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EDIBLE COATING OF CEREAL BARS USING DIFFERENT BIOPOLYMERS: EFFECT ON PHYSICAL AND CHEMICAL PROPERTIES DURING STORAGE

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ABSTRACT
Cereal bars were coated with three different biopolymers to prevent the changes during storage. The edible coating using sodium alginate (SA), carboxymethyl cellulose (CMC) and whey protein isolate (WPI) had little effect on chemical properties of the bars. The moisture content of coated bars was found to be significantly higher than that of control samples because of moisture diffusion during treatments and prevention of moisture loss during storage. SA was the most effective coating materials in terms of preservation of the textural properties. On the other hand, coating cereal bars with CMC caused some undesirable changes in the color and textural properties of the bars. All three coating materials provided higher content of total phenolics compared to control. As a result of the study, it is recommended to use of SA as an edible coating for cereal bars to increase the physical and chemical stability of the product.
Keywords: cereal bar, edible coating, storage, textural properties, chemical properties

TAHIL BARLARININ FARKLI BİYOPOLİMERLER İLE YENİLEBİLİR KAPLANMASI: DEPOLAMA SÜRESİNCE FİZİKSEL VE KİMYASAL ÖZELLİKLER ÜZERİNE ETKİSİ

ÖZ
Bu çalışmada tahıl barlarının depolanması sırasında, değişiklikleri önlemek için 3 farklı biyopolimer ile kaplanmıştır. Sodyum aljinat (SA), karboksimetil selüloz (KMS) ve peynir altı suyu protein izolatı (PASP) kullanılarak yenilebilir kaplamanın barların kimyasal özellikleri üzerinde çok az etkisi olmuştur. Kaplanmış barların nem içeriğinin, kontrol numunelerinden önemli ölçüde daha yüksek olduğu bulunmuştur. Bu durum uygulama sırasında nem difüzyonu ve depolama sırasında nem kaybının önlenmesi ile açıklanmıştır. Depolama sırasında barların tekstürel özelliklerinin korunması açısından en etkili kaplama SA olmuştur. Öte yandan, tahıl barı örneklerinin KMS ile kaplanması, renk ve tekstürel özelliklerinde bazı istenmeyen değişikliklere neden olmuştur. Üç kaplama malzemesinin hepsi kontrole göre daha yüksek toplam fenolik içeriği sağlamıştır. Çalışmanın sonucu olarak, ürünün fiziksel ve kimyasal stabilitesini arttırmak için tahıl barları için yenilebilir kaplama olarak SA kullanılması tavsiye edilmektedir.
Anahtar kelimeler: Tahıl barı, yenilebilir kaplama, depolama, tekstürel özellikler, kimyasal özellikler

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INTRODUCTION

Cereals are an essential part of the diet since they contain the dietary fibers, proteins, minerals, vitamins and antioxidants. Cereals comprise dietary fibers such as beta-glucan, arabinoxylan, resistant starch, as well as phenolic substances and phytoestrogens that exhibit antioxidant properties. The most commonly consumed cereals are reported as wheat, rice, corn, oats and barley. Cereals have been reported to prevent cancer and cardiovascular diseases, reduce blood pressure, cholesterol and fat absorption rate, and reduce the risk of heart disease (Chaturvedi *et al.*, 2011).

Due to the increase in the health awareness of people, instead of snacks with high fat, energy and salt concentrations, demand to alternatives that have high fiber content, suitable energy level and rich in vitamins and minerals increased. The market share of extruded or baked products has risen in recent years as an alternative to fried products (Harper, 2019). Such products are generally cereal-based and occasionally supplemented with dried fruits and nuts.

