp), extend its shelf life, and provide a commercially viable solution for the pestil industry. Coated samples were stored for 45 days and analyzed periodically. The results showed that coated pestils had higher L^* values, lower moisture loss, and increased Fe (iron), Ca (calcium), and Na (sodium) contents compared to controls. The coatings effectively reduced HMF (hydroxymethylfurfural) content and preserved the overall quality, although they masked the fruity odor and darkened the color. The coated samples maintained better quality characteristics, particularly during the first 15 days.

Keywords: gelatin; grape seed oil; pestil; sodium alginate; storage

Introduction

In Turkey, pestil is a traditional dessert produced from various fruits such as grapes, mulberries, apples, pears, plums, figs, and apricots. Among these fruits, mulberry holds a particularly important place in pestil production. Mulberries belong to the Morus genus of the Moraceae family, and three species are commonly grown in Turkey: white (*Morus alba*), red (*Morus rubra*), and black (*Morus nigra*) (Yavaş *et al*., 2023). Different types of mulberry pestils are made from these three species, known as "Bastegh," "Qamar el deen," "Bestil," and "Fruit Leather" in regions such as Anatolia, Armenia, Lebanon, Syria, Arabia, and Iran (Yılmaz *et al*., 2017). Pestil is a soft, leather-like chewable product formed by drying the viscous liquid obtained by thickening the fruit pestil with substances such as starch and flour, giving it a fine structure under pressure or by laying it out (Phuong *et al*., 2016). The drying process in pestil production is carried out using various methods such as traditional ovens, solar energy, and electric cabinet dryers. In this process, the flour or starch in the product gelatinizes and gains consistency and shape. However, moisture loss and retrogradation processes during drying may continue after pestil production or after it is unpacked, which may cause the pestil structure to harden and become inedible (Yüksel *et al*., 2020).

Pestil is a product with high nutritional value and health benefits. It is rich in carbohydrates, energy, antioxidants, minerals, and fiber, and can be enriched with ingredients such as honey and walnuts during production. Its light texture and the fact that it can be easily consumed in every season make pestil a popular snack (Şengül *et al*., 2020). However, changes in consumer demands and the need for long shelf life have made it more important to preserve the quality of pestil. To prevent this problem, manufacturers try to create a barrier by applying oil to the

pestil surface to prevent moisture loss and extend shelf life by maintaining the softness of the product. However, this method is usually not sufficient, and research in this area is quite limited (Yüksel *et al*., 2020).

One of the most important problems encountered in pestil production is the increase in the amount of HMF (hydroxymethylfurfural) during storage. HMF is an intermediate product that occurs during the breakdown of hexose or Maillard reaction in an acidic environment. HMF is formed as a result of the burning of sugar at a certain rate during the boiling phase of fruit pestil. Factors affecting the formation of HMF in grapes must include sugar concentration, heat treatment time and temperature, pH (potential of hydrogen) level, and storage time of the product (Yavuz, 2019).

Packaging is also very important in pestil production. The packaging material should be both convenient to use and facilitate the consumption of the product. Pestil is highly hygroscopic and is easily affected by moisture in the environment. Changes in the moisture content of the product can affect the textural properties during storage. Therefore, the moisture permeability of the packaging material used is a critical factor. Pestil should be packed with appropriate packaging material immediately after production and stored in a clean and dry environment (Kara and Küçüköner, 2019).

The development and application of bioactive packaging systems have become an attractive area of research in recent years. In particular, polysaccharides and proteins are promising biopolymers for the production of packaging materials. Alginates are polysaccharides derived from brown algae that are biocompatible, biodegradable, and economical. Alginate exhibits important properties due to the ability of its functional groups to interact with multivalent cations (e.g., Ca^{2+}, Al^{2+}, and Fe^{2+}) (Lisitsyn *et al*., 2021). Gelatin, however, has strong gas barrier and swelling properties in water, but its use as a packaging material is limited by its low mechanical strength and permeability to water vapor molecules. These properties can be improved by mixing gelatin with other functional materials and agents (Lu *et al*., 2022). Grape seed oil has been shown to have health benefits such as anti-inflammatory, cardioprotective, antimicrobial, and anticancer properties and can help eliminate waste generated by industry (Garavaglia *et al*., 2016).

In this study, mulberry (*Morus alba*) pestil was coated with edible coating solutions prepared by using sodium alginate (SA), gelatin, and grape seed oil instead of the oil application method, which is common in commercial applications. In this way, the aim was to reduce the moisture loss of the pestil during storage, extend its shelf life, and minimize the formation of HMF. In addition, this study aimed to examine the quality changes caused by the coating on the product and to contribute to the literature in this field.

Materials and Methods

Grape seed oil (commercially obtained, Karam Natural, Turkey), bovine gelatin (E441, Alfasol, Turkey), glycerol (Sigma-Aldrich, Germany), SA (E401, Alfasol, Turkey), glycerol monostearate (E471, Alfasol, Turkey), and $CaCl_2$ (calcium chloride) (E509, Alfasol, Turkey) were obtained for edible coating material. All chemicals and solvents (analytical or HPLC [high-performance liquid chromatography] purity) were purchased from Merck (Darmstadt, Germany).

Production of mulberry pestil

Pestil production was carried out in Yozgat Akdut Pestil and Köme company (Turkey). The process steps are as follows:

Mixture 1: 200 L water, 75 kg glucose syrup, and 60 g citric acid were added to the boiler and boiled at 150°C for 1.5 hours (KM100, Keskin, Turkey); 10 kg sugar was added to the boiling mixture and boiled for another 30 minutes.

Mixture 2: 10 kg was taken from the boiling mixture and 1.26 kg flour, 3 kg wheat starch, 3 kg corn starch, 1.5 kg milk powder, and 15 kg cold water were added and whisked in a high speed mixer (KM100, Keskin, Turkey).

Molasses mixture: To break the heat of the boiling mixture, 1.5 kg of cold water was added; then, mixture 2 was slowly added to the syrup and left to boil for another 1 hour. After boiling, 8 kg mulberry molasses was added and boiled for another 20 minutes. After the mixture was mixed well with molasses and boiled, the laying process was started. Here, some molasses mixture was taken with a wooden spoon and checked for fluidity, lumping, and shearing.

Laying process: 5 kg of the molasses mixture (herle) was poured onto m^2 cloths and spread evenly with a steel trowel (Figure 1).

Drying process: It was dried in a natural gas-insulated oven at 62°C for 20 hours with the help of a burner blowing dry and hot air. An aspirator was used to remove moisture from the pestil in the oven (DS, Dipaz, Turkey).

Resting and cutting: The pestils removed from the oven were rested at room conditions for two days, and then cut into 10 × 20 pieces. The pestils were sprinkled with starch to prevent sticking and packaged.

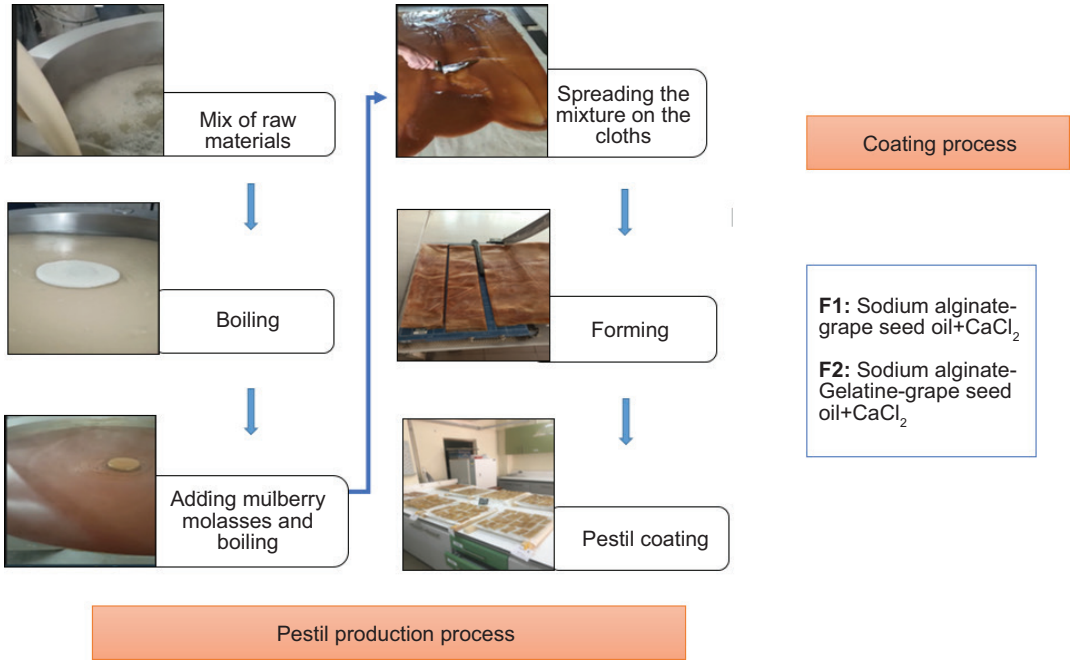

Figure 1. Preparation of edible coated pestils.

