DOI: 10.29050/harranziraat.517742
Harran Tarım ve Gıda Bilimleri Derg. 2019, 23(3): 313-323

Research Article/Araştırma Makalesi

# Effect of pectin-wax coating on the quality of fresh-cut apples

## *Pektin-vaks kaplamanın taze kesilmiş elma kalitesi üzerine etkisi*

**Dima Al HABBAL[1], Hatice Neval ÖZBEK[1*], Derya KOÇAK YANIK[1], Fahrettin GÖĞÜŞ[1]**

[1]University of Gaziantep, Engineering Faculty, Department of Food Engineering, 27310 Gaziantep, Turkey

***To cite this article:***
Habbal, D.A., Özbek, H.N., Koçak Yanık, D. & Göğüş, F. (2019). effect of pectin-wax coating on the quality of fresh-cut apples. Harran Tarım ve Gıda Bilimleri Dergisi, 23(3): 313-323.
DOI:10.29050/harranziraat.517742

***Address for Correspondence:***
*Hatice Neval ÖZBEK*
***e-mail:***
haticeneval@gantep.edu.tr

***Received Date:***
25.01.2019
***Accepted Date:***
21.06.2019



**ABSTRACT**

The effect of edible coating using pectin-wax mixture and its incorporation with pistachio hull extract were investigated on the quality characteristics of fresh-cut apples. For this purpose, fresh-cut apples were treated with citric acid (control), pectin-wax (PW) mixture and pectin-wax mixture containing pistachio hull extract (PWE). The samples were kept under two separate temperatures at 5 °C for 8 days and at 20 °C for 32h. Changes in weight, color, total phenolic content, were examined at different time points along storage time. Results indicated that the apple pieces coated with PWE showed the lowest increase in browning index followed by samples coated with PW. The applications of coatings were effective on delaying the degradation of samples' colors. The effect of coating fresh-cut apples with PWE was less pronounced on a* values than on L* and b* values. Furthermore coating with PW was affected L* values significantly. The temperature was also a factor affecting the samples color. It was observed that samples kept at 5 °C have maintained the color coordinates. Weight loss was observed significantly in uncoated samples comparing to those prepared with coating. The weight losses were 4.77±0.21% and 6.60±0.24% at 20 °C, while these values were 17.29±0.54 and 26.81±0.60 at 5 °C for coated and uncoated samples respectively. The coatings were effective in maintaining phenolic components. Total phenolic contents were 187.86±0.95 and 199.80±0.99 mg GAE 100 $g^{-1}$ apple at 5°C for uncoated and coated sample with pistachio hull extract, respectively. However, phenolic contents were recorded as 128.89±0.80 and 130.53±0.86 mg GAE 100 $g^{-1}$ apple after 32 h storage time at 20 °C for uncoated and coated sample with pistachio hull extract, respectively.

**Key Words:** Fresh-cut apple, Browning, Color parameters, Pectin, Wax

**ÖZ**

Pektin-mum (vaks) (PW) karışımı ve bu karışımın antepfıstığı kabuğu ekstraktı ile birleştirilmesinden oluşan yenilebilir film kaplamanın, taze kesilmiş elmaların kalite özellikleri üzerindeki etkisi incelenmiştir. Bu amaçla taze kesilmiş elmalar, sitrik asit (kontrol), pektin-mum (vaks) (PW) karışımı ve antepfıstığı kabuğu ekstraktı içeren pektin-mum (vaks) (PWE) karışımı ile muamele edilmiştir. Örnekler 5 ° C'de 8 gün ve 20 ° C'de 32 saat olmak üzere iki ayrı sıcaklıkta depolanmıştır. Depolama süresi boyunca farklı zaman aralıklarında ağırlık, renk, toplam fenolik içeriğinde meydana gelen değişiklikler incelenmiştir. Esmerleşme indeksinde en düşük artışı fıstık kabuğu ekstraktı içeren pectin-mum (vaks) ile kaplanmış elma parçaları göstermiş, onu pektin-mum (vaks) ile kaplanmış örnekler takip etmiştir. Uygulanan kaplamalar örneklerin renklerinde meydana gelen bozulmayı engellemede etkili olmuştur. Taze kesilmiş elmaların fıstık kabuğu ekstraktı içeren pektin-mum (vaks) ile kaplanması L * ve b * değerlerine göre *a değeri üzerinde daha az etkili olmuştur. Ek olarak pektin-mum (vaks) ile kaplama L* değerlerini önemli ölçüde etkilemiştir. Sıcaklık örneklerin rengini etkileyen diğer bir faktördür. 5 °C sıcaklıkta saklanan örneklerin renklerini korudukları gözlemlenmiştir. Kaplanmamış örneklerde kaplanmış örneklere kıyasla önemli ölçüde ağırlık kaybı gözlenmiştir. Ağırlık kaybı kaplanmış ve kaplanmamış örnekler için sırasıyla 20 ° C'de % 4.7 ±0.21 ve % 6.60±0.24 iken, bu değerler 5 ° C'de 17.29 ± 0.54 ve 26.81 ± 0.60 idi. Kaplamalar fenolik bileşenlerin korunmasında etkili olmuştur. Toplam fenolik içeriği fıstık kabuğu ekstresi ile kaplanmış ve kaplanmamış örnekler için sırasıyla 5 ° C'de 187.86 ± 0.95 ve 199.80 ± 0.99 mg GAE 100 $g^{-1}$

elma idi. Ancak toplam fenolik içeriği 20 ° C'de 32 saat depolama süresinden sonra fıstık kabuğu ekstresi ile kaplanmış ve kaplanmamış örnekler için sırasıyla 128.89±0.80 ve 130.53±0.86 mg GAE 100 $g^{-1}$ olarak kaydedildi.

**Anahtar Kelimeler:** Taze kesilmiş elma, Esmerleşme, Renk parametreleri, Pektin, Mum (vaks)

## Introduction

Food packaging is a process that demands science, art and technology of protecting edible goods when these three are combined, the product is ready for sale or to be shipped. Ready-to-eat (RTE) is a trendy food and increasingly has been used in modern lifestyle. Popularity of RTE food types is growing, especially amongst women who are preoccupied with activities outside. Ongoing efforts to provide the best options to mitigate the challenges of shelf-life extension for these kinds of food. Many studies are trying to produce new technologies and preservation procedures, which include bringing them in line with the increasing volume of purchasing (Manalili et al., 2011).