The edible coating is defined as packaging materials obtained from natural sources, which can be consumed together with food, used to protect food and extend the shelf life (Keleş, 2002). Edible coating of foods has many advantages such as protection of food from environmental effects, low impact to the environment, allowing to use of different technologies, improvement of the nutritional value of product and biodegradability (Bourtoom, 2008). Biopolymers, used in the edible coating of various food products, are classified into four groups: polysaccharides, proteins, lipids and composites (Williams *et al.*, 2006). Polysaccharide and protein-based biopolymers, generally known as their excellent gas barrier properties. In this way, they prevent oxidation reactions typically occurs in coated food. On the other hand, since they have hydrophilic properties, their water vapor permeability is high (Yang & Paulson, 2000). As hydrophobic materials, lipid-based biopolymers have very low water vapor permeability, but their mechanical properties are adequate (Vieira *et al.*, 2011). Since different biopolymers can be used in the edible coating of food, some considerations must be taken into account in the production of a good quality edible coating material. These are;

-It should be generally recognized as safe (GRAS).

-It should have low oxygen permeability to prevent various reactions that oxygen catalyzes in the product.

-The water vapor permeability should be at the appropriate level to prevent moisture loss/gain.

-It should improve the textural properties of the product (Williams *et al.*, 2006).

In the present study, the edible coating of cereal bars to prevent or limit physical and chemical changes occurred during storage of product was carried out. For this aim, three different biopolymers, namely sodium alginate, carboxymethyl cellulose and whey protein isolate, were tested.

Cereal bars are produced by mixing different cereals and their products (oats, corn flakes, wheat, rice), dried fruits (apricots, figs, dates, grapes and apples), nuts (sunflower seeds, nuts, and peanuts) and other ingredients (honey, sugar syrup, vegetable oil, vanilla, salt, etc.). This homogenous mixture is spread on trays, baked for a specified duration and sliced into a rectangular form. Since cereal bars are both delicious and nutritious, they are highly preferred by consumers in recent years. Consumers prefer cereal bars because of their high dietary fiber, carbohydrate, protein and low-fat content (Bower & Whitten, 2000). Cereal bars which are quite good in terms of organoleptic properties and portable foods with a moderate shelf life is consumed as a snack or supplementary food. However, the textural and chemical properties of cereal bars are tended to change during storage because of environmental factors such as temperature, relative humidity, oxygen etc. To prevent or limit these changes, edible coating of cereal bars were tested in the present study for the first time in literature.

Several studies have been published on cereal bars. In one of these studies, Dutcosky et al. (2006) developed a cereal bar with prebiotic properties. The optimum formulations (50% inulin + 50% oligofructose or 8.46% inulin + 66.16% gum arabic + 25.38% acacia gum) reported having better textural properties than bars produce using prebiotics alone. Sun-Waterhouse et al. (2010) comparatively analyzed enriched cereal bars (with dietary fiber and/or polyphenols) and control bars. According to the results, apple fiber added bars had the highest total fiber content (5.3%). It was also determined that the cooking process had no significant effects on the fiber and polyphenol content. Polyphenol or dietary fiber-enriched bars were found to contain more phenolic substances than control bars. In different studies, cereal bars were produced using different exotic fruits (jenipapo and jackfruit) (Torres *et al.*, 2011), proteins (Padmashree et al., 2012) and probiotics (Bampi *et al.*, 2016). Mendes et al. (2013) aimed to evaluate the oxidative stability and changes in the chemical composition of cereal bars packed in different packages (laminated, transparent, transparent under vacuum and laminated under vacuum). After 120 days of storage, cereal bars did not indicate of oxidation at all samples, thereby low-cost packages such as vacuum-free transparent packaging were suggested.

The study is conducted to preserve the physical and chemical properties of cereal bars with edible coating using three different biopolymers (SA, CMC, WPI) during storage at two different temperatures (25 and 37 °C). First of all, the effect of edible coating on the chemical composition of cereal bars was determined. Then, the impact of biopolymers and storage temperature on moisture content, color, browning index, textural properties, total phenolic content and radical scavenging activity of cereal bars was comparatively investigated.

MATERIAL AND METHODS

Material

Oat (Sağlık agricultural products, Konya, Turkey), grapes (Temel 1993, Manisa, Turkey), butter (Çağlak, Konya, Turkey), glycerol (Tastearom, İstanbul, Turkey) and honey (Billur, Samsun, Turkey) were used in cereal bar production. Whey protein isolate (Hipro IsoWhey, Hard Line Nutrition, İstanbul, Turkey), sodium alginate (Alfasol, İstanbul, Turkey), carboxymethyl cellulose (Alfasol, İstanbul, Turkey) and glycerol (Tastearom, İstanbul, Turkey) were used in edible coating material production. All chemicals used in the analysis were reagent grade and provided from Merck (Germany).