Preparation of coating solutions

A total of 1% (a/h) SA, 5% (h/h) glycerol, 0.5% glycerolmonosterate, and 2% grape seed oil was used for the alginate-based coating solution (F1) and 0.75% SA, 0.25% gelatin, 5% (h/h) glycerol, 0.5% glycerolmonosterate, and 2% grape seed oil was used for SA gelatin-based coating solution (F2). Both coating solution mixtures were dissolved in 60°C pure water in a magnetic mixer for 25 minutes. Preliminary trials determined the ratios used for coating solution formulations. In addition, a 1% solution of $CaCl_2$ was prepared to use during the coating of mulberry pestils.

Coating and drying of pestils

Pestils were cut in 5 cm × 10 cm ratios and immersed in coating solutions cooled to 30°C. After removal from excess fluids, the coated pestils were immersed in a 1% solution of $CaCl_2$ to form an alginate and calcium bond. After these steps, the pestils were laid out on cloths used specifically for pestil production (Figure 1). After drying at room temperature (20.4 ± 2 °C), it was stored for 45 days and subjected to analysis every 15 days.

Color analysis

The color of the samples was measured using a Minolta Chromameter (CR-400) (Konica Minolta Sensing, Inc., Japan) to determine the L^* (lightness/darkness), a^* (redness/greenness), and b^* (yellowness/blueness) values. In addition, the chroma (C), hue angle (h), and ΔE values were calculated using the following formula. The ΔE value was calculated based on the day 0th control sample (Equations 1, 2, and 3) (Quek *et al*., 2007).

$$\Delta E = \sqrt{(L^* - L_{ref})^2 + (a^* - a_{ref})^2 + (b^* - b_{ref})^2} \quad (1)$$

$$C = \sqrt{\left((a^*)^2 + (b^*)^2\right)} \quad (2)$$

$$h^\circ = \tan^{-1}\left(\frac{b}{a}\right) \quad \left(\text{if } a^* > 0 \text{ and } b^* \geq 0\right) \quad (3)$$

Total solids and moisture analysis

Total solids were determined and analyzed following the TS 9131 Cezeriye (Turkish Special Carrot Dessert) standard. The total solids amount and moisture were calculated based on the formulas (Equations 4 and 5) (Turkish Standards Institution, 2021).

$$\text{Moisture \%} = 100 - (\text{Water-soluble solids \%} + \text{Water-insoluble solids \%}) \quad (4)$$

$$\text{Total solids \%} = \text{Water-soluble solids \%} + \text{Water-insoluble solids \%} \quad (5)$$

Total ash analysis

A total of 2.5 g of pestil was weighed in a porcelain crucible and burned in an ash furnace (MF-12, Nuve, Turkey)

until it reached a constant weight at 550°C after pre-incineration (Turkish Standards Institution, 2001b).

pH value analysis

A total of 50 mL of pure water was added to 20 g of the sample and treated in a homogenizer. Then, the device electrode (Ohaus ST2100F desktop pH meter) was immersed in the sample mixture and read at 20 ± 2°C (Turkish Standards Institution, 2001a).

Total acidity analysis

A total of 75 mL of distilled water was added to 10 g of pestil sample and homogenized in the homogenizer. It was titrated with 0.1 N NaOH until the pH value was 8.3. The result was given as percentage (m/m) of the anhydrous citric acid (SSA) (Turkish Standards Institution, 2002).

Mineral analysis

After dissolving the ash samples in 1 mL concentrated H_2O_2 (hydrogen peroxide) and 7 mL concentrated nitric acid, the sample solutions were filled with ultrapure water to 50 mL. Mineral analysis was performed with an MP-AES device (4200 MP-AES System, Agilent Technology, USA). Contents of Fe (iron), Mn (manganese), Cu (copper), Al (aluminum), Zn (zinc), Co (cobalt), Ni (nickel), Cr (chromium), Cd (cadmium), Pb (lead), Na (sodium), K (potassium), Ca (calcium), and Mg (potassium) in pestils were measured by MP-AES (NordVal International c/o Institute of Marine Research, 1998).

Hydroxymethylfurfural analysis

A total of 25 mL of pure water is added to 5 g of pestil sample and homogenized in a homogenizer. Then, the sample solution volume, adding 0.5 mL Carrez I and 0.5 mL Carrez II, was completed at 50 mL. The solution was taken to the vials through a 0.45-micron filter and injected into the conditioned HPLC system (Thermo Finnigan HPLC-UV), and 1.0, 2.0, 4.0, 8.0, and 12.0 mg/L HMF standards were used to prepare the calibration curve (Baltaci and Aksit, 2016).

Protein analysis

One (1) g of pestil samples were transferred to the kjeldahl tube and one catalyst tablet and 20 mL concentrated sulfuric acid were added. After incineration, it was distilled (Gerhardt Vapodest, Gerhardt GmbH & Co. KG, Germany) and factor 6.25 was used in protein calculation (Turkish Standards Institution, 2016).

Microscopic analysis

The method for microscopic analysis has been adapted from the study conducted by Arzate-Vázquez *et al.* (2012). Nikon ECLIPSE E200 microscope and Nikon brand camera were used for analysis. Samples were cut to a thickness of 0.2 mm. Magnifications of 4 × 10 and 10 × 10 were used with 0.10 mm, 0.05 mm, and 0.01 mm graduated slides and photographs taken. The thickness of pestils and coatings has been determined.

Sensory analysis

At 15 days and 30 days after coating, coated and uncoated pestils were tasted by nine trained panelists. The panelists were asked to rate the samples from 1 to 7 points according to color (1 lightest, 7 darkest), flavor (1 palatable, 7 unpalatable), odor (1 odorless, 7 fragrant), chewiness (1 chewy, 7 non-chewy), stickiness (texture: 1 nonsticky, 7 sticky), and hardness (1 soft, 7 hard) (Altuğ and Elmacı, 2005).

Statistical analysis

Statistical analyses were conducted using one-way ANOVA (Analysis of Variance) for repeated measures in SPSS (Statistical Package for the Social Sciences). Differences between means were evaluated with Duncan's multiple range test at a 95% confidence level. Results are expressed as the mean ± standard deviation from at least three replicates.

Results and Discussion

Total solid, moisture, and ash values

Table 1 shows the total dry matter, moisture, and ash values. The total dry matter value of the control sample at the beginning of storage was 91 g/100 g, the moisture value was 9 g/100 g, and the ash value was 0.36 g/100 g. These values comply with the TS 12677 standard (moisture content maximum 18 g/100 g; ash content maximum 4.0 g/100 g) (Turkish Standards Institution, 2000). In similar studies, Cağındı and Otles (2005) determined the dry matter content of mulberry pestil in the range of 86.20–88.20 g/100 g. Levent and Yüksel (2022) reported moisture and ash values of mulberry pestil

Table 1. Data of various analyses of uncoated (control) and coated (F1, F2) pestils after the 15th, 30th, and 45th days of storage.