Recently, edible coating applications have been under intentness for their great role into promoting product shelf-life. It is an altenative to reduce the deterioration caused by minimal processing of fresh fruits (León-Zapata et al., 2015). Edible coatings provide semipermeable barrier to extend the shelf-life of fresh-cut products by reducing the migration of moisture and solute, transmission of gas, maturation process and oxidative reaction rates (Perez-Gago et al., 2005). Their protective function may also be enhanced with the addition of antioxidants, antimicrobials, colorants, flavors, nutrients and etc. In this way, they may also act as carriers of food additives (Robles-Sánchez et al., 2013).

Apples are extremely rich in important antioxidants, flavonoids, and dietary fiber (Du et al., 2019). It is also one of the most consumable fruits internationally (Carbone et al., 2011). Turkey is one of the biggest producer of apple with the annual production of 3,032,164 tonnes (FAO, 2019). In respect of apple importance, the apple fruit has been engaged into the experimental design to apply the technique of coating.

Pistachios (*Pistacia vera* L.) fruit is well known for its oleaginous and edible seed. Less information is available about the hull constituted by the epicarp and the mesocarp. This part of the fruit contains an essential oil that can be valorized (Chahed et al., 2007). Turkey is the second largest pistachio producer after United States with the annual production of 155,000 tonnes (USDA, 2017). Organic hull is covering the harvested pistachio fruit. A key by-product from pistachio is produced from essential process after harvesting called dehulling (remove the organic hull) applied on the pistachio fruit (Pineiro, 2001). Dry matter of dehulling process is a great source of antioxidant, phenolic compounds and essential oil such as α-pinene and alpha terpinolene (Özel et al., 2004; Goli et al., 2005). Moreover, green hull is a good source of protein, fat, mineral salts and vitamins (Goli et al., 2005; Chahed et al., 2008).

The aim of the present study is to formulate a new edible coating using pectin-wax mixture and its incorporation with pistachio hull extract to enhance the coating process efficiency and quality attributes of fresh-cut apples.

## Material and Methods

### *Materials*

Pectin APA 168 DB powder and carnauba wax were procured from Cagdas Kimya (Istanbul, Turkey). Folin-Ciocalteau phenol reagent, citric acid (CA), gallic acid, sodium carbonate ($Na_2CO_3$) and other chemicals were purchased from Sigma-Aldrich Corp. (St. Louis, Mo., U.S.A.).

### *Coating formulations*

Two different coating mixtures were prepared to coat the fresh fruit cuts. Wax solution (40 %, w/v) (mixture 1) was prepared through mixing 10 g wax-flakes in 250 ml heated water using a hot plate (Isolab, 613.01.001, Germany) at 80±5 °C. After wax started softening a homogenizer was used to get a homogeneous solution at 15000 rpm for 15 min using IKA® ULTRA-TURRAX® T18 Homogenizer (Staufen, Germany). Pectin solution (80 %, w/v) (mixture 2) was prepared by dissolving 20 g powdered pectin into 250 ml water at 80±5 °C throughout bain marie. Then, the solution stirred at 300 rpm for 30 min using a homogenizer.

Mixture 1 added to mixture 2 at 80±5 °C on a hot plate. Then 15 minutes stirring applied at 15000 rpm and the first coating material pectin-wax (PW) solution was formed. Finally, the solution was cooled to room temperature and then used immediately.

Pistachio hull extract was obtained to prepare pectin-wax mixture containing pistachio hull extract (PWE). 10 g of dried and powdered pistachio hull was extracted with 250 mL of 50 % ethanol (v/v) for 2 h at 60 °C in a rotary incubator (New Brunswick Scientific, Nova 40, Edison, NJ, USA). At the end of the extraction, the mixture was centrifuged at 6000 rpm for 15 min (Hettich-EBA 20, Andreas Hettich GmbH & Co. KG, Germany) and the supernatant was collected. Subsequently, the supernatant was concentrated at 40 °C under vacuum using a rotary vacuum evaporator (Heidolph Instrument GmbH & Co. KG, Schwabach, Germany) and the concentrated extract was subjected to the liquid-liquid extraction with ethyl acetate (1:1, v:v) to get a purified extract. Then, the ethyl acetate fraction was collected and the solvent was evaporated at 40 °C under vacuum.

1 g of pistachio hull extract was added to the solution after the addition of mixture 1 to mixture 2 using the same method as described above to form the second coating solution (PWE).

*Fruit selection and preparation*

The green uniform sized, defect-free apples (Granny Smith) were purchased from local market. The fresh apples stored at 4°C before processing. The apples were washed, peeled and cut into square pieces (approximately 2.5cm × 2.5cm × 0.7cm). A sharp stainless-steel knife was used throughout the process to reduce mechanical bruising and samples were processed in a temperature-controlled room at 20±1°C. The fresh-cut pieces immersed into a 100 mg $l^{-1}$ citric acid solution (pH≈3) for 5 min before coating process in order to avoid the enzymatic browning. After draining, the fresh-cut apples were dipped into the coating solutions for 3 min and then all pieces drained over a metal mesh for 10 min. A maximum of 15 apples were processed at the same time to minimize excessive exposure to oxygen. Control samples were drained from citric acid and kept without any further treatment. Four apple pieces were placed in each foil tray, a total of 69 trays were prepared for all treatments. All trays were covered with plastic wrap. Finally, samples were stored under two different temperatures; 5±2°C and 20±2° C for 8 days and 32 h, respectively.

*Weight loss determination*

The weight of samples was measured at time 0 and at the different sampling times for both storage conditions and treatments by weighing three trays containing for apple pieces. Results were expressed as the percentage loss of initial weight (%) for non-coated and coated samples. The weight loss (%) on wet basis (wb) of samples was defined through the following linearized form of the Peleg equation:

$$\text{Weight Loss (\%)} = \frac{W_{L_t} - W_{L_o}}{W_{L_o}} \times 100 \qquad (1)$$

Where; $W_{Lt}$ = weight of the sample at any point (g) and $W_{L0}$ = initial weight of the sample (g).

*Color measurements*

The color measurements were made periodically by a HunterLab ColorFlex instrument (Hunter Associates Laboratory, Inc., Reston, VA, USA) for each treatments and storage conditions using the CIELAB color parameters, L*, a*, and b*. Each measurement was taken at three locations for each apple piece. A Minolta standard white calibration plate was used for the calibration of colorimeter. Furthermore, the results were reported as browning index (BI) using the following formula:

$$BI = \frac{(x-0.31)}{0.172} \times 100 \quad (2)$$

Where:

$$x = \frac{(a^*+1.75L^*)}{(5.645L^*+a^*-3.012b^*)} \quad (2.1)$$

Also, the total color difference (ΔE (Eq. (3)), chroma C* (Eq. (4)), Hue angle (Eq. (5)) were calculated from the Hunter L*, a*, b* values and used to describe the color changes during storage.

$$\Delta E = \sqrt{(L_o - L^*)^2 + (a_o - a^*)^2 + (b_o - b^*)^2} \quad (3)$$

Where symbol "$_o$" in ΔE refers to the color reading of fresh apples.

$$Chroma = \left(a^{*2} + b^{*2}\right)^{½} \quad (4)$$

$$Hue\ angle = \tan\left(\frac{b^*}{a^*}\right)^{-1} \quad (5)$$

*Total phenolic contents*

The total phenolic content (TPC) of noncoated sample (NCS) and the samples coated with extract (CSX) stored at 20 °C and 5 °C was determined at the end of the storage period using Folin-Ciocalteu method. The procedure reported by Song et al. (2010) was used at a wavelenght of 760 nm. TPC of samples was calculated using a gallic acid calibration curve. The results were expressed as gallic acid equivalent (mg GAE 100 $g^{-1}$ apple).

*Statistical analysis*

Effects of the coating on quality parameters were interpreted relating the coefficients of the parameters and corresponding p values. The p value below 0.05 indicates a confidence interval of 95%. For weight loss and total phenolic content experiments, two sample replicates were analyzed at each corresponding time whereas for color assessment three sample replicates were analyzed at each corresponding time. The least square (LS) means values were considered for all recorded data. XLSTAT (Microsoft® Excel® 2016 MSO (16.0.9226.2126) 46-bit.) was used to conduct Analysis of Variance (ANOVA).

## Results and Discussion

*Weight loss*

Average weight of the non-coated sample (NCS) and coated sample (CS) was recorded during storage period at 5 °C and 20 °C and weight loss (%) was calculated. Figure 1 and Figure 2 shows the weight loss of samples stored at 5 °C and 20 °C, respectively. Both coated and non-coated samples experienced a significant weight loss during storage time. The results indicated a dramatically lower percent weight loss in CS when compared to the NCS. The weight loss for CS (4.77±0.21%) was considerable different from the NCS (6.60±0.24%) after the storage period of 32 h at 20 °C. Similarly, the results showed a lower weight loss for CS (17.29±0.54) compared to NCS (26.81±0.60) after 8 days at 5 °C.

Fresh-cut products are highly vulnerable to lose weight since they have elevated water transpiration rates (Watada and Qi, 1999; Toivonen and Brummell, 2008). Therefore, edible coatings help to decrease water loss of fresh-cut products (Raybaudi-Massilia et al., 2008).

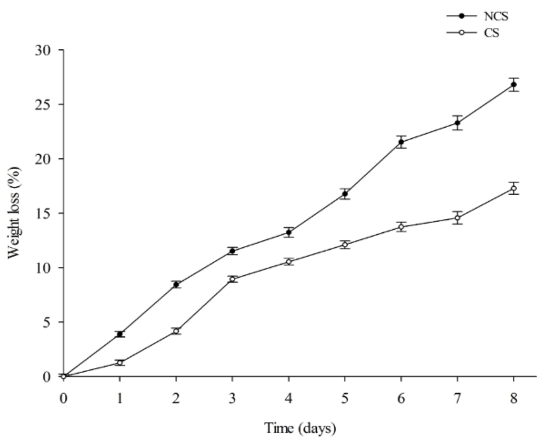


Figure 1. Effect of coating on weight loss of fresh-cut apples during storage at 5 °C. (NCS:Noncoated sample, CS: Coated sample)

*Şekil 1. Kaplamanın 5 °C'de depolama boyunca taze kesilmiş elmaların ağırlık kaybına etkisi. (NCS:Kaplanmamış örnek, CS: Kaplanmış örnek)*

The results of this study suggested a significant influence of the coating process to reduce the fresh weight loss thus extend the shelf life of treated samples with coating solution. The findings are in harmony with the results reported by Kraśniewska et al. (2014) who assessed the effects of pullulan coating on weight loss of pepper kept at 16°C for 14 and 28 days and apple at 16°C and 2°C for 14 and 28 days, respectively.

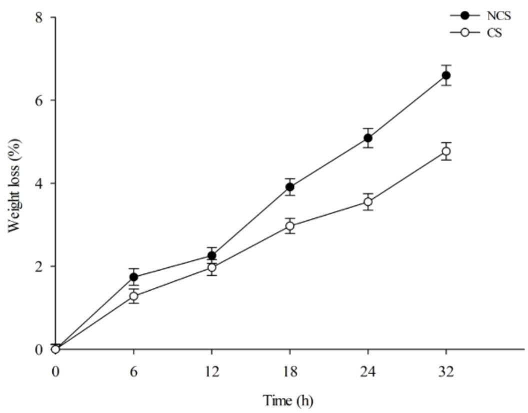


Figure 2. Effect of coating on percentage weight loss of fresh-cut apples during storage at 20 °C. (NCS:Noncoated sample, CS: Coated sample)

*Şekil 2. Kaplamanın 20 °C'de depolama boyunca taze kesilmiş elmaların yüzde ağırlık kaybına etkisi. (NCS:Kaplanmamış örnek, CS: Kaplanmış örnek)*

Their results showed that the coating process resulted extension of storage time by the means of preservation of weight and reduction of water transportation. It has been also reported that the use of lipids as a coating material decreases the weight loss (Kester and Fenema, 1986) in fruits as apples (Assis and Pessoa, 2004), mangoes (Hoa and Marie Noelle, 2008), green bell peppers (Beaulieu et al., 2009) and lemons (Bisen et al., 2012).