Cereal bar production

Cereal bar formulation was determined preliminary experiments using different amounts of oat flakes, dried fruits (grapes, apricots), nuts, butter, glycerol and honey. As a result of the preliminary experiments, the acceptable formulation was determined as 50% cereal (baked oat flakes at 150 °C for 15 min), 28% dried fruits (grapes), 0.5% glycerol, 1.5% butter and 20% honey. All materials were homogenized using Hobart mixer (N50 5-Quart, Ontario, Canada) for 6 min. The mixture was laid in trays [3 cm (thickness) × 40 cm (width) × 60 cm (length)] and baked at 150 °C for 15 minutes. After baking both sides of the bars were dried for 24 hours at room temperature under shade. Finally, cereal bars were sliced to obtain a rectangular shape (3.0 cm × 6.0 cm). A total of 112 bars were obtained for each replication, and the bars were divided into four groups. Three groups were used in coating experiments and the other one evaluated as a control group.

Preparation of coating solutions and treatment

SA (1%), CMC (1%) and WPI (10%) were used as coating materials and glycerol was used as a plasticizer. In preparing the coating solutions, required amount of coating material and glycerol (the ratio of coating material to plasticizer was 1:1) were dissolved in distilled water, and the volume of the solution was made up to 4 L. The solution heated to 90 °C in a water bath and held for 30 minutes under stirring continuously. Finally, the coating solution kept in an ultrasonic bath which operated at 35 kHz and 650 W (Bandelin Sonorex, Berlin, Germany) for 5 minutes to degassing. After cooling of the solutions to room temperature, the cereal bars were coated by dipping into the solution for 5 s. Both sides of the bars were dried for 24 hours at room temperature under shade.

Storage
Samples were packaged in low-density polyethylene pouches, and packages were closed with heat sealing. Storage was done at two different temperatures; conditioned room temperature (~25) and 37 ºC in an incubator. Six packages were stored for each treatment at each replication. Analyzes were carried out every two weeks at 25 ºC (70 days), and every week at 37 ºC (35 days).

Chemical composition and energy content
The moisture content of the cereal bars was gravimetrically determined by drying of samples at 70 ºC until constant weight. The protein (AACC 46-12), crude oil (AACC 30-25) and ash (AACC 08-01) contents of the cereal bars were determined according to the AACC (2000). Carbohydrate content of the samples was calculated from moisture, crude oil, protein and ash content as reported by Nergiz and Ötleş (1993) (Eq.1). The total energy content of the cereal bars was calculated using Eq. 2. The protein, crude oil, carbohydrate, ash and energy content of the cereal bars were only determined after the production of samples.

$$\text{Carbohydrate (g)} = 100 - (\text{Moisture} + \text{Crude oil} + \text{Protein} + \text{Ash}) \quad (1)$$

$$\text{Energy (kcal/100 g)} = \text{Crude oil} \times 9 + \text{Protein} \times 4 + \text{Carbohydrate} \times 4 \quad (2)$$

Color and browning index
Color analyses were carried out using a Konica Minolta colorimeter (CR-400, Japan). Before measurement of samples, the colorimeter was calibrated using the reference white tile. After calibration, the color of samples was measured from 10 different parts of bars. Color was determined in terms of L*, a* and b* color scale and Hue angle, chroma and browning index were calculated using these values according to Tontul *et al.* (2016).

Texture analysis
The textural properties of the cereal bars were determined using a texture analyzer (TA.XT 2Plus, Stable Micro Systems, Surrey, UK). The hardness, resilience, cohesiveness, springiness and chewiness of the cereal bars were calculated from the plot obtained by texture profile analysis (AACC, 2000). The measurement conditions were; probe: P / 36R cylindrical probe, pretest speed: 10 mm/s, trigger force: 0.196 N, test speed: 0.2 mm/s, compression ratio: 30%, holding time: 5 s.