Results for various analysis										
Sample	**Control**				**F1**		**F2**			
Sample storage time	**C-0**	**C-15**	**C-30**	**C-45**	**F1-15**	**F1-30**	**F1-45**	**F2-15**	**F2-30**	**F2-45**
TSM % (m/m)	91.00 ± 0.08^{a}	92.57 ± 0.09^{d}	93.23 ± 0.04^{e}	94.16 ± 0.04^{i}	92.41 ± 0.05^{c}	93.53 ± 0.12^{f}	93.85 ± 0.01^{g}	92.20 ± 0.02^{b}	93.24 ± 0.06^{e}	93.66 ± 0.11^{h}
Moisture % (m/m)	9.00 ± 0.08^{i}	7.43 ± 0.09^{f}	6.77 ± 0.04^{e}	5.84 ± 0.04^{a}	7.59 ± 0.05^{g}	6.47 ± 0.12^{d}	6.15 ± 0.01^{b}	7.80 ± 0.02^{h}	6.76 ± 0.06^{e}	6.34 ± 0.11^{c}
Total Ash % (m/m)	0.36 ± 0.00^{a}	0.35 ± 0.02^{a}	0.36 ± 0.02^{a}	0.35 ± 0.01^{a}	0.62 ± 0.04^{c}	0.69 ± 0.02^{de}	0.72 ± 0.00^{e}	0.57 ± 0.03^{b}	0.64 ± 0.05^{cd}	0.79 ± 0.04^{f}
Total Acidity % (SSA)	0.09 ± 0.00^{a}	0.15 ± 0.00^{c}	0.15 ± 0.00^{c}	0.19 ± 0.02^{d}	0.10 ± 0.00^{a}	0.14 ± 0.01^{c}	0.18 ± 0.01^{d}	0.11 ± 0.00^{b}	0.15 ± 0.01^{c}	0.17 ± 0.00^{d}
pH	5.44 ± 0.08^{bc}	5.39 ± 0.07^{ab}	5.36 ± 0.10^{ab}	5.28 ± 0.06^{a}	5.77 ± 0.05^{e}	5.65 ± 0.00^{d}	5.42 ± 0.06^{bc}	5.50 ± 0.01^{c}	5.35 ± 0.02^{ab}	5.29 ± 0.02^{a}
Color Analysis										
L*	49.07 ± 1.02^{bc}	49.10 ± 1.09^{bc}	48.25 ± 0.85^{ab}	46.63 ± 0.61^{a}	55.61 ± 1.32^{ef}	57.30 ± 1.19^{f}	61.66 ± 0.53^{g}	50.36 ± 2.03^{c}	53.60 ± 0.66^{d}	54.60 ± 0.53^{de}
a*	6.78 ± 0.33^{abc}	7.93 ± 0.22^{de}	8.60 ± 0.48^{e}	9.61 ± 0.38^{f}	6.28 ± 0.33^{a}	6.73 ± 0.22^{ab}	7.97 ± 0.01^{de}	7.68 ± 1.73^{cde}	7.69 ± 0.30^{cde}	7.60 ± 1.10^{bcd}
b*	38.08 ± 2.08^{c}	35.39 ± 1.43^{bc}	27.57 ± 1.22^{a}	25.71 ± 1.42^{a}	38.37 ± 0.94^{c}	36.18 ± 1.19^{bc}	29.02 ± 2.71^{a}	36.69 ± 0.74^{c}	32.85 ± 4.26^{b}	25.71 ± 0.78^{a}
C*	38.68 ± 2.11^{c}	36.27 ± 1.44^{bc}	28.89 ± 1.04^{a}	27.45 ± 1.33^{a}	38.89 ± 0.89^{c}	36.80 ± 1.15^{bc}	30.10 ± 2.62^{a}	37.49 ± 0.67^{c}	33.74 ± 4.16^{b}	26.82 ± 1.01^{a}
ΔE	1.87 ± 0.48^{a}	3.14 ± 1.10^{a}	10.71 ± 1.24^{cd}	12.93 ± 1.45^{de}	6.62 ± 1.33^{b}	8.48 ± 1.42^{bc}	15.64 ± 1.86^{e}	2.59 ± 1.30^{a}	7.33 ± 3.32^{b}	13.60 ± 0.71^{e}
Hue	79.89 ± 0.13^{ef}	77.36 ± 0.16^{cd}	72.63 ± 1.58^{b}	69.46 ± 1.30^{a}	80.69 ± 0.68^{f}	79.45 ± 0.57^{def}	74.56 ± 1.40^{b}	78.16 ± 1.15^{cde}	76.69 ± 1.68^{c}	73.58 ± 1.89^{b}

*n = 3, ± standard deviation, $^{a, b, c}$differences in storage time of the same sample in the same column at $p < 0.05$, $^{A, B, C}$samples (Control, F1, F2) show significant differences in the same column at $p < 0.05$.

as 10.58 g/100 g and 0.71 g/100 g, Yüksel *et al*. (2020) reported 11.65 g/100 g and 0.83 g/100 g, and Nakilcioğlu-Taş *et al*. (2018) reported 12.29 g/100 g and 1.81 g/100 g, respectively.

Moisture is an important quality indicator for pestil. Especially during the storage process, the pestil may lose moisture, dry out, and become unsuitable for consumption. Therefore, the moisture levels of the pestils were analyzed in detail during storage. When the first 15 days of storage data of the pestils were analyzed, a statistically significant difference was observed between the control and coated samples in terms of moisture values ($p < 0.05$). During the first 15 days, the moisture loss was 17.44% in the control sample, 15.66% in the pestils coated with the formula containing only SA as a coating agent, and 13.33% in the samples coated with the formula containing SA-gelatin. These results indicate that the addition of gelatin is effective in preventing moisture loss. In a study supporting this, Abdallah *et al*. (2018) stated that gelatin is superior to alginate in reducing weight loss due to its hydrophobic structure. Furthermore, Antoniewski *et al.* (2007) stated that gelatin can delay weight loss in food products by reducing water permeation due to its high surface tension properties. In contrast, alginate is known to have weaker water resistance due to its hydrophilic nature (Borchard *et al*., 2005).

When the 30th-day storage data was compared with the 15th-day storage data, it was observed that moisture loss continued in all samples. However, the coated samples lost more moisture than the control sample. There was no statistical difference between the control sample and F2 on the 30th day ($p > 0.05$). Also, the F1 sample lost more moisture than the control sample. However, this situation changed on day 45: moisture loss was 35.11% in the control sample, 31.66% in the F1 sample, and 29.55% in the F2 sample. The results show that the edible coating acts as a water barrier on the pestil and reduces moisture loss, and these coatings can be effective in preventing the drying problem of pestil.

Eyiz (2019) coated fruit bars with edible coatings to prevent drying and solidification of fruit bars over time and oxidation problems. He used SA, carboxymethyl cellulose, and whey protein as edible coating materials. All coating materials tested were reported to limit moisture loss during storage and retain the textural properties of SA-coated bars compared to control samples. However, Kim *et al.* (2015) reported that moisture migration can cause morphological changes in coatings. They stated that dry environments can cause shrinkage in coatings, while humid environments can lead to stickiness and wetness. Similarly, in this study, it was observed that coated pestils shrunk over time. Further research can be conducted on this topic.

The ash values of the control sample varied between 0.35–0.36 g/100 g during the storage period, and this change was not statistically significant ($p > 0.05$). However, the ash content of F1 and F2 samples increased after storage ($p < 0.05$). This increase in ash content was attributed to the increase in dry matter due to moisture loss. Similarly, Şengül and Ünver (2022) reported that the ash content of pestils increased at the end of storage. The ash values of the F1 and F2 samples were higher than the control sample and were determined as 0.62 and 0.72 g/100 g for the F1 sample and 0.57 and 0.79 g/100 g for the F2 sample on the 15th and 45th days, respectively. At the end of the 45th day, the highest ash value was observed in the F2 sample. These data indicate that the substances used in the coating formulation may increase the amount of ash. In contrast, Eyiz (2019) reported that film coating did not cause a statistically significant change in the ash content of the products.

Titration acidity and pH values

Titration acidity and pH values of the pestils during storage are presented in Table 1. The titration acidity values of the samples in terms of citric acid varied between 0.09 and 0.19. According to TSE (Türk Standardlari Enstitüsü) standards, the acidity of mulberry pestil should be a maximum of 0.2% (Turkish Standards Institution, 2000). In this regard, the acidity values of the samples were determined to comply with these standards. In the studies conducted, the percentage of acidity values of mulberry pestil was determined as 0.21 by Levent and Yüksel (2022), 0.21 by Yüksel *et al*. (2020), and 3.76 by Nakilcioğlu-Taş *et al*. (2018).

In the first 15 days of storage, the control sample had higher total acidity and lower pH values than the coated samples ($p < 0.05$). On day 15, the titration acidity was 0.15 in the control sample, while it was 0.10 and 0.11 in the F1 and F2 samples, respectively. When the data of the coated pestils between day 15 and day 30 were compared, it was observed that the total acidity value increased ($p < 0.05$). However, the difference in acidity between the 30th-day data and the control sample was not statistically significant ($p > 0.05$). Similarly, differences in pH values were also observed in the first 15 days. pH values were 5.39 in the control sample, 5.77 in the F1 sample, and 5.50 in the F2 sample. This may be attributed to the fact that the coated samples were initially better able to control moisture loss; coating materials may affect the solubility properties of acidic compounds by limiting moisture loss. In addition, the effectiveness of the coating may decrease over time.

At the end of storage, the total acidity values of the samples ranged between 0.17 and 0.19, and there was no

statistically significant difference between these values ($p > 0.05$). After storage, an increase in total acidity and a decrease in pH values were observed in all three samples ($p < 0.05$). The continued loss of moisture and increase in the concentration of acidic compounds during long-term storage can explain this increase in total acidity and decrease in pH. It may also indicate that the coating materials had no significant effect on acidity in the long term. However, at the end of 45 days, the highest pH value of 5.42 was detected in sample F1, which may indicate the effect of the F1 coating formulation on pH changes. Changes in pH values show different results in various studies on pestil. For example, in the study by Babalola *et al*. (2002), the pH value of papaya pestil stored at 8°C for two months increased from 6.37 to 6.50, while the pH value of guava pestil decreased from 5.47 to 5.27. Atıcı (2014) reported that the pH value increased in plum pestils as a result of nine months of storage in the control group pestils dried with hot air and microwave. Similarly, Şengül and Ünver (2022) found that the pH value of cranberry pestils increased and titration acidity decreased during three months of storage. These studies reveal that changes in pH value may vary depending on product type and storage conditions.

Color values

The color values (L^*, a^*, b^*, C^*, ΔE, and Hue) of the pestils during storage are presented in Table 1. The color values were evaluated based on brightness (L^*), red-green (a^*), and yellow-blue (b^*) parameters. The L^* value of the initially used mulberry pestil was 49.07, the a^* value was 6.78, and the b^* value was 38.08. In a similar study conducted by Levent and Yüksel (2022), the L^* value of mulberry pestil was determined as 36.13, the a^* value as 5.47, and the b^* value as 19.85.

The L^* (brightness) values of the control sample were 49.10 on day 15, 48.25 on day 30, and 46.63 on day 45. When the L^* values of the control sample were analyzed, no statistically significant difference was observed during the first 30 days, but a decrease in the L^* value occurred at the end of the storage period ($p < 0.05$). This suggests that there was a decrease in the brightness of the pestil during storage, possibly as a result of browning reactions (Kara and Küçüköner, 2019).

The L^* value of the coated pestils increased at the end of storage, and was higher than the control sample ($p < 0.05$). There are several possible reasons for this increase: coating materials may partially prevent browning reactions on the surface of the food (Ojeda *et al*., 2014), stabilize its color, and slow down color changes. Furthermore, coatings can provide uniform and smooth surfaces; these smooth surfaces can provide a more uniform reflection of light (Liyanapathiranage *et al*., 2023). Coatings can provide more gloss on the surface by preserving the oil content. The content of the coating solution, especially components with reflective properties, can provide a better reflection of light on the surface of the pestil. However, the coating materials in the formulation (grape seed oil, gelatin, SA) may cause discoloration (Galus and Lenart, 2013).

The L^* values of sample F2 were 50.36 at day 15, 53.60 at day 30, and 54.60 at day 45. Sample F2 showed the potential of the coating to increase the gloss but was less effective in increasing the gloss than sample F1 (day 15: 55.61, day 30: 57.30, day 45: 61.66). This suggests that the effect of the coating solution may vary according to the content of the formulation, and coatings containing gelatin may reduce the brightness. In Eyiz's (2019) study, no statistically significant difference was observed between the L^* values of SA-coated samples and control samples; it was stated that a decrease in L^* values occurred in general. It was reported that the reason for the decrease in brightness and darkening of the product is the browning reactions that occur during storage. In our study, it was determined that the effect of coating materials on gloss varies depending on the formulation used.

The a^* (red-green) values of the control sample were 7.93 on day 15, 8.60 on day 30, and 9.61 on day 45. A general increase in a^* value was observed in the control sample during storage, and this increase was statistically significant ($p < 0.05$). This indicates that the color shade of the pestil during storage becomes reddish, and this change is probably due to browning reactions (Kara and Küçüköner, 2019).

The a^* values of the coated pestils were 6.28 on day 15, 6.73 on day 30, and 7.97 on day 45 for the F1 sample, and 7.68 on day 15, 7.69 on day 30, and 7.60 on day 45 for the F2 sample. At the end of the storage period, an increase in the a^* value of the F1 sample was observed ($p < 0.05$), while no significant change was observed in the F2 sample ($p > 0.05$). Especially at the end of the 45th day, the a^* value of the coated pestils was lower than the control sample, but the a^* value of the F1 sample was lower. This indicates that the formulation used in the F1 sample tends to lower the a^* value, and this effect may be associated with the coating materials. The antioxidant properties of grape seed oil and the coating materials acting as an oxygen barrier and reducing water activity may have helped prevent enzymatic browning. Eyiz (2019) reported that the a^* values of SA coated samples were similar to the control samples, and an increase in a^* values was observed in general. It was reported that the effect of SA on color change was limited, but browning reactions during storage caused a significant increase in a^* values. These findings indicate that SA has a limited

effect on color stability. In our study, we observed that the coatings tended to decrease the *a** value, and these effects were related to the coating materials. Grape seed oil may be effective in reducing browning reactions due to its antioxidant properties, which may lead to lower *a** values by reducing color changes. In this context, our findings regarding the effect of SA on color stability can be more clearly evaluated by comparing the effects of coating materials containing antioxidants such as grape seed oil. The *b**(yellow-blue) values of the control, F1, and F2 samples were measured as follows: 35.39 for the control sample, 38.37 for the F1 sample, and 36.69 for the F2 sample at day 15; 27.57 for the control sample, 36.18 for the F1 sample, and 32.85 for the F2 sample at day 30; 25.71 for the control sample, 29.02 for the F1 sample, and 25.71 for the F2 sample at day 45. At the end of the storage period, a general decrease in the *b** value of all three samples was observed ($p < 0.05$). This decrease indicates that the yellowish tones of the pestil decreased over time. The reasons for this change may be chemical factors such as oxidative and enzymatic reactions and physical factors such as changes in pigment density as the pestils dry out. It was also found that coating materials generally did not cause a significant change in *b** values ($p > 0.05$). This finding is consistent with Eyiz's (2019) study. Eyiz (2019) also stated that the effect of coating on *b** values was limited; a similar trend was observed in *b** values in general.

At the end of the storage period, a decrease in the chroma (*C**) values of the control, F1, and F2 samples was observed. This means that the colors become paler, less distinct, or less vivid. Reduced color intensity, especially in food products, can be the result of factors such as loss of freshness, oxidative reactions, enzymatic degradation, or breakdown of pigments. At day 15, there was no difference in *C** values between the three samples. However, on day 30, the F1 and F2 samples had higher *C** values than the control sample, suggesting that the coatings affected color intensity ($p < 0.05$). Upon reaching day 45 of storage, no notable difference was observed in the *C** values of the three samples. This indicates that coating materials may have color protection properties; however, this protection could diminish over extended periods of storage.

An increase in the ΔE value of all three samples was observed throughout the storage period, indicating a significant change in the color of the samples during storage ($p < 0.05$). At day 15, the ΔE value of sample F1 was higher than the control and F2 samples ($p < 0.05$). However, there was no significant difference in ΔE values between the three samples at day 30 and day 45, indicating that this change stabilized in the later stages of storage.

At the end of storage, the hue values of the control, F1, and F2 samples decreased ($p < 0.05$), indicating that the hue changes over time. At the end of 45 days, the hue value of the control sample was lower than the coated samples, indicating that the coatings affected the hue ($p < 0.05$).

Metallic material values

Pestil is a dessert noted for its high energy content and rich vitamin-mineral profile. Consumers particularly favor it because of its iron and calcium content. Storage time and the coating process can alter the amount of metallic substances in pestil, which can affect the overall nutritional value and quality of the product.

The analyses provide important information about the mineral content of the pestil. The results of the analysis are presented in Table 2. When the data were analyzed, an increase in mineral matter concentration was observed during the storage period ($p < 0.05$). This increase may be due to increased moisture loss. While the moisture content of the product was 9.00% at the beginning of storage, at the end of the storage period, the moisture content decreased to 5.84%, 6.15%, and 6.34% in control, F1, and F2 samples, respectively.

Iron (Fe) content was measured as 11.71 mg/kg in the control sample and 18.27 and 19.71 mg/kg in the F1 and F2 samples on day 15, respectively. On day 45, these values increased and reached 12.41, 21.76, and 22.97 mg/kg in control, F1, and F2 samples, respectively ($p < 0.05$). Fe content in F1 and F2 samples was significantly higher than the control sample ($p < 0.05$). This difference is thought to be due to the coating formulations. This increase in iron content in the pestil due to coating is an important factor that increases the nutritional value of the product.

Calcium (Ca) content was measured as 227.19, 339.10, and 319.46 mg/kg in control, F1, and F2 samples on day 15 and 241.10, 410.44, and 372.68 mg/kg on day 45, respectively. The Ca content of F1 and F2 coated samples was higher from the beginning compared to the control sample ($p < 0.05$). It is thought that this may be due to the $CaCl_2$ solution used in the coating process.

Magnesium (Mg) content was measured as 125.88, 106.97, and 101.40 mg/kg in control, F1, and F2 samples, respectively, on day 15. On day 45, these values increased and reached 129.80, 127.35, and 119.30 mg/kg in control, F1, and F2 samples, respectively ($p < 0.05$). The magnesium content of the F1 and F2 coated samples was significantly lower on day 15 and day 30 compared to the control sample ($p < 0.05$). Although the magnesium content of F1 and F2 samples approached the control sample during the storage process, the initial low values

Table 2. Mineral data of uncoated (control) and coated (F1, F2) fruit pestil after the 15th, 30th, and 45th days of storage.

Minerals (mg/kg)										
	Control				F1		F2			
	C-0	C-15	C-30	C-45	F1-15	F1-30	F1-45	F2-15	F2-30	F2-45
Fe	9.72 ± 0.10^{a}	11.71 ± 0.12^{ab}	11.33 ± 0.11^{ab}	12.41 ± 0.66^{b}	18.27 ± 0.95^{c}	20.24 ± 1.06^{cd}	21.76 ± 1.14^{de}	19.71 ± 1.65^{cd}	20.82 ± 2.11^{d}	22.97 ± 1.77^{e}
Ca	195.28 ± 13.49^{a}	227.19 ± 5.72^{b}	236.62 ± 6.61^{b}	241.10 ± 16.62^{b}	339.10 ± 15.88^{cd}	374.04 ± 19.08^{e}	410.44 ± 15.44^{f}	319.46 ± 9.21^{c}	352.98 ± 22.45^{de}	372.68 ± 5.39^{e}
Zn	5.12 ± 0.65^{ef}	5.14 ± 1.36^{ef}	6.30 ± 3.33^{fg}	6.66 ± 0.42^{g}	3.44 ± 0.43^{bcd}	3.69 ± 0.66^{cd}	3.97 ± 0.71^{de}	2.15 ± 0.47^{a}	2.33 ± 0.51^{ab}	2.53 ± 0.56^{abc}
Cd	00.00 ± 0.00^{a}	00.00 ± 0.00^{a}	00.00 ± 0.00^{a}	00.00 ± 0.00^{a}	00.00 ± 0.00^{a}	00.00 ± 0.00^{a}	00.00 ± 0.00^{a}	00.00 ± 0.00^{a}	00.00 ± 0.00^{a}	00.00 ± 0.00^{a}
Mg	105.11 ± 3.28^{a}	125.88 ± 3.92^{bcd}	121.98 ± 3.80^{bcd}	129.80 ± 4.05^{d}	106.97 ± 4.52^{a}	118.44 ± 5.00^{b}	127.35 ± 5.38^{cd}	101.40 ± 4.66^{a}	109.75 ± 5.04^{a}	119.30 ± 5.48^{bc}
Cu	0.99 ± 0.24^{ab}	1.18 ± 0.28^{abc}	1.15 ± 0.27^{abc}	1.22 ± 0.28^{abc}	0.99 ± 0.23^{a}	1.06 ± 0.25^{ab}	1.32 ± 0.21^{ab}	1.32 ± 0.21^{abc}	1.44 ± 0.22^{bc}	1.56 ± 0.24^{c}
Co	00.00 ± 0.00^{a}	00.00 ± 0.00^{a}	00.00 ± 0.00^{a}	00.00 ± 0.00^{a}	00.00 ± 0.00^{a}	00.00 ± 0.00^{a}	00.00 ± 0.00^{a}	00.00 ± 0.00^{a}	00.00 ± 0.00^{a}	00.00 ± 0.00^{a}
Ni	0.31 ± 0.00^{a}	0.37 ± 0.00^{a}	0.36 ± 0.00^{a}	0.38 ± 0.00^{a}	0.56 ± 0.06^{b}	0.62 ± 0.07^{bc}	0.66 ± 0.07^{cd}	0.66 ± 0.02^{cd}	0.72 ± 0.02^{de}	0.78 ± 0.02^{e}
Al	2.40 ± 0.22^{a}	2.87 ± 0.27^{a}	2.78 ± 0.25^{a}	2.96 ± 0.28^{a}	4.01 ± 2.27^{a}	2.99 ± 0.97^{a}	4.77 ± 2.70^{a}	2.99 ± 0.96^{a}	3.24 ± 1.04^{a}	3.52 ± 1.13^{a}
Mn	1.72 ± 0.17^{a}	2.06 ± 0.20^{a}	2.00 ± 0.19^{a}	2.12 ± 0.21^{a}	3.15 ± 0.63^{bc}	3.49 ± 0.69^{c}	3.75 ± 0.75^{c}	2.09 ± 0.19^{a}	2.26 ± 0.21^{a}	2.45 ± 0.22^{ab}
Pb	00.00 ± 0.00^{a}	00.00 ± 0.00^{a}	00.00 ± 0.00^{a}	00.00 ± 0.00^{a}	00.0 ± 0.00^{a}	00.00 ± 0.00^{a}	00.00 ± 0.00^{a}	00.00 ± 0.00^{a}	00.00 ± 0.00^{a}	00.00 ± 0.00^{a}
Cr	00.00 ± 0.00^{a}	00.00 ± 0.00^{a}	00.00 ± 0.00^{a}	00.00 ± 0.00^{a}	00.0 ± 0.00^{a}	00.00 ± 0.00^{a}	00.00 ± 0.00^{a}	00.00 ± 0.00^{a}	00.00 ± 0.00^{a}	00.00 ± 0.00^{a}
Na	270.56 ± 21.41^{a}	317.34 ± 13.10^{b}	313.98 ± 24.84^{b}	337.37 ± 3.63^{b}	492.28 ± 8.94^{c}	546.74 ± 7.44^{d}	584.14 ± 13.62^{e}	735.21 ± 37.51^{f}	782.42 ± 17.70^{g}	851.62 ± 21.21^{h}
K	751.76 ± 11.08^{a}	871.28 ± 27.24^{cd}	886.93 ± 8.93^{cd}	921.63 ± 22.80^{d}	761.42 ± 28.66^{a}	858.60 ± 5.22^{bc}	911.21 ± 25.91^{cd}	763.14 ± 44.74^{a}	814.14 ± 40.75^{b}	890.93 ± 41.27^{cd}

*n = 3, ± standard deviation, $^{a, b, c}$differences in storage time of the same sample in the same column at $p < 0.05$, $^{A, B, C}$samples (Control, F1, F2) show significant differences in the same column at $p < 0.05$.

indicated that the coatings had an effect on the magnesium content.

Sodium (Na) content was measured as 317.34, 492.28, and 735.21 mg/kg in control, F1, and F2 samples on day 15, respectively. On day 45, these values increased to 337.37, 584.14, and 851.62 mg/kg in control, F1, and F2 samples, respectively ($p < 0.05$). In the F1 and F2 coated samples, the sodium content was initially significantly higher than in the control sample ($p < 0.05$). This may have been due to the sodium-containing ingredients used in the coating process. Although an increase in sodium content was observed, this increase did not exceed the daily sodium intake recommendations. The effects of the coating process on sodium content should be considered as part of the nutrient profile of the product but do not pose a significant health risk.

Cd, Co, Pb, and Cr values were not detected in the samples. Cu content was similar in all samples and ranged between 0.98 mg/kg and 1.57 mg/kg. Ni content was 0.37, 0.56, and 0.66 mg/kg in control, F1, and F2 samples on day 15 and 0.38, 0.66, and 0.78 mg/kg on day 45, respectively. Mn content was measured as 2.06, 3.15, and 2.09 mg/kg in control, F1, and F2 samples on day 15 and 2.12, 3.75, and 2.45 mg/kg on day 45, respectively. K content was 871.28, 761.42, and 763.14 mg/kg in control, F1, and F2 samples on day 15 and 921.63, 911.21, and 890.93 mg/kg on day 45, respectively. K content remained at similar levels during storage, but the control sample showed higher values than the coated samples on other days ($p < 0.05$). Aluminum (Al) content ranged between 2.39 and 4.78 mg/kg and showed no significant difference during storage.

In the study by Nakilcioğlu-Taş *et al.* (2018), the mineral matter ratios in mulberry pestils produced with 100% starch were determined as follows: Ca 123.2 mg/kg, Fe 39.73 mg/kg, K 208.85 mg/kg, Mg 37.59 mg/kg, Na 163.45 mg/kg, Zn 33.53 mg/kg, and P 563.70 mg/kg. These results provide a basis for comparing the mineral contents in pestil samples.

Protein and hydroxymethylfurfural values

The protein and HMF analysis results of the samples are presented in Figure 2. The protein content obtained on the first day of storage was 2.78 g/100 g and the HMF content was 10.36 mg/kg. Analyses performed during storage showed that the HMF values of the pestil samples were well below the maximum limit of 50 mg/kg set by the Turkish Standards Institute (TSI) (Turkish Standards Institution, 2000). This shows that the HMF content of our samples complies with the standards and does not pose a health risk.

Exceeding the standards of HMF content may cause quality and nutritional losses in food and may threaten human health. It should also be kept in mind that the amount of HMF may increase in a short time, depending on the storage temperature. In our study, it was found that the amount of HMF increased in the control sample during storage, and this increase was significant at 15-day intervals ($p < 0.05$). At the end of day 45, the HMF value of the control sample was 20.91 mg/kg. In longer storage periods, the HMF value may exceed the standards.

The amount of HMF in the coated samples increased in the first 15 days ($p < 0.05$), but no significant change was observed in the following days. At the end day 45, the HMF value was 16.07 mg/kg in sample F1 and 16.35 mg/kg in sample F2. This indicates that the coating process prevented the increase in the amount of HMF and

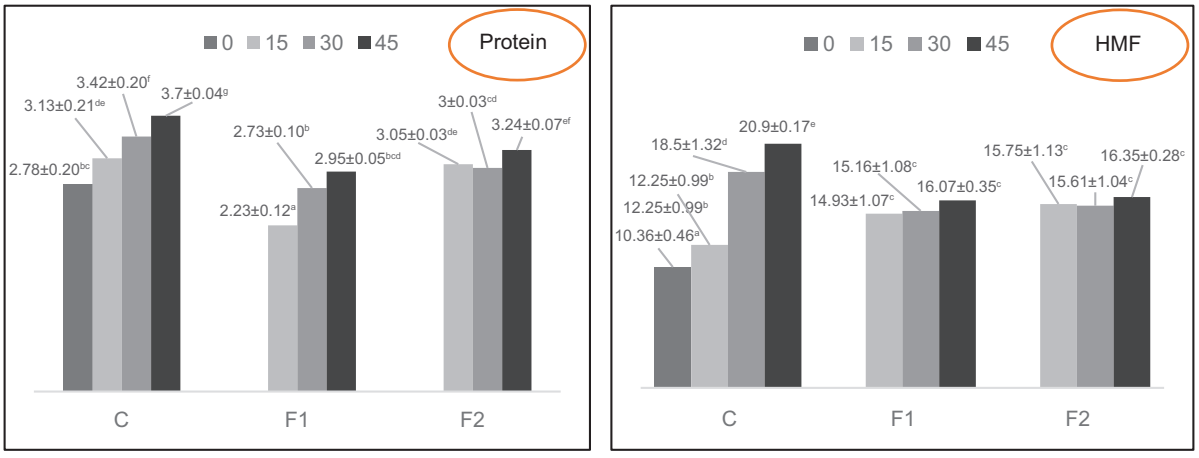

Figure 2. Protein and HMF analysis data of uncoated (control) and coated (F1, F2) pestils after 15, 30, and 45 days of storage. *n = 3, (±) standard deviation, $^{a, b, c}p < 0.05$ indicates significant differences in samples for protein and HMF analysis.

slowed down the oxidation processes by limiting the contact of the pestil with oxygen. The removal of oxygen, which promotes the Maillard reaction, may reduce the formation of HMF.

The Maillard reaction occurs through interactions between carbohydrates and proteins and occurs during heat treatments. Therefore, oxidation and reduction of proteins can also have an impact on HMF formation. In this regard, it is important to study the protein content in detail to understand the formation and variation of HMF in pestil samples. Indeed, a significant correlation was observed between the HMF content and protein values, suggesting that changes in protein levels may influence HMF formation.

According to the results of protein analysis, the protein values on days 15 and 45 for control, F1, and F2 samples were 3.12 g/100 g and 3.70 g/100 g, 2.23 g/100 g and 2.95 g/100 g, and 3.05 g/100 g and 3.24 g/100 g, respectively. On day 0, the protein content increased significantly ($p < 0.05$) in the control and F2 samples but not in the F1 sample. This increase at the end of storage may be due to the increase in dry matter content of the samples. In addition, the protein content of the control sample was higher than that of the coated samples at the end of storage. The protein values of the F2 sample were also higher than those of the F1 sample. Based on this situation, we can say that the coating process and formulation are effective in reducing protein content. Contrary to our study, Eyiz (2019) found that the protein values of the control group and coated samples were statistically similar.

The findings obtained in other studies are as follows: Yüksel *et al*. (2020) determined the protein and HMF values of mulberry pestil at 5.14 g/100 g and 11.64 mg/kg; Levent and Yüksel (2022) 5.87 g/100 g and 3.95 mg/kg; and Nakilcioğlu-Taş *et al*. (2018) 1.23 g/100 g and 23.29 mg/kg, respectively. In another study, it was reported that HMF contents in Gümüşhane pestils were between 22.45 and 25.27 mg/kg (Baltacı *et al*., 2016). Yıldız (2013) also found the HMF value of the pestil sample as 27.94 mg/kg in his study. Yüksel *et al*. (2020) determined the HMF values of the samples between 11.64 and 21.55 mg/kg.

Microscopic analysis

The thickness of the pestil used in this study was measured as 0.97 ± 0.04 mm (Figure 3A and B). The total thickness of sample F1, which was coated with SA, together with the coating material, was 1.42 ± 0.07 mm. In this sample, the thickness of the pestil itself was 1.00 ± 0.10 mm, and the coating thickness was 0.42 ± 0.10 mm (Figure 3C and D). In sample F2, which was coated with a mixture of gelatin and SA, the total thickness was 1.50 ± 0.11 mm, the thickness of the pestil was 1.00 ± 0.10 mm, and the coating thickness was 0.50 ± 0.09 mm (Figure 3E and F).

The difference in coating thicknesses in samples F1 and F2 may be due to the differences in the formulation of the coating solutions. The study by Sipahi *et al*. (2013) showed that there were significant differences in the thicknesses of coatings made with different concentrations of SA and other components. In particular, it was reported that higher concentrations of SA formed thicker coatings, but these thicknesses may not show a homogeneous distribution (Tapia *et al*., 2008).

In our study, although the pestil samples were turned upside down every two days, it was observed that the coating thickness was slightly less on the lower parts. This may be due to factors such as the effect of gravity and uneven distribution of the coating solutions on the surface of the pestil. It is also thought that the viscosity of the coating solutions and application methods may affect the coating thickness. Further investigation of these factors in future studies may help to provide more consistent coating thicknesses.

Sensory analysis

Sensory analysis plays a critical role in understanding how food is perceived and accepted by consumers; hence, sensory evaluation was carried out to assess the effect of the coating process on pestil. This analysis was performed on samples stored under room conditions after 15 days. Parameters such as color, odor, stickiness, chewiness, flavor, and hardness were evaluated by panelists, and the results are presented in Figure 4. Sensory analysis could not be conducted on day 30 and day 45 because the samples stored at room conditions had dried out, making them unsuitable for evaluation. Further studies could explore methods to extend the sensory shelf life of pestil beyond 15 days.

When the color data were examined, the panelists rated the pestil in the control group as lighter (2.8) on day 15, while the F1 (4.3) and F2 (4.0) samples were found to be darker. This difference can be attributed to the color of the coating solutions: the grape seed oil was greenish and the SA solution was yellow. At the end of 30 days, the color of the pestil in the control group darkened to 3.9. This may be due to enzymatic browning that occurred during the storage period. In contrast, the color values of the coated samples remained stable throughout the storage period.

In the odor evaluation, the control sample was found to have a slight fruity odor on days 15 and 30 (2.3, 2.3), while

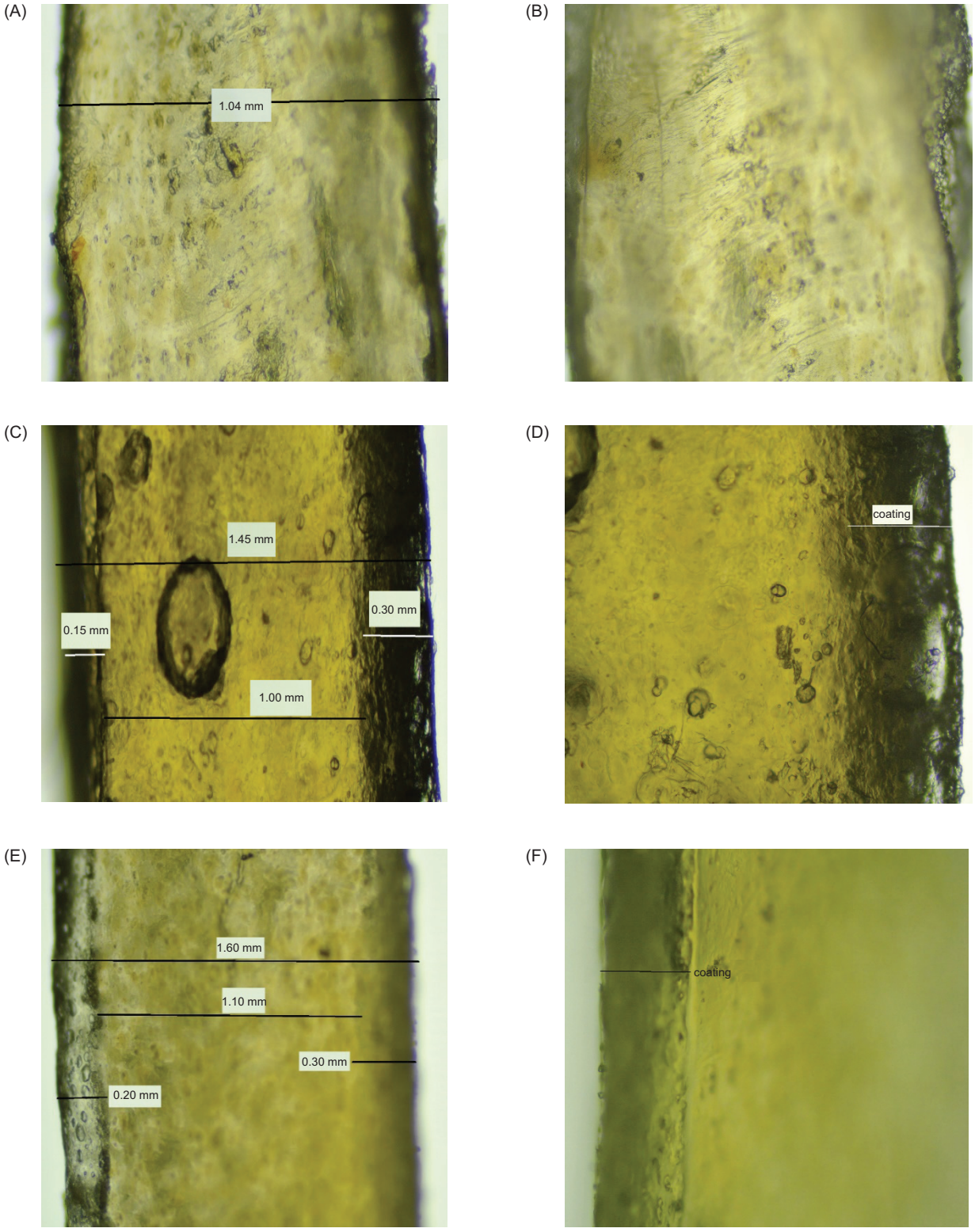

Figure 3. Microscope image of uncoated (control) and coated (F1, F2) pestils. (A) Control sample (4 × 10 magnification) (B) Control sample (10 × 10 magnification) (C) F1 film coating (4 × 10 magnification) (D) F1 film coating (10 × 10 magnification) (E) F2 film coating (4 × 10 magnification) (F) F2 film coating (10 × 10 magnification).

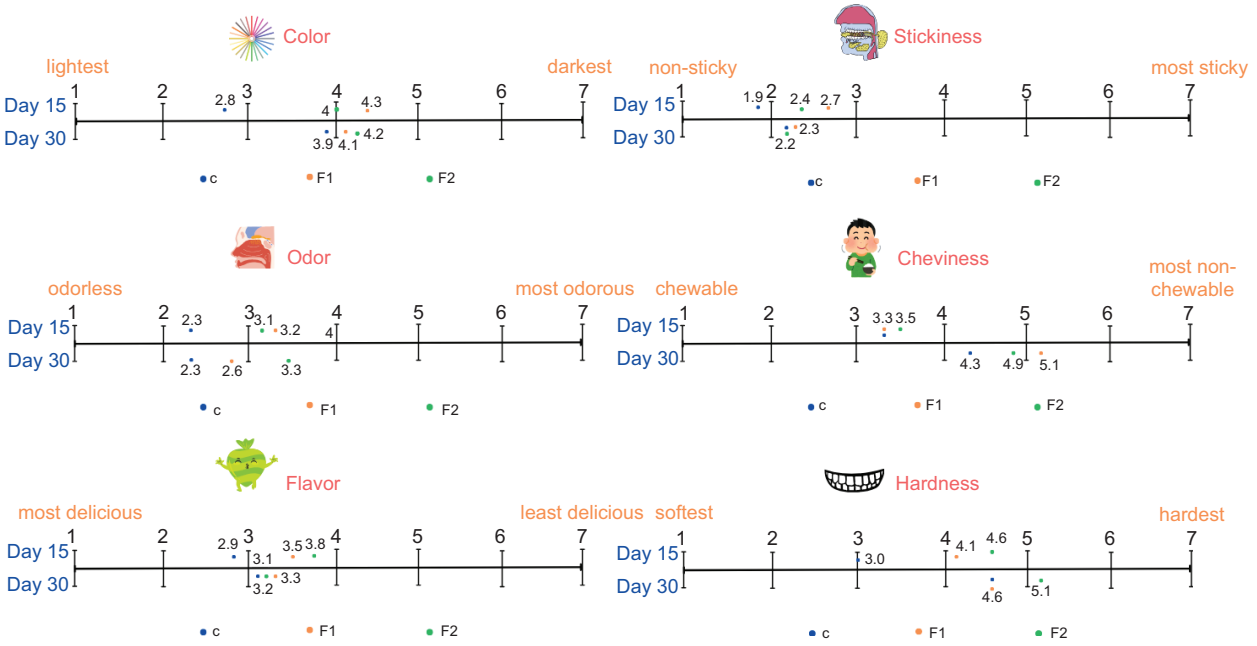

Figure 4. Sensory evaluation results.

samples F1 (3.2, 2.6) and F2 (3.1, 3.3) were reported to have a slight chemical odor. This suggests that the coating solutions changed the natural odor of the pestil. When 15- and 30-day stickiness data were analyzed, it was determined that control (1.9, 2.2), F1 (2.3, 2.7), and F2 (2.2, 2.4) samples were slightly sticky. In terms of chewability, while the control, F1, and F2 samples had similar values on the 15th day (3.3, 3.3, 3.5), these values increased to 4.3, 5.1, and 4.9 on the 30th day, respectively. The difficulty in chewability during the storage period may be attributed to the drying of the products through moisture loss. On the flavor scale, the pestils scored between 3 and 4 overall, indicating that the coating did not greatly affect the flavor. This finding suggests that the coating was effective in maintaining the original flavor of the product.

In the hardness evaluation, the hardness values of the control, F1, and F2 samples were found to be 3.0, 4.1, and 4.6, respectively, on day 15. On the 30th day, these values increased to 4.6 in the control sample, while they were 4.6 and 5.1 in the F1 and F2 samples, respectively. It was observed that the coating process increased the hardness of the F2 sample in particular. This may be due to the coating process supporting the structural integrity of the pestil. In addition, the hardness of the control sample increased in the later part of storage. This hardening may be related to moisture loss in the pestil.

Conclusion

Coating pestil with SA, gelatin, and grape seed oil effectively maintained its quality during the first 15 days, particularly by reducing moisture loss. Among the coating materials tested, gelatin-based coatings were found to be the most effective in preserving moisture and preventing drying. The coated pestils exhibited brighter and more vivid colors compared to the control samples, suggesting that the color pigments in the coating solutions may have contributed to the enhanced appearance. Additionally, the coating process led to an increase in the mineral content of the pestils, with higher levels of iron, calcium, and sodium detected. Moreover, the coating significantly reduced the formation of HMF in the pestils, which is a sign of protection against oxidation and a preservation of quality. Further studies should focus on optimizing coating formulations, evaluating the effects of long-term storage on quality, and improving the sensory properties to enhance the commercial viability of pestil and similar products.

Author Contribution

The author contributed to the planning and conducting of the research, editing of the manuscript, literature review, and interpretation of the results.

Conflict of Interest

The author declares that there is no conflict of interest.

Funding

There is no funding for the study.

References

Altuğ T, Elmacı Y. 2005. "Gıdalarda Duyusal Değerlendirme" Meta Printing Services, Bornova-İzmir, Turkey.

Alvarado-González JS, Chanona-Pérez JJ, Welti-Chanes JS, Calderón-Domínguez G, Arzate-Vázquez I. Pacheco-Alcalá SU, et al. Optical, microstructural, functional and nanomechanical properties of Aloe Vera gel/gellan gum edible films. Rev Mex Ing Quim. 2021;11(2):193–210.

Antoniewski MN, Barringer SA, Knipe CL, Zerby HN. Effect of gelatin coating on the shelf life of fresh meat. J Food Sci. 2007;72(6):382–7. https://doi.org/10.1111/j.1750-3841.2007.00430.x

Atıcı G, Fenercioğlu H. Erik pestilinin kalite parametreleri ve kuruma davranışı üzerine 'sıcak havalı kurutma ve mikrodalga kurutma' yöntemlerinin etkisinin belirlenmesi üzerine bir araştırma. Çukurova Üniv Fen Mühendis. Bilim Derg. 2014;31(3):23–32.

Babalola SA, Ashaye OA, Babalola AO, Aina JO. Effect of could temperature storage on the quality attributes of pawpaw and guava leathers. African J Biotechnol. 2002;1(2): 61–3. https://doi.org/10.5897/AJB2002.000-011

Baltacı C, Akşit Z. Validation of HPLC method for the determination of 5-hydroxymethylfurfural in pestil, köme, jam, marmalade, and pekmez. Hittite J Sci Eng. 2016;3(2):91–7. https://doi.org/10.17350/HJSE19030000037

Baltacı C, İlyasoglu H, Gündogdu A, Üçünçü O. Investigation of hydroxymethylfurfural formation in herle. Int J Food Prop. 2016; 19:2761–8. https://doi.org/10.1080/10942912.2016.1144612

Borchard W, Kenning A, Kapp A, Mayer C. Phase diagram of the system sodium alginate/water: A model for biofilms. Int J Biology Macromol. 2005;35(5):247–56. https://doi.org/10.1016/j.ijbiomac.2005.02.006

Cağındı O, Ötleş S. Comparison of some properties on the different types of pestil: A traditional product in Turkey. Int J Food Sci Technol. 2005;40(8):897–901. https://doi.org/10.1111/j.1365-2621.2005.00962.x

Eyiz V. 2019. The effect of edible fılms on physical chemical and sensory characteristics of fruit and cereal bars. Necmettin Erbakan University. Ms. thesis, Konya, Türkiye.

Galus S, Lenart A. Development and characterization of composite edible films based on sodium alginate and pectin. J Food Eng. 2013;115(4):459–65. https://doi.org/10.1016/j.jfoodeng.2012.03.006

Garavaglia J, Markoski MM, Oliveira A, Marcadenti A. Grape seed oil compounds: Biological and chemical actions for health. Nutr Metab Insights. 2016;9:59–64. https://doi.org/10.4137/NMI.S32910

Kara OO, Küçüköner E. Geleneksel bir meyve çerezi: Pestil. Akademik Gıda 2019;17(2): 260–8. https://doi.org/10.24323/akademik-gida.613621

Kim SRB, Choi YG, Kim JY, Lim ST. Improvement of water solubility and humidity stability of tapioca starch film by incorporating various gums. LWT – Food Sci Technol. 2015;64 (1):475–82. https://doi.org/10.1016/j.lwt.2015.05.009

Levent O, Yüksel F. The investigatıon of certain physico-chemical, color, bioactive and sensory properties of mulberry pestils enriched with buckwheat (*Fagopyrum esculentum*) flour. KSU J Eng Sci. 2022;25(4):714–23. https://doi.org/10.17780/ksujes.1160294

Lisitsyn A, Semenova A, Nasonova V, Polishchuk E, Revutskaya N, Kozyrev I, et al. Approaches in animal proteins and natural polysaccharides application for food packaging: Edible film production and quality estimation. Polymers. 2021;13(10):1592. https://doi.org/10.3390/polym13101592

Liyanapathiranage A, Dassanayake RS, Gamage A, Karri RR, Manamperi A, Evon P, et al. Recent developments in edible films and coatings for fruits and vegetables. Coatings. 2023;13:1177. https://doi.org/10.3390/coatings13071177

Lu Y, Luo Q, Chu Y, Tao N, Deng S, Wang L, et al. Application of gelatin in food packaging: A review. Polymers. 2022;14(3):436. https://doi.org/10.3390/polym14030436

Maiti S, Singha K, Ray S, Dey P, Sa B. Adipic acid dihydrazide treated partially oxidized alginate beads for sustained oral delivery of flurbiprofen. Pharm Dev Technol. 2009;14(5): 461–70. https://doi.org/10.1080/10837450802712658

Nakilcioğlu-Taş E, Çakaloğlu B, Ötleş S. The determination of some physical, chemical and sensory properties of pestil containing carob flour at different ratio. Turkish J Agric – Food Sci Technol. 2018;6(8):945–52. https://doi.org/10.24925/turjaf.v6i8.945-952.1445

NordVal International c/o Institute of Marine Research NMKL 161. 1998. Determination by Atomic Absorption Spectrophotometry after Wet Digestion in a Microwave Oven. NMKL – NordVal International c/o Institute of Marine Research PO Box 1870 Nordnes 5817 Bergen, Norway.

Ojeda GA, Sgroppo SC, Zaritzky NE. Application of edible coatings in minimally processed sweet potatoes (Ipomoea batatas L.) to prevent enzymatic browning. Int J Food Sci Technol. 2014;49:876–83

Phuong HMK, Hoa NDH, Ha NVH. Effects of added pectin amounts and drying temperatures on antıoxidant propertıes of mulberry fruit leather. J Biotechnol. 2016;14(1A):487–95.

Quek SY, Chok NK, Swedlund P. The physicochemical properties of spray-dried watermelon powders. Chem Eng Process: Process Intensification 2007;46(5):386–92. https://doi.org/10.1016/j.cep.2006.06.020

Ragab Abdallah M, Mohamed MA, Mohamed H, Emara MT. Application of alginate and gelatin-based edible coating materials as alternatives to traditional coating for improving the quality of pastırma. Food Sci Biotechnol. 2018;27(6):1589–97. https://doi.org/10.1007/s10068-018-0393-2

Şengül M, Ünver H. Some physicochemical properties of cornelian cherry pestils produced using different sweeteners. ATA-Food J. 2022;1(1):1–6.

Şengül M, Karataş N, Zor M, Topdas EF, Yilmaz B. Screening of the chemical composition and antioxidant activity of the prunus salicina Pestil. Erzincan Univ J Sci Technol. 2020;13(3):1317–33. https://doi.org/10.18185/erzifbed.829149

Sipahi RE, Castell-Perez ME, Moreira RG, Gomes C, Castillo A. Improved multilayered antimicrobial alginate-based edible coating extends the shelf life of fresh-cut watermelon (*Citrullus lanatus*). LWT – Food Sci Technol. 2013;51(1):9–15. http://dx.doi.org/10.1016/j.lwt.2012.11.013

Tapia MS, Rojas-Grau MA, Carmonac A, Rodriguez FJ, Soliva-Fortuny R, Martin-Belloso O. Use of alginate- and gellan-based coatings for improving barrier, texture and nutritional properties of fresh-cut papaya. Food Hydrocoll. 2008;22(8):1493–1503. https://doi.org/10.1016/j.foodhyd.2007.10.004

Turkish Standards Institution TS 12677. 2000. Spread Dried Mulberry. Turkish Standards Institution, Ankara (24.10.2000).

Turkish Standards Institution TS 1728 ISO 1842. 2001a. Fruit and Vegetable Products – Determination of pH. Turkish Standards Institution, Ankara (15.02.2001).

Turkish Standards Institution TS 2131 ISO 928. 2001b. Spices and Condiment – Determination of Total Ash. Turkish Standards Institution, Ankara (30.01.2001).

Turkish Standards Institution TS 1125 ISO 750. 2002. Fruit and Vegetable Products – Determination of Titratable Acidity with a Potentiometric Reference Method. Turkish Standards Institution, Ankara (07.03.2002).

Turkish Standards Institution TS 1620. 2016. Macaroni. Turkish Standards Institution, Ankara (18.02.2016).

Turkish Standards Institution TS 9131/T3. 2021. Cezeriye (Turkish Special Carrot Sweet). Turkish Standards Institution, Ankara (30.09.2021).

Yavaş O, Sengul M, Zor M. Changes in some physical and chemical properties of black mulberry (Morus nigra L.) concentrate during storage. J Food Process Preserv. 2023(1):13. https://doi.org/10.1155/2023/2802241

Yavuz B. 2019. Farklı unlar kullanılarak hazırlanan pestillerin fizikokimyasal, biyoaktif, reolojik ve duyusal özellikleri ile optimizasyonun belirlenmesi. Ms. thesis, Gümüşhane University, Gümüşhane, Türkiye.

Yıldız O. Physicochemical and sensory properties of mulberry products: Gümüşhane pestil and köme. Turk J Agric For. 2013;37:762–71. https://doi.org/10.3906/tar-1301-41

Yılmaz FM, Yüksekkaya S, Vardin H, Karaaslan M. The effects of drying conditions on moisture transfer and quality of pomegranate fruit leather (pestil). J Saudi Soc Agric Sci. 2017;16(1): 33–40. https://doi.org/10.1016/j.jssas.2015.01.003

Yüksel F, Yavuz B, Baltacı C. Investigation of some physicochemical, color and sensory properties of mulberry pestils enriched with coconut flour. GUSTIJ. 2020;10(1): 43–50. https://doi.org/10.17714/gumusfenbil.545872