*Color change*

Fresh color of fruits and vegetables is enhancing the customers' appeal to consume the products. During storage, color change is one of the most important changes in fresh-cut fruit which directly affects perception of quality by customers (Olivas and Barbosa-Cánovas, 2005). In the study context, color measurements were an essential factor to evaluate the impact of coating process on cut-fresh apples. Further analysis was conducted after measuring the color coordinates L*, a* and b* for all coated and non-coated samples. A better understanding of the fluctuation of color coordinates was explored through calculating chroma, hue angle, browning index (BI) and ΔE-the color variation.

The coating treatment with pistachio hull extract had a significant negative effect ($p \leq 0.05$) on L* values; by the means of the lowest L* values (LS means=69.64) at the end of storage period at 5 °C (Figure 3). Whereas coated samples with PW showed the highest ability of maintaining L* (LS means=72.34) amongst the treatments followed by the CS (LS means=70.446). Significant differences were found between samples coated with PW compared to CSX ($p \leq 0.05$). No significant differences were observed between NCS and CS regarding L* values ($p=0.27$). As shown in Figure 3, the highest values of L* were observed for CS as followed by NCS and CSX at 20 °C, this might be explianed by the effect of the light brown color of pistachio hull extract that affect L* values and brightnees of samples.

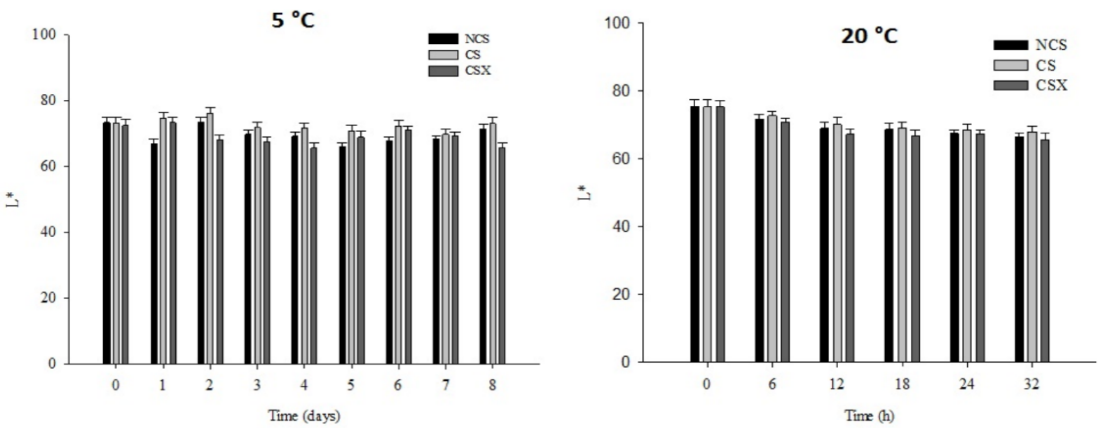


Figure 3. Effect of different apple coating applications on L* values during storage at 5 °C and 20 °C. (NCS:Noncoated sample, CS: Coated sample, CSX: Coated sample with extract)

*Şekil 3. Elmada farklı kaplama uygulamalarının 5 °C ve 20 °C'deki depolama boyunca L* değerlerine etkisi. (NCS:Kaplanmamış örnek, CS: Kaplanmış örnek, CSX: Ekstrakt ile kaplanmış örnek)*

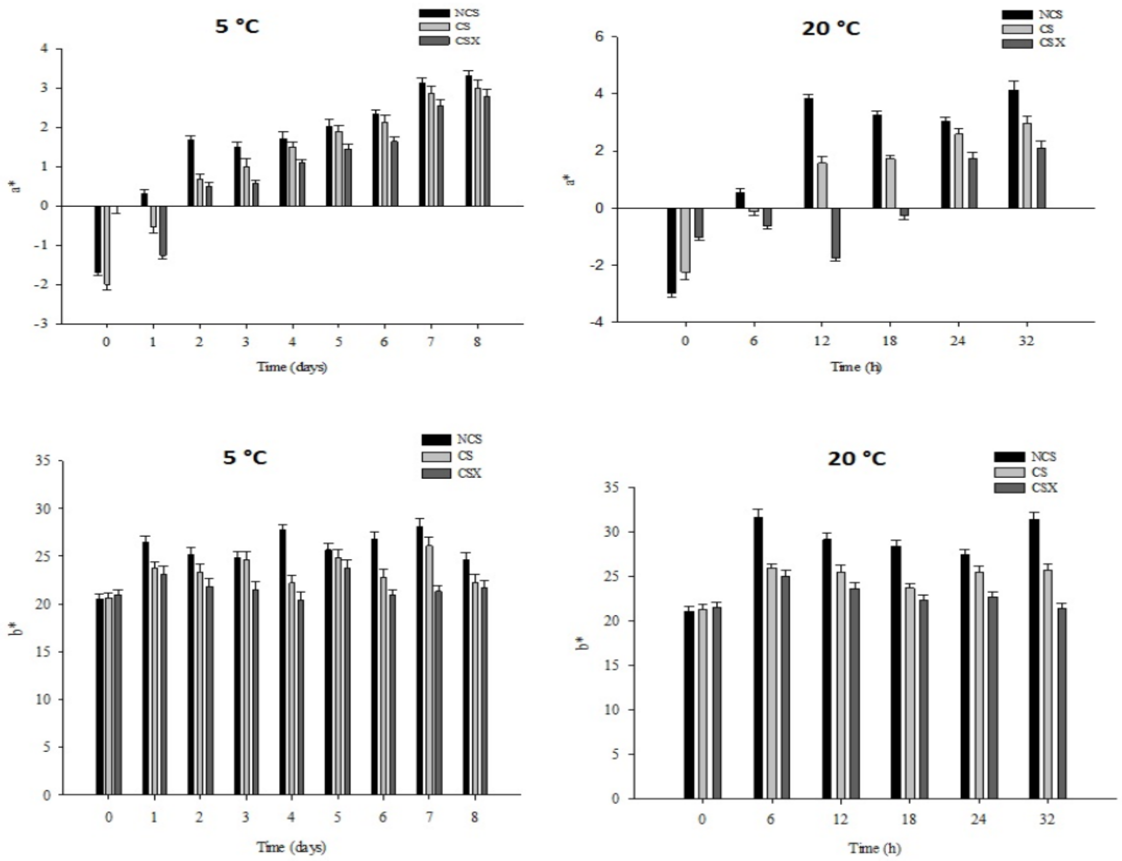


Figure 4. Effect of different apple coating applications on a* and b* values during storage at 5 °C and 20 °C. (NCS:Noncoated sample, CS: Coated sample, CSX: Coated sample with extract)

*Şekil 4. Elmada farklı kaplama uygulamalarının 5 °C ve 20 °C'deki depolama boyunca a* ve b* değerlerine etkisi. (NCS:Kaplanmamış örnek, CS: Kaplanmış örnek, CSX: Ekstrakt ile kaplanmış örnek)*

Figure 4 shows the a* and b* values of samples during the storage period at both temperatures of 5 and 20°C. Coating fresh-cut apples with PWE was a significant source of variation in regards of b*. Significant differences were found between CSX and NCS ($p=0.001$), similarly between CSX and CS ($p=0.001$). However, no significant effect was found between CSX and CS ($p=0.06$). The positive effect of the PWE was observed at both storage temperature. As a result, lower b* values were shown with CSX (LS means= 22.33) followed by b* values of CS (LS means= 23.43) and higher b* values recorded of NCS (LS means= 26.21). Therefore, the coating process played a significant role to protect the degradation of b* values, thus maintaining the yellowness of the samples.

Meighani et al. (2015) studied the coating process on pomegranate fruit by using three different coating materials; resin wax (Britex Ti), carnauba wax (Xedasol M14), and chitosan (1 and 2 % w/v) and evaluated the quality parameters of samples during 40, 80 and 120 days storage at 4.5 °C and 3 additional days at 20 °C. Their results showed that the carnauba wax could maintain considerably higher fruits quality in compare to other coating materials. They have also obtained a significant increase in b* values in the last days of storage and they reported lower b* values for the coated sample compared to control although no significant differences were observed among coating treatments.

The findings of this study are completely in line with what reported by Meighani et al. (2015). It's worthy to mention that at the end of storage, the highest and lowest b* were recorded with PWE and control fruits with mean 26.21± 0.6 and 22.33 ± 0.5, respectively, while b* value for the PW coating was recorded as 23.44±0.3. No significant differences were observed in regards of a* values amongst all treatments ($p≤0.05$); however, the CSX shows the highest ability to maintain a* values along storage at lower and higher temperatures (Figure 4). LS means of a* showed lower values of CSX (LS means=0.54) followed by CS (LS means=0.62), lastly, higher values of a* recorded for NCS (LS means=1.40).

Figure 5 and Figure 6 shows the effect of coating type on BI of fresh-cut apples stored at 5 °C and 20 °C, respectively. The obtained results demonstrated that coating process had a significant effect on BI values of samples (p≤0.05). However, no significant differences were observed between CS and CSX (p≥0.05). Coating the samples with PWE has the highest effect on browning index and the lowest BI value was recorded for CSX. Storing samples on a lower temperature (5 °C) showed lower browning index records in a respect to data recorded for samples stored at 20 °C. However the differences were not significant (p≥0.05).

A research conducted by Alves et al. (2017) showed that the application of soybean coating incorporated with ferulic acid could have significant positive impact on a* values. They reported that the coating reduced the rise of a* values for the treated apples after 7 days of storage at 10°C whose increase is associated with an increase in red color.

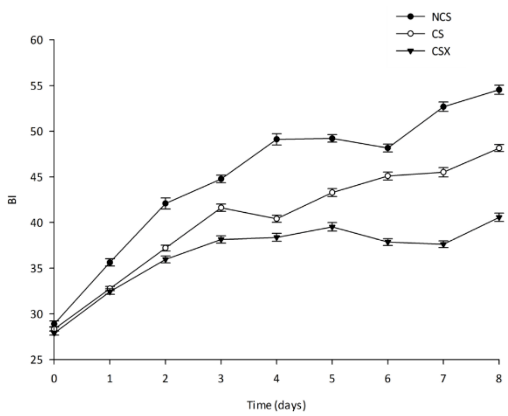


Figure 5. Effect of different apple coating applications on browning index during storage at 5 °C. (NCS:Noncoated sample, CS: Coated sample, CSX: Coated sample with extract)

*Şekil 5. Elmada farklı kaplama uygulamalarının 5 °C'deki depolama boyunca esmerleşme indeksi üzerine etkisi. (NCS:Kaplanmamış örnek, CS: Kaplanmış örnek, CSX: Ekstrakt ile kaplanmış örnek)*

Oms-Oliu et al. (2008) studied the effect of alginate and gellan based coatings incorporated with antioxidants; N-acetylcysteine and glutathione to preserve the quality of fresh-cut pears. Their results showed that incorporation of antioxidants into coating solutions has a positive influence in avoiding browning and intercept browning edges in pears pieces over storage period. On the other hands, substantial decrease observed after calculating the hue angle values, related to browning development, in both coated or non-coated fresh-cut pears that not handled with antioxidants.

Ceroli et al. (2018) applied various preservation technologies on potato cubes including application of edible coating, osmotic dehydration and antioxidants, and immersion in antioxidants to determine major changes in quality indicators including color indexes; L*, a*, b*, BI and ΔE. Final results indicated that a*, ΔE and BI showed differences between conservation technologies, otherwise no significant variations showed between treatments for L* and b* parameters. Immersing potato cubes into antioxidants resulted lower values of a*. Also, lower value of ΔE amongst all other treatments. The positive impact of antioxidants could be explained with the capabilities of antioxidants against oxygen interaction that causes enzymatic browning and facilitating color changes.

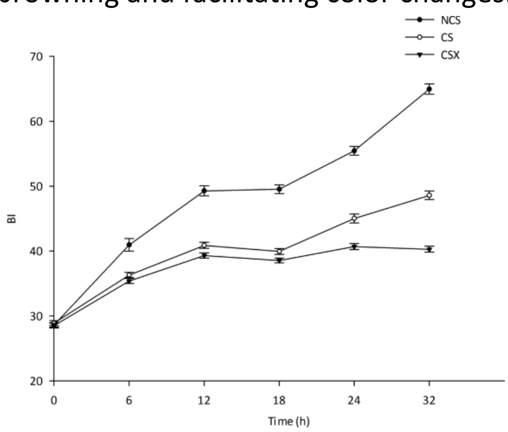


Figure 6. Effect of different apple coating applications on browning index during storage at 20 °C. (NCS:Noncoated sample, CS: Coated sample, CSX: Coated sample with extract)

*Şekil 6. Elmada farklı kaplama uygulamalarının 20 °C'deki depolama boyunca esmerleşme indeksi üzerine etkisi. (NCS:Kaplanmamış örnek, CS: Kaplanmış örnek, CSX: Ekstrakt ile kaplanmış örnek)*

A review by Muñoz-Labrador et al. (2018) showed that pectin coatings had better behavior in the color variation (ΔE) after applying the citrus pectin treatment as an edible coating on strawberries during storage. Generally, the pectin coatings presented a better behavior in the variation of color with respect to the control.

Table 1. C*, hue, and ΔE values for the samples of noncoated, coated and coated with extract at 5 °C.
*Çizelge 1. Kaplanmamış, kaplanmış ve ekstrakt ile kaplanmış örneklerin 5 °C'deki C*, renk açısı ve ΔE değerleri.*

| Time *Zaman* | Noncoated sample *Kaplanmamış örnek* | | | Coated sample *Kaplanmış örnek* | | | Sample coated with extract *Ekstrakt ile kaplanmış örnek* | | |
|---|---|---|---|---|---|---|---|---|---|
| Day *Gün* | C* | hue | ΔE | C* | hue | ΔE | C* | hue | ΔE |
| 0 | 20.59 | 2.53 | 0 | 22.59 | 0.42 | 0 | 20.96 | 0.35 | 0 |
| 1 | 26.53 | -0.38 | 7.53 | 21.79 | 29.15 | 2.62 | 23.15 | 2.03 | 1.90 |
| 2 | 25.18 | -0.58 | 6.06 | 23.31 | 0.17 | 2.89 | 21.85 | -26.17 | 7.33 |
| 3 | 24.84 | -0.01 | 8.03 | 24.67 | 2.74 | 6.84 | 21.53 | -0.12 | 7.98 |
| 4 | 27.90 | -1.57 | 10.72 | 22.21 | 1.50 | 5.73 | 20.53 | -51.95 | 9.92 |
| 5 | 25.72 | 0.08 | 7.56 | 24.88 | -1.19 | 9.50 | 23.89 | -0.73 | 10.00 |
| 6 | 26.83 | 0.05 | 7.84 | 22.83 | 0.27 | 6.79 | 21.01 | 2.70 | 7.66 |
| 7 | 28.28 | -0.77 | 10.66 | 26.12 | 0.06 | 10.40 | 21.42 | 0.49 | 9.18 |
| 8 | 24.60 | -0.16 | 5.21 | 22.26 | -2.29 | 6.24 | 21.77 | 2.93 | 9.71 |

Table 2. C*, hue and ΔE values for the samples of noncoated, coated and coated with extract at 20 °C.
*Çizelge 2. Kaplanmamış, kaplanmış ve ekstrakt ile kaplanmış örneklerin 20 °C'deki C*, renk açısı ve ΔE değerleri.*

| Time *Zaman* | Noncoated sample *Kaplanmamış örnek* | | | Coated sample *Kaplanmış örnek* | | | Sample coated with extract *Ekstrakt ile kaplanmış örnek* | | |
|---|---|---|---|---|---|---|---|---|---|
| h *saat* | C* | hue | ΔE | C* | hue | ΔE | C* | hue | ΔE |
| 0 | 21.31 | -1.04 | 0.00 | 19.43 | 0.93 | 0.00 | 21.58 | 0.99 | 0.00 |
| 6 | 31.83 | -0.40 | 13.73 | 21.98 | 0.18 | 5.90 | 25.04 | 0.17 | 5.07 |
| 12 | 29.30 | -2.04 | 11.10 | 25.49 | -0.67 | 8.53 | 23.61 | -4.80 | 5.63 |
| 18 | 28.41 | -5.90 | 9.60 | 23.71 | -2.74 | 7.65 | 22.28 | 1.27 | 7.95 |
| 24 | 25.62 | -0.61 | 20.32 | 27.59 | 0.36 | 12.28 | 22.73 | 2.03 | 7.38 |
| 32 | 31.69 | 0.26 | 14.98 | 25.82 | -5.12 | 11.78 | 21.59 | 0.73 | 8.91 |

The Chroma (C*) relates the chromatic parameters a*, b* and L*, and reflects the enzymatic activity being greater whenever that value decreases (Muñoz-Labrador et al., 2018). CSX showed the lowest values of C* (LS means= 22.33) preceded by CS (LS means= 23.78) and NCS had the highest C* values at 5 °C (LS means= 26.71) as values given in Table 1. Table 2 shows LS means values of C*, hue, and ΔE when the samples are kept at 20 °C. Significant differences were observed between C* values of coated and uncoated samples (p=0.001). In contrast with, hue values where CSX showed the lowest hue values (LS means= -4.39), On the other hand, PW samples had (LS means=2.02) and the highest hue values recorded for NCS (LS means=-0.42) and the differences were not significant amongst the treatments(p≥0.05).

*Total phenolic contents*

Testing the concentrations of phenolic content in a product provides a summary about the treatments used and also gives an idea about product deterioration throughout the storage process. Furthermore, oxidize phenolic components forming o-quinones which is speeding up the process of browning reactions eventually brown pigments formulation happened (Sapers, 1993).

Enhancing pectin-wax coating with pistachio hull extract to form edible PWE coating has a positive impact on sustaining the concentration of TPC in fresh-cut apples at both 20 and 5 °C temperatures. Table 3 shows TPC values by testing total phenolic levels at time zero and by the end of experiments. The results showed that the samples treated with pistachio hull extract-based coating had higher TPC compared to non-coated samples. Increasing TPC for coated sample with pistachio hull extract can be explained by the extract contribution since pistachio hull is known as high content of natural antioxidants. However, the effect of PWE was not significant ($p \geq 0.05$) with a confidence interval of 95%. In regards of storage temperature effect, analysis indicates that storage temperature did not have a significant effect on NCS and CSX, however samples kept at lower temperature could maintain higher TPC values (LS means=157.64) compared to samples stored at 20 °C (LS means=125.58).

Table 3. Effect of coating with pistachio hull extract on the total phenolic content (TPC) (mg GAE 100 $g^{-1}$ apple) of samples during storage at 5 °C and 20 °C.

*Çizelge 3. Antepfıstığı kabuğu ekstraktı ile kaplamanın 5 °C ve 20 °C'deki depolama boyunca örneklerin toplam fenolik içeriğine (TPC) (mg GAE 100 $g^{-1}$ elma) etkisi.*

| Sample *Örnek* | 5°C | | 20°C | |
|---|---|---|---|---|
| | Time (days) *Zaman (gün)* | | Time (h) *Zaman (saat)* | |
| | 0 | 8 | 0 | 32 |
| Noncoated sample *Kaplanmamış örnek* | 120.56±0.87 | 187.86±0.95 | 120.56±0.89 | 128.89±0.80 |
| Sample coated with extract *Ekstrakt ile kaplanmış örnek* | 122.36±0.72 | 199.80±0.99 | 122.36±0.76 | 130.53±0.86 |

The findings are aligned with the results reported by Simões et al. (2009) who studied modified atmosphere packaging (MAP) and edible coating on carrot sticks. Their results showed that some phenolic components identified at day 0 were lost by the end of evaluated storage period. Whereas, new undetected phenolics were formed in respect of coated carrot sticks. Tudela et al. (2002) reported similar findings explored with testing fresh-cut potato. Synthesized phenolics might explained by wounding the product and cooling storage temperature by the means of mechanism of abiotic stress (Cisneros-Zevallos, 2003). Santagata (2018) used the edible coatings based on pectin and honey on dehydrated cut fruits to promote fruit conservation. According to their results the coated and non-coated fruits reported losing in total phenolic contents, however values of coated samples were shifted at higher concentration interval. This result was attributed to the fruit dehydration, followed by the increasing in substances contents such as; solutes and bioactive and also usage of honey-based coating that contribute into supporting phenolic contents of treated dried fruits. It's known that the honey has very high polyphenols content naturally (Al-Mamary et al., 2002).

## Conclusion

The results of this study give some insight into pectin-wax coating and its incorporation with pistachio hull extract for the edible coating of fresh-cut apples. The findings showed that edible coating has a significant role to maintain product color and reduce the browning of fresh-cut apples. Furthermore, coating process can extend the shelf-life of apple pieces.

Investing in innovative food packaging techniques such as edible coatings is extremely important to maintain the food value chains and increase the food production to its maximum thus, contributes into protecting environment and reduce the massive plastic packages are used in food industry. Adoption of suitable packaging technologies by the food industry can be useful to extend the shelf life, improve quality, safety, and provide information about the product. The findings of this research can open the door for further studies on incorporating pistachio hull extract as a natural additive into edible coating materials and the opportunities to scale up the production of this innovative coating materials for industrial purposes.

## References

Al-Mamary, M., Al-Meeri, A., & Al-Habori, M., (2002). Antioxidant activities and total phenolics of different types of honey. *Nutrition Research*, 22(9): 1041-1047.

Alves, M. M., Gonçalves, M. P., & Rocha, C. M., (2017). Effect of ferulic acid on the performance of soy protein isolate-based edible coatings applied to fresh-cut apples. *Food Science and Technology*, 80: 409-415.

Assis, O., & Pessoa, J., (2004). Preparation of thin films of chitosan for use as edible coatings to inhibit fungal growth on sliced fruits. *Brazilian Journal of Food Science*, 7(1): 17–22.

Beaulieu, J. C., Park, H. S., Ballew Mims, A. G., & Kuk, M. S., (2009). Extension of green bell pepper shelf life using oilseedderived lipid films from soapstock. *Industrial Crops and Products*, 30: 271–275.

Bisen, A., Pandey, S. K., & Patel, N., (2012). Effect of skin coating on prolonging shelf life of kagzi lime fruits

(Citrus aurantifolia Swingle). *Journal of Food Science and Technology*, 49: 753–759.

Carbone, K., Giannini, B., Picchi, V., Scalzo, R. L., & Cecchini, F., (2011). Phenolic composition and free radical scavenging activity of different apple varieties in relation to the cultivar, tissue type and storage. *Food Chemistry*, 127(2): 493-500.

Ceroli, P., Garcia Procaccini, L. M., Corbino, G., Monti, M. C., & Huarte, M., (2018). Evaluation of Food Conservation Technologies for Potato Cubes. *Potato Research*, 1-11.

Chahed, T., Dhifi, W., Hamrouni, I., Msaada, K., Bellila, A., Kchouk, M. E., & Marzouk, B., (2007). Comparison of pistachio hull essential oils from different Tunisian localities. *The Italian Journal of Biochemistry*, 56(1), 35-39.

Chahed, T., Dhifi, W., Hosni, K., Msaada, K., Kchouk, M. E., & Marzouk, B., (2008) Composition of Tunisian pistachio hull essential oil during fruit formation and ripening. *Journal of Essential Oil Research*, 20(2): 122-125.

Cisneros-Zevallos, L., (2003). The use of controlled postharvest abiotic stresses as a tool for enhancing the nutraceutical content and adding-value of fresh fruits and vegetables. *Journal of Food Science*, 68(5): 1560-1565.

De León-Zapata, M. A., Sáenz-Galindo, A., Rojas-Molina, R., Rodríguez-Herrera, R., Jasso-Cantu, D., & Aguilar, C. N., (2015). Edible candelilla wax coating with fermented extract of tarbush improves the shelf life and quality of apples. *Food Packaging and Shelf Life*, 3: 70-75.

Du, G., Zhu, Y., Wang, X., Zhang, J., Tian, C., Liu, L., Meng, Y., & Guo, Y., (2019) Phenolic composition of apple products and by-products based on cold pressing technology. *Journal of Food Science and Technology*, 56(3): 1389-1397.

FAO, (2019). Statistical data of FAO. http://www.fao.org/faostat/en/#data/QC Access date: 15.01.2019.

Goli, A.H., Barzegar, M., & Sahari, M. A., (2005) Antioxidant activity and total phenolic compounds of pistachio (*Pistachia vera*) hull extracts. *Food Chemistry*, 92(3): 521-525.

Hoa, T. T., & Marie Noelle, D., (2008). Effects of different coatings on biochemical changes of ‘‘cat hoa loc’’ mangoes in storage. *Postharvest Biology and Technology*, 48: 150–152.

Kester, J., & Fennema, O., (1986). Edible Films and Coatings: A Review. *Food Technology*, 40(1): 47-59.

Kraśniewska, K., Gniewosz, M., Synowiec, A., Przybył, J. L., Bączek, K., & Węglarz, Z., (2014). The use of pullulan coating enriched with plant extracts from Satureja hortensis L. to maintain pepper and apple quality and safety. *Postharvest Biology and Technology*, 90: 63-72.

Manalili, N. M., Dorado, M. A., & Otterdijk, R., (2011). Appropriate food packaging solution for developing countries. Rome, Italy. Food and Agriculture Organization of the United Nations. 28 p.

Meighani, H., & Ghasemnezhad, M., Bakhshi, D., (2015). Effect of different coatings on post-harvest quality and bioactive compounds of pomegranate (Punica granatum L.) fruits. *Food Science and Technology*, 52(7): 4507–4514.

Muñoz-Labrador, A., Moreno, R., Villamiel, M., & Montilla, A., (2018). Preparation of citrus pectin gels by power ultrasound and its application as edible coating in strawberries. *Journal of the Science of Food and Agriculture*, 98(13): 4866-4875.

Olivas, G. I., & Barbosa-Cánovas, G. V., (2005). Edible coatings for fresh-cut fruits. *Critical Reviews in Food Science and Nutrition*, 45(7-8): 657-670.

Oms-Oliu, G., Soliva-Fortuny, R., & Martín-Belloso, O., (2008). Edible coatings with antibrowning agents to maintain sensory quality and antioxidant properties of fresh-cut pears. *Postharvest Biology and Technology*, 50(1): 87-94.

Özel, M. Z., Gogus, F., Hamilton, J. F., & Lewis, A. C., (2004). The essential oil of *Pistacia vera* L. at various temperatures of direct thermal desorption using comprehensive gas chromatography coupled with time-of-flight mass spectrometry. *Chromatographia*, 60(1-2): 79.

Perez-Gago, M. B., Serra, M., Alonso, M., Mateos, M., & Del Río, M. A., (2005). Effect of whey protein-and hydroxypropyl methylcellulose-based edible composite coatings on color change of fresh-cut apples. *Postharvest Biology and Technology*, 36(1): 77-85.

Pineiro, M., (2001). Manual on the application of the HACCP system in mycotoxin prevention and control (No. 73). Food & Agriculture Organization of the United Nations.

Raybaudi-Massilia, R. M., Mosqueda-Melgar, J., & Martín-Belloso, O., (2008). Edible alginate-based coating as carrier of antimicrobials to improve shelf-life and safety of fresh-cut melon. *International Journal of Food Microbiology*, 121(3): 313-327.

Robles-Sánchez, R. M., Rojas-Graü, M. A., Odriozola-Serrano, I., González-Aguilar, G., & Martin-Belloso, O., (2013). Influence of alginate-based edible coating as carrier of antibrowning agents on bioactive compounds and antioxidant activity in fresh-cut Kent mangoes. *LWT-Food Science and Technology*, *50*(1): 240-246.

Santagata, G., Mallardo, S., Fasulo, G., Lavermicocca, P., Valerio, F., Di Biase, M., & Volpe, M. G., (2018). Pectin-honey coating as novel dehydrating bioactive agent for cut fruit: Enhancement of the functional properties of coated dried fruits. *Food Chemistry*, 258: 104-110.

Sapers, G. M., (1993). Browning of foods: control by sulfites, antioxidants, and other means. *Food Technology*, 47(10): 75-84.

Simões, A. D., Tudela, J. A., Allende, A., Puschmann, R., & Gil, M. I., (2009). Edible coatings containing chitosan and moderate modified atmospheres maintain quality and enhance phytochemicals of carrot sticks. *Postharvest Biology and Technology*, 51(3): 364-370.

Song, F. L., Gan, R. Y., Zhang, Y., Xiao, Q., Kuang, L., & Li, H. B., (2010). Total phenolic contents and antioxidant capacities of selected Chinese medicinal plants. *International Journal of Molecular Sciences*, 11(6): 2362-2372.

Toivonen, P. M., & Brummell, D. A., (2008). Biochemical bases of appearance and texture changes in fresh-cut fruit and vegetables. *Postharvest Biology and Technology*, 48(1): 1-14.

Tudela, J. A., Cantos, E., Espín, J. C., Tomás-Barberán, F. A., & Gil, M. I., (2002). Induction of antioxidant flavonol biosynthesis in fresh-cut potatoes. Effect of domestic cooking. *Journal of Agricultural and Food Chemistry*, 50(21): 5925-5931.

U. S. Dept. Agriculture, (2017). Foreign Agricultural Service, Tree Nuts: World Markets and Trade. https://apps.fas.usda.gov/psdonline/circulars/TreeNuts.pdf Access date: 15.05.2018.

Watada, A. E., & Qi, L., (1999). Quality of fresh-cut produce. *Postharvest Biology and Technology*, 15(3):201-205.