Total phenolic content and radical scavenging activity
The total phenolic content (Folin-Ciocalteu method) and radical scavenging activity (DPPH inhibition method) of the cereal bars were analyzed according to Tontul and Topuz (2017).

Statistical analyses
The treatment and analyses were performed in duplicate. Analysis of variance (at P <0.01 or P <0.05 level) and Duncan's multiple range test (at P <0.05 level) were applied to data using SAS v9 software (SAS Institute, Cary, NC, USA).

RESULTS AND DISCUSSION

Chemical composition and energy content
The effect of edible film coating on chemical properties was determined. Protein, oil, carbohydrate, ash and energy values of cereal bars were determined in the range of 8.64-10.37 g/100g, 1.18-1,40 g/100g, 72.48-78,95 g/100g, 1.35 -1.51 g/100 g and 339.90-362.19 kcal/100 g, respectively (Table 1.). It was determined that edible coating caused a statistically significant decrease in energy value. This phenomenon could be related to the increased moisture content as a result of moisture diffusion during the coating of cereal bars. Indeed, the moisture content of coated bars was significantly higher than the control samples (Table 2). Mridula *et al.* (2013) produced energy bars containing flaxseeds and sweeteners enriched with omega 3 in their studies. The maximum energy values of the bars were determined as 397.95 kcal/100 g. The chemical properties of the produced bars were as followed: moisture content 11-13%, protein content 10-11%, fat content 5-11%, ash content 1-1.5%, carbohydrate content 60-71%. The result of the present study was found to be consistent with the literature.

Table 1. Chemical composition and energy content of cereal bars[1]

Sample	Protein (g/100g)	Crude oil (g/100g)	Carbohydrate (g/100g)	Ash (g/100g)	Energy (kcal/100 g)
Control	8.64±0.33[b]	1.31±0.40	78.95±1.05[a]	1.51±0.02[a]	362.19±0.77[a]
SA	9.14±0.13[b]	1.40±0.63	74.37±0.63[b]	1.40±0.04[ab]	346.64±3.72[b]
CMC	8.99±0.11[b]	1.18±0.09	73.32±0.26[b]	1.46±0.02[ab]	339.90±1.45[b]
WPI	10.37±0.31[a]	1.39±0.04	72.48±1.33[b]	1.35±0.05[b]	343.91±3.72[b]

[1] Mean ± std error. different letters in same column shows significant difference (*P* <0,05).

Table 2. Moisture content. total phenolic content. radical scavenging activity and ascorbic acid content of cereal bars[1]

Variation sources		Moisture (g/100g)		Total phenolic content (mg GAE/kg dm)		Radical scavenging activity (mg TEAA/kg dm)	
		25 ºC	37 ºC	25 ºC	37 ºC	25 ºC	37 ºC
Coating	Control	9.80±0.13c	9.64±0.20[c]	1766.8±152.8[d]	2283.2±198.8[c]	1563.8±93.8[a]	1528.4±98.8[a]
	SA	15.26±0.37a	14.67±0.28[a]	2046.3±91.3[c]	2437.2±62.2[bc]	1412.5±63.2[bc]	1396.0±74.6[a]
	CMC	14.11±0.33b	14.12±0.37[ab]	2360.2±67.7[a]	2635.8±69.7[a]	1447.7±73.7[c]	1528.3±55.1[a]
	WPI	13.75±0.39b	13.45±0.43[b]	2184.9±94.7[b]	2520.9±129.3[ab]	1497.5±64.8a[b]	1475.7±62.2[a]
Storage	Initial	13.18±0.83[a]	13.18±0.83a[b]	2725.2±66.0[a]	2725.2±66.0[a]	1767.0±62.2[a]	1767.0±62.2[a]
	1. Storage time	12.92±0.74[a]	13.87±0.83[a]	2161.0±56.6[b]	2802.5±40.2[a]	1680.8±49.6[a]	1619.9±60.7[a]
	2. Storage time	13.10±0.97[a]	13.40±0.81[a]	2055.4±103.9[bc]	2677.6±81.3[a]	1669.6±23.7[a]	1472.8±82.3[a]
	3. Storage time	13.43±0.90[a]	13.10±0.81[ab]	1969.5±111.9[c]	2369.3±61.7[b]	1330.3±30.4[b]	1433.5±19.7[b]
	4. Storage time	13.57±0.95[a]	12.04±0.77[b]	1786.2±127.4[d]	2430.6±122.2[b]	1254.9±24.0[bc]	1417.8±50.5[b]
	5. Storage time	13.18±0.82[a]	12.21±0.86[b]	1839.9±131.0[d]	1810.4±202.2[c]	1179.6±34.7[c]	1181.8±97.6[c]

[1] Mean ± std error of 12 observations for coating and 8 observations for storage. Different letters in same column shows significant difference (*P* <0,05). Initial. 1. 2. 3. 4. 5. storage times represent 0. 14. 28. 42. 56 and 70 days of storage for 25 ºC and 0. 7. 14. 21. 28 and 35 days of storage for 37 ºC respectively.

The protein content of WPI coated bars was significantly higher than other samples. Since WPI as coating material was prepared at a higher concentration (10%) than other counterparts, this result was expected. However, this result also shows edible coating material constituted an important portion of the product. By edible coating of cereal bars with WPI, the nutritional value of the product was increased since WPI contains essential amino acids, minerals and proteins (Ha & Zemel, 2003). Additionally, coated bars contained lower content of ash compared to control samples. This result could be related to the reduction of the oat flake ratio in the product.

Moisture content

The moisture content of cereal bars stored at two different temperatures was given in Table 2. The bars with the highest moisture content were SA coated samples, and it was followed by CMC-coated, WPI-coated and control samples at both temperatures, respectively. No significant change in the moisture content of samples stored at 25 ºC was observed. On the other hand, a considerable reduction was determined throughout the storage at 37 ºC. As previously discussed, the reason for the lower moisture content of the control samples could be related to the higher initial moisture content of coated samples because of moisture diffusion during coating. Additionally, the resistance of coating materials to the moisture loss during the storage period may contribute to this result. Similarly, Albert and Mittal (2002) reported that coating grain products with WPI prevented water loss. Moreover, Rossi Marquez *et al.* (2014) found that WPI coating prevents moisture loss in cooked foods. Oms-Oliu *et al.* (2008) stated polysaccharide-based coatings provides moisture balance in product during storage by increasing the water vapor resistance.

Total phenolic content and radical scavenging activity

Changes in total phenolic content and radical scavenging activity during storage of cereal bars stored at 25 and 37 ºC are given in Table 2. The highest total phenolic contents were found in the bars coated with CMC, followed by WPI coated and SA coated bars, at both temperatures. On the other hand, control samples have the lowest content of total phenolics. These results clearly show that edible coating has a protective effect on degradation/oxidation of phenolics. This protective effect of edible coating sourced from barrier properties of coating materials to oxidative factors such as light, oxygen and humidity (Fabra *et al.*, 2012). Indeed, it has been emphasized in many previous studies that WPI is an excellent oxygen barrier (Galus & Kadzińska, 2016; Vukić *et al.*, 2017). As expected, there was a significant reduction in the total phenolic content of bars during storage at both temperatures.

Radical scavenging activity of the bars was determined using DPPH inhibition method. Opposite to total phenolic content results, control samples had higher radical scavenging activity than those of coated bars at 25 ºC. On the other hand, all treatments had statically similar radical scavenging activity at 37 ºC. The higher radical scavenging activity of control bars, although low total phenolic content, could be related to higher non-enzymatic browning reactions that occurred in these samples. Indeed, some products of non-enzymatic browning reactions have high radical scavenging activity (Lee & Shibamoto, 2002). Among the coated samples stored at 25 ºC, WPI coated bars had the highest radical scavenging activity. LE Tien *et al.* (2001) stated that the radical scavenging activity of WPI is quite high. Many studies have shown that WPI is a much better aroma and gas barrier than other polysaccharides used in the edible coating (Mahboobