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INFLUENCE OF WHEY PROTEIN ISOLATE-WAX COMPOSITE EDIBLE COATING ON THE QUALITY OF FRUIT BARS

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ABSTRACT
Composite edible coating of fruit bars using whey protein isolate (WPI) and waxes (beeswax or carnauba wax) was tested in the present study to prevent physicochemical changes during storage in the present study. Dry matter content (96.16-98.43 g/100 g), colour, hardness (54.17-258.16 N), total phenolic content (3097.7-9752.9 mg GAE/kg dm), ascorbic acid content (133.4-203.9 mg/kg dm), antioxidant activity (DPPH: 3681.1-4538.6 mg/kg dm, FRAP: 2531.5-3057.4 mg/kg dm) and peroxide value (1.85-2.06 meq peroxide/kg oil) of samples were determined. Composite edible coating resulted in higher dry matter content and hardness compared to WPI-coated samples. While the total phenolic content of samples coated with WPI+carnauba wax was the lowest, it provided the highest ascorbic acid content and antioxidant activity. A gradual decrease in all analysed parameters except dry matter content and peroxide value was observed throughout the storage period. Overall, edible coating using WPI and carnauba wax composite was suggested for fruit bars.
Keywords: composite edible coating, beeswax, carnauba wax, fruit bar, antioxidant activity

PEYNİR ALTI SUYU PROTEİN İZOLATI-VAKS BAZLI KOMPOZİT YENİLEBİLİR KAPLAMANIN MEYVE BARLARININ KALİTESİ ÜZERİNE ETKİSİ

ÖZ
Bu çalışmada, depolama süresince meyve barlarında gerçekleşen fizikokimyasal değişiklikleri önlemek için peynir altı suyu protein izolatı (PASP) ve vaks (balmumu veya karnauba mumu) bazlı yenilebilir kaplamalar test edilmiştir. Örneklerin kuru madde içeriği (96.16-98.43 g/100 g), renk, sertlik (54.17-258.16 N), toplam fenolik madde içeriği (3097.7-9752.9 mg GAE/kg dm), askorbik asit içeriği (133.4-203.9 mg/kg dm), antioksidan aktivite (DPPH: 3681.1-4538.6 mg/kg dm, FRAP: 2531.5-3057.4 mg/kg dm) ve peroksit değeri (1.85-2.06 meq peroksit / kg yağ) belirlenmiştir. Yenilebilir kompozit kaplama, PASP kaplı numunelere kıyasla daha yüksek kuru madde içeriği ve sertlik sağlamıştır. PASP karnauba mumu ile kaplanmış numunelerin toplam fenolik içeriği en düşük iken, bu örnekler en

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yüksek askorbik asit içeriği ve antioksidan aktiviteye sahip olmuştur. Depolama süresi boyunca kuru madde içeriği ve peroksit değeri dışında analiz edilen tüm parametrelerde kademeli bir düşüş gözlenmiştir. Genel olarak, meyve barları için PASP ve karnauba mumu bazlı kompozit yenilebilir kaplama önerilmektedir.
Anahtar kelimeler: kompozit yenilebilir kaplama, balmumu, karnauba mumu, meyve barı, antioksidan aktivite

INTRODUCTION

Snack products are consumed by a wide range of consumers, and the products available in markets are usually chocolates, chips and wafers with high fat, refined sugar and energy content. The producers of these snacks are focused on the taste of the product rather than their nutritive properties (Munir vd., 2016). However, the demand for healthy snacks that have a high content of vitamins, minerals and fibres and low content of the oil has been increased since the consumers' awareness on the health effect of foods has increased in recent years. Therefore, the importance of healthy snacks such as nuts, dried fruits, extruded products and fruit bars has been increased for both consumers and producers (Eyiz vd., 2020). Among these products, fruit bars are produced using dried fruits, nuts and honey (or sugar syrup). Other additives such as binders, flavours, antioxidants and milk powders can also be used in the formulation (Munir vd., 2016). Because of the used dried fruits, the bars contain a high content of vitamins, minerals and dietary fibres. The nuts used in the formulation contributes to the nutritional value as unsaturated fatty acid.

Fruit bars, which are important for their nutritional value, are sensitive to chemical, textural and sensory changes that occur during storage. While some of these changes occur due to internal factors, the majority of the changes depend on environmental factors such as relative humidity, oxygen concentration and UV lights. The edible coating seems to be a good alternative to limit or prevent the changes related to the environmental factors. Indeed, Eyiz vd. (2020) reported that edible coating of fruit bars with sodium alginate or whey protein isolate limited the chemical and textural changes during storage.

The edible coating is one of the major techniques used to prevent the effect of environmental factors on foods. This technique generally used to increase the shelf life fresh and fresh-cut fruits and vegetables. These products have high water activity, and their metabolic activities continue. There are many studies on the edible coating of fresh and fresh-cut fruits and vegetables in literature which were reviewed in several papers (Misir vd., 2014; Olivas ve Barbosa-Canovas, 2005; Rojas-Grau vd., 2009). However, there are limited studies on the effect of edible coating of low water activity foods. In one of these studies, Bilbao-Sainz vd. (2018) reported that edible coating did not provide significant protection in moisture content, water activity, total phenolic content and browning of pear bars compared to the control samples during storage. On the other hand, edible coating of nut kernels using different biopolymers reported to limit lipid oxidation and therefore increase the shelf life (Bonilla vd., 2018; Haq vd., 2013; Javanmard, 2008). In another study on the edible coating of low water activity crackers, the shelf life of coated crackers was determined as much longer than those of uncoated samples (Bravin vd., 2006). Similarly, edible coating of rice cakes using different mixtures of waxy corn starch, gellan gum and sodium alginate retarded/limited the textural changes related to the retrogradation without changing the sensorial properties (Eom vd., 2018). In all of the mentioned studies, hydrophilic biopolymers, carbohydrate or protein-based, were used as edible coating materials. To the best of authors' knowledge, no study was conducted to determine composite coatings on fruit bars or low water activity foods.

Composite edible coatings are prepared using a combination of hydrophilic and hydrophobic coating materials. By using these coating, oxygen barrier and improved textural properties of hydrophilic biopolymers and water vapour barrier properties of hydrophobic biopolymers are both utilized (Vargas vd., 2008). Therefore, the present study was conducted to determine the effect of composite coatings prepared by whey protein isolate (WPI) and waxes (beeswax of carnauba wax) on the physical and chemical properties of the fruit bars. To reach this aim, fruit bars coated with three different coatings, WPI, WPI+beeswax and WPI+carnauba wax, were stored at two different temperatures (25 and 37ºC) for four months. The moisture content, colour, hardness, total phenolic content, ascorbic acid content, antioxidant activity and peroxide value of the samples were determined at each month. Finally, the effect of coating material, storage temperature and storage time was statistically analysed.

MATERIAL AND METHODS

Materials

The fruit bar was produced using dried fruits [apricot (Metro Chef, Ankara, Turkey), fig (Üzümsan Lion Brand, Izmir, Turkey) and raisins (Metro Chef, Ankara, Turkey)], nuts [hazelnut (Metro Chef, Ankara, Turkey), peanut (Metro Chef, Ankara, Turkey) and sunflower seed (Amigo, Milhans Kuruyemis, Kocaeli, Turkey)] and honey (Billur, Samsun, Turkey). Whey protein isolate (Isowhey, HardLine, İstanbul, Turkey), beeswax (Gustav Heess, Leonberg, Germany) and carnauba wax (Gustav Heess, Leonberg, Germany) were used in the preparation of edible composite coatings. The chemicals used in the present study were reagent grade and purchased from Merck (Darmstadt, Germany)

Fruit bar production

The fruit bar formulation and production were performed according to Eyiz vd. (2020) with slight modifications. The ratio of fruits, nuts and honey were the same, but sunflower seeds were used instead of almond. The blending duration was prolonged to 15 min. After spreading of the mixture at 3 cm thickness, the drying was achieved in 2 days in room temperature to obtain a robust structure. Finally, the dried mixture was cut into 3 cm×6 cm to obtain fruit bars. A total of 120 bars were obtained in one replicate and divided into three groups for coating treatments.

Edible coating

Three different edible coatings were compared in the present study. Sample coated by 10% of whey protein isolate (WPI) was evaluated as the control since it is reported as a suitable single layer coating for fruit bars in a previous study (Eyiz vd., 2020). Two different composite edible coatings prepared by WPI (8%) + beeswax (2%) and WPI (8%) + carnauba wax (2%) were the composite coatings used in the study. The edible coating solutions were prepared by dissolving of WPI in distilled water, heating of the solution to 90ºC, adding of waxes into the hot mixture, keeping the solution at 90ºC for 30 min under continuous stirring. Then, the heat was turned off, and the solution was kept stirring until the temperature was reached to 70ºC. The solution did not need a degassing stage due to high temperature and slow stirring. All edible coatings were applied as 70ºC to prevent solidification of the waxes. In a replication for a coating type, 40 different fruit bars were dipped into the coating solution for 20 s and excess solution was drained on a strainer. Finally, both side of the fruit bars were dried for two days at room temperature (25ºC and 50% RH).

Analyses

Dry matter content of the fruit bars was determined by drying at 70ºC (Eyiz vd., 2020). Colour of the fruit bars were evaluated as L*, hue angle and chroma. For this purpose, a chromameter (Konica Minolta CR400, Osaka, Japan) was used to record L*, a* and b* values. Hue angle and chroma was calculated using a* and b* values, according to Eyiz vd. (2020).

The hardness of the samples was determined using a texture analyser (TA-XT2 Plus, Stable Microsystems, Surrey, UK) equipped with a 36 mm cylindrical probe. Four different bars were used in the analyses. The sample was compressed to 30 % under pre-test speed of 1mm/s, test speed of 3 mm/s and post-test speed of 10 mm/s (Eyiz vd., 2020).

The extract used in the determination of the total phenolic content, DPPH radical scavenging activity (DPPH) and ferric reducing antioxidant power (FRAP) was prepared by homogenization of 2 g of fruit bar sample in 20 mL of aqueous ethanol (80%) at 10000 rpm for 2 min. Then, the mixture was stirred at 200 rpm in a water bath adjusted to 40ºC for 2 h. Finally, it was filtered through a filter paper (20µm) to obtain the extract. This extract was stored at -18ºC until analyses which were completed in 2 days.

Folin-Ciocalteu procedure was used to determine total phenolic content. Briefly, 0,5 mL sample extract, 2 mL Folin-Ciocalteu solution (0.2 N) and 2.5 mL sodium carbonate solution (7.5%) were added in a test tube, mixed and incubated at 50ºC for 5 min. The absorbance of the solution was recorded at 760 nm using a Libra S22 spectrophotometer (Biochrom, Cambridge, UK). The total phenolic content was calculated as mg gallic acid equivalent (GAE)/kg dm (Eyiz vd., 2020).

DPPH was performed by using the procedure described by Fernández-León vd. (2013). 50 µL of sample extract and 950 µL of freshly prepared DPPH solution (60 µM in methanol) were added in a test tube and incubated at room temperature for 30 min. The absorbance of the solution was read at 517 nm. The DPPH of the samples were calculated as mg Trolox equivalent (TE)/kg dm using a calibration curve prepared by Trolox at different concentration.

The procedure of Benzie ve Strain (1996) was employed in the FRAP assay. 75 µL of sample extract, 2.25 mL of freshly prepared FRAP reagent (sodium acetate buffer: TPTZ solution: $FeCl_3.6H_2O$ solution at 10:1:1 ratio) and 225 µL of distilled water was added in a test tube. After incubation of the tube at room temperature for 30 min and the absorbance was recorded at 593 nm. The FRAP of the samples was calculated as mg TE/kg dm

The ascorbic acid content of the fruit bars was determined by the method performed by Eyiz vd. (2020), and results were expressed as mg/kg dm.

Peroxide value was evaluated as the oxidation indicator and determined in the oil extracted from the bars. For this purpose, 10 g of bar sample were homogenized in 100 mL of extraction solvent (hexane: isooctane, 1:1) at 10000 rpm for 5 min. Then, the mixture was filtered, and the solvent in the clear mixture was evaporated at 60ºC for overnight. The peroxide value was determined according to the method performed by (Tontul ve Topuz, 2013).

Statistical analyses

The fruit bar production and analyses were performed in duplicate. Analysis of variance (ANOVA) and Duncan's multiple-range was applied to data using SAS software (SAS Institute, NC, USA).

RESULTS AND DISCUSSION

Dry matter content

The dry matter content of the samples was ranged in a narrow range of 96.16-98.43 g/100g (Table 1). The dry matter content of the bars coated with composite coating had a higher content of dry matter compared to the those coated with WPI. This finding could be related to the limitation of moisture absorption because of increased hydrophobicity by the addition of waxes into the coating solution. Indeed, the addition of oil into the coating solutions reported to decrease the moisture content of the coated cakes stored at different water activities compared to non-coated samples (Bravin vd., 2006). Haq vd. (2013) studied the effect of gum Cordia and carboxymethyl cellulose on weight gain (an indicator of moisture increment) of a nut, Chilgoza, and determined a significant difference between the coating materials. The authors explained these differences with the adhering properties of the coating material. Moreover, the edible coating of papaya before drying as a pre-treatment was reported to reduce the drying rate by causing difficulties in moisture diffusivity (Islam vd., 2019).

As expected, increasing storage temperature caused lower content of the dry matter (Table 1) by increasing the rate of moisture absorption. The moisture content of the fruit bars showed variation during storage period probably due to the moisture content changes in the environment. Similarly, a variation in the moisture content of the samples throughout the storage period was determined in a previous study on the fruit bars coated with WPI, sodium alginate and carboxymethyl cellulose (Eyiz vd., 2020). Moreover, while the moisture content of the coated apple snack with methylcellulose showed variation between 2.4 and 3.1 g/100g, a gradual increase was observed in the control sample (Tavera-Quiroz vd., 2015).

Table 1. Moisture content color and harness of the fruit bars coated with different composite edible coatings and stored at different temperatures for 4 months

Variation sources		Dry matter conten (g/100 g)	L*	Hue angle	Chroma	Hardness (N)
Coating type	WPI	96.47±0.94b	41.70±0.75a	66.10±0.98a	19.70±0.42a	151.75±25.41b
	WPI+BW	97.61±0.22a	42.13±0.79a	65.27±1.22a	19.07±0.37b	170.96±27.29a
	WPI+CW	97.88±0.23a	42.20±0.88a	66.03±0.87a	18.44±0.27c	179.90±28.37a
Storage temperature (ºC)	25	97.99±0.20a	43.18±0.35a	68.64±0.37a	19.61±0.23a	105.53±8.02b
	37	96.65±0.62b	40.83±0.80b	62.96±0.84b	18.53±0.34b	229.54±23.83a
Storage time (months)	0	97.29±0.19abc	46.44±0.28a	71.19±0.16a	20.11±0.25a	54.17±0.74a
	1	96.16±1.60c	43.79±0.35b	65.48±1.14b	19.67±0.23ab	170.31±20.65b
	2	98.43±0.25a	41.75±0.29c	64.63±0.99b	19.40±0.26ab	187.51±26.87c
	3	97.89±0.21ab	39.90±0.68d	64.92±1.09b	19.00±0.30b	258.16±30.67d
	4	96.83±0.22bc	38.15±1.05e	62.77±1.44c	17.16±0.71c	dna*

Results are mean ± standard error of 20 observations (16 for hardness) for coating type, 30 observations (24 for hardness) for storage temperature and 12 observations for storage time. The values in a column with different letters are significantly ($p < 0.05$) different for each parameter. WPI: whey protein isolate, BW: beeswax, CW: carnauba wax,

*dna: did not analyzed because the value is higher than equipment capacity.

Colour

Coating type did not cause a significant change in the L* and Hue angle of the fruit bars. On the other hand, samples coated with WPI had the highest chroma values, and it was followed by WPI+BW and WPI+CW, respectively (Table 1). In a study on edible coating of guava using either cassava starch or cassava starch+BW, similar L* and b* values were also determined (Oliveira vd., 2018). Similarly, L*, Hue angle and chroma value of the strawberries coated with chitosan and its mixtures with wax did not change significantly during the storage period (Velickova vd., 2013).

The L*, Hue angle and chroma values of the fruit bars decreased by the increase of the temperature (Table 1). The fruit bars are prone to the non-enzymatic browning reactions due to their high content of proteins and reducing sugars. These reactions play an important role in the colour change. Similar changes in colour values of coated fruit bars with WPI, carboxymethyl cellulose or sodium alginate according to the storage temperature was also reported by Eyiz vd. (2020). As expected, longer storage period caused a gradual decrease in all colour parameters of the samples due to the non-enzymatic browning reactions (Table 1).

Hardness

The hardness of the samples coated with composite edible coatings was determined to be significantly higher than those coated with WPI (Table 1). This result suggested that the addition of the waxes into the edible coating solution provided a more compact structure during storage. Khoshnoudi-Nia ve Sedaghat (2019) reported that edible coating materials had a significant effect on the hardness of the pistachio. They explained this finding with increasing cross-linking of the coating solutions, which lead to a tight structure.

Storage at 37°C resulted in much harder samples compared to those stored at 25°C (Table 1). This phenomenon could be related to the acceleration of the reactions that cause a tighter structure. Eyiz vd. (2020) reported that hardness of the fruit bars stored at 37°C for 35 days (86.16 N) was much higher than that stored at 25°C for 70 days (71.95 N). Similarly, an increase in hardness of the regional cheese coated with galactomannan-based coating materials was observed by increasing temperature (Cerqueira vd., 2010). On the other hand, higher storage temperature caused a decrease in the hardness of the coated pistachios (Khoshnoudi-Nia ve Sedaghat, 2019). Therefore, the structure of the product affects the hardness during the storage period.

A gradual increase was observed during the storage of the fruit bars (Table 1). The hardness of the samples stored at 37°C for four months was higher than the measurement limit of the equipment. Therefore, it did not be analysed. An increment of hardness during storage of similar foods was also reported by several researchers (Cerqueira vd., 2010; Eyiz vd., 2020; Khoshnoudi-Nia ve Sedaghat, 2019; Munir vd., 2016).

Total phenolic content

A significant effect of coating type was observed on the total phenolic content of fruit bars. The results showed that WPI coated samples had the highest content of total phenolics and followed by WPI+BW and WPI+CW, respectively (Table 2). This finding could be related to the oxygen permeability of the coating materials. Indeed, the oxygen permeability of the whey protein concentrate and glycerol mixtures was reported to be lower than beeswax by Mishra vd. (2010). Carbohydrate and protein-based edible coatings are generally used because of their oxygen barrier properties. On the other hand, lipid-based edible coatings limit the water vapour permeability (Bourtoom, 2008). Totad vd. (2019) compared the total phenolic content of the coated with four different biopolymers and determined the highest total phenolic content in the samples coated with carboxymethyl cellulose.

Table 2. Chemical properties of the fruit bars coated with different composite edible coatings and stored at different temperatures for 4 months

Variation sources		Total phenolic content (mg GAE/kg dm)	Ascorbic acid content (mg/kg dm)	DPPH (mg TE/kg dm)	FRAP (mg TE/kg dm)	Peroxide value (meq peroxide/kg oil)
Coating type	WPI	3752.9±61.7a	166.5±9.0b	3681.1±107.1c	2613.5±52.0c	1.89±0.04a
	WPI+BW	3446.5±73.9b	164.7±6.4b	4087.0±68.6b	2724.1±55.2b	1.96±0.05a
	WPI+CW	3097.7±58.01c	177.4±5.2a	4506.9±67.8a	3056.6±44.6a	2.04±0.07a
Storage temperature (°C)	25	3447.8±75.9a	172.1±5.9a	4233.4±73.9a	2818.1±53.0a	1.95±0.04a
	37	3416.9±68.5a	167.0±5.6b	3950.0±100.4b	2777.9±54.7a	1.98±0.05a
Storage time (months)	0	3673.4±75.0a	203.9±1.1a	4538.6±69.4a	3057.4±43.3a	1.92±0.02ab
	1	3669.2±110.4a	200.5±5.0a	4211.2±114.4b	2919.2±62.0b	2.00±0.07ab
	2	3422.2±110.9b	161.7±5.1b	3982.5±146.8c	2824.3±78.2b	2.06±0.08a
	3	3246.3±96.4c	148.2±3.9c	3930.7±149.5c	2657.8±69.7c	1.98±0.1ab
	4	3150.7±93.7c	133.4±3.6d	3795.3±137.1d	2531.5±77.0d	1.85±0.05b

Results are mean ± standard error of 20 observations for coating type, 30 observations for storage temperature and 12 observations for storage time. The values in a column with different letters are significantly ($p < 0.05$) different for each parameter. WPI: whey protein isolate, BW: beeswax, CW: carnauba wax

Opposite to the expectation, storage temperature did not cause significant changes in the total phenolic content of the samples (Table 2). This finding could be related to the formation of non-enzymatic reaction products that interfere with the determination of the total phenolics (Tontul, 2019) since higher non-enzymatic browning reactions occurred in the samples stored at 37ºC according to the colour values (Table 1).

Prolonged storage caused a gradual decrease in the total phenolic content of the fruit bars (Table 2). The reduction percentage of total phenolic content at the end of the storage period was calculated as 14.2%. Phenolic compounds are sensitive to the environmental conditions such as temperature, oxygen, light and enzymes. Therefore, similar reports on the gradual decrease in total phenolic content of different products were reported in many previous reports (Bilbao-Sainz vd., 2018; Eyiz vd., 2020; Kim vd., 2013; Meighani vd., 2015; Totad vd., 2019).

Ascorbic acid content

The ascorbic acid content of the samples coated with WPI+CW was significantly higher than those coated with WPI or WPI+BW (Table 2). Bilbao-Sainz vd. (2018) compared layer-by-layer (LbL) coating and monolayer coating on the ascorbic acid content of pear bars. They reported that LbL coating provided higher content of ascorbic acid compared to those coated with the monolayer. The authors explained this finding with the higher protectivity of the LbL coating on ascorbic acid.

As expected, higher content of ascorbic acid in the fruit bars was determined in the samples stored at 25ºC compared to the 37ºC (Table 2). In a study on pomegranate leather, increasing the drying temperature from 4ºC to 37ºC resulted in much lower ascorbic acid content (Tontul ve Topuz, 2019). In this study, the reaction rate constant of ascorbic acid degradation 35ºC was calculated as 10 times higher than that of 4ºC. Higher ascorbic acid content in fruit products stored at lower temperature was also reported by several researchers (Eyiz vd., 2020; Thakur vd., 2018).

A gradual decrease in the ascorbic acid content of samples was detected throughout the storage period (Table 2), and total reduction percentage was 34.6% at the end of the storage. Kumar vd. (2017) reported ascorbic acid content of the guava-papaya bar reduced 15-20% in 60 days of storage. In a study on coating of blueberries with four different biopolymers, the reduction percentage of ascorbic acid was reported in the range of 28% (coated with carboxymethyl cellulose) and 68% (non-coated control) (Totad vd., 2019). Ascorbic acid retention in pear bars (which is a type of fruit leather) coated with five different biopolymers was reported in the range of ~22-45% after 28 days of storage at room temperature under 100% RH (Bilbao-Sainz vd., 2018).

Antioxidant activity

Coating of the samples with WPI+CW provided the highest antioxidant activity, determined by DPPH and FRAP assays, and it was followed by those coated with WPI+BW and WPI, respectively (Table 2). In a study on comparing the effect of chitosan and alginate coating on antioxidant activity of guavas, chitosan coating provided higher antioxidant activity compared to those of alginate coating (Nair vd., 2018). This result could be related to the modification of the internal atmosphere by coating material which subsequently changes oxidation reactions in products.

Storage temperature had a significant effect on the DPPH of the samples, while no significant differences were observed in FRAP of the samples stored at different temperature (Table 2). In a study on storage stability of apple bars, higher reduction in antioxidant activity was observed at 30ºC compared to those of 20ºC (Quintero Ruiz vd., 2012). Similarly, Eyiz vd. (2020) reported similar antioxidant activity in fruit bars stored at 25 and 37ºC, although they did not evaluate these values statistically. For example, the average antioxidant activity of the fruit bars coated with WPI was reported as 1365 mg TEAA/kg dm at 25ºC storage, while it was 1302.3 mg TEAA/kg dm at 37ºC.

Storage time caused a gradual decrease in both of the antioxidant activities (Table 2). The reduction percentage of the DPPH and FRAP was calculated as 16.4% and 17.2%, respectively. These results are consistent with the literature (Bilbao-Sainz vd., 2018; Eyiz vd., 2020; Nair vd., 2018; Totad vd., 2019). Bilbao-Sainz vd., (2018) reported that antioxidant activity of reduced upto 25% throughout the storage depending on the coating material for pear bars. Moreover, Eyiz vd., (2020) determined 22% and 28% reduction in the antioxidant activity of fruit bars at 25 °C and 37°C, respectively. The antioxidant activity of the guava (initial 65%) coated with chitosan and alginate based coatings were determined in the range of 40.2%-57.3% at the end of storage (Nair vd., 2018). Much higher reduction percentages was reported for antioxidant activity of coated blueberries using different coating materials (Totad vd., 2019). The reduction of antioxidant activity during storage is expected since antioxidant compounds are prone to oxidation reactions.

Peroxide value

Peroxides and hydroperoxides are the initial products of lipid oxidation reactions. Therefore, peroxide value is used as an indicator for rancidity in initial stages (Kazemian-Bazkiaee vd., 2020). Peroxide value of the samples determined in a narrow range of 1.85 and 2.06 meq peroxide/kg oil and did not change according to the coating type and storage temperature (Table 2). Opposite to the obtained results in the present study, peroxide value of the peanuts using three different coating materials (chitosan, β-glucan and their mixture) was found to be significantly different (Kazemian-Bazkiaee vd., 2020). Storage time caused a slight variation in the peroxide value of the fruit bars (Table 2). In a study on the edible coating of Brazil nuts, coating type significantly affected the peroxide value of the sample. Among the tested coating materials, chitosan, gelatine and sodium caseinate mixture, and gelatine and chitosan mixture were efficiently limited the formation of peroxides. In the samples coated with these materials, peroxide value was slightly increased throughout the storage period (Bonilla vd., 2018). In another study on edible coated nut, peroxide value of the control and coated samples significantly increased during storage period. The increment rate was slower in antioxidant added coating materials (Haq vd., 2013). The distinctive results obtained for the fruit bars in the present study could be related to the low oil and high antioxidant content of the products.

CONCLUSION

The results obtained in the present study showed that the addition of waxes to the coating materials efficiently control the transfer of the water between fruit bars and environment. Therefore, higher content of dry matter was determined in the samples coated with composite biopolymers. Among the evaluated colour parameters, coating material caused a significant variation only in chroma values. Higher storage temperature and longer storage duration resulted in a decrease in colour parameters due to the occurred non-enzymatic browning reactions. Addition of the waxes into the edible coating solution increased the hardness of the samples compared to the WPI-coated samples probably due to formation of a more compact structure or increment of crosslinking between fruit bar components. Total phenolic content of fruit bars coated with composite coating materials was found to be lower than that of WPI-coated samples. This finding could be related to the oxygen barrier properties of the biopolymers. Hydrophilic biopolymers are known with their higher resistance to oxygen compared to hydrophobic biopolymers. On the other hand, ascorbic acid content and antioxidant activity of the sample coated with WPI and carnauba wax mixture was higher than other counterparts. Storage temperature caused a significant difference in ascorbic acid content and DPPH of the samples, while no significant difference was observed in total phenolic content and FRAP according to storage temperature. As expected, longer storage caused a significant reduction in total phenolic content, ascorbic acid content and antioxidant activity of samples. No significant change was observed in peroxide value which shows no oxidation occurred in samples. According to the obtained results in the present study, whey protein isolate and carnauba wax composite were suggested for edible coating of fruit bars since it provides higher ascorbic acid content and antioxidant activity with slight changes in colour and hardness.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Zeynep Feyza Karakaş: Methodology, investigation, data curation; İsmail Tontul: Supervision, resources, investigation, writing - original draft, writing - review & editing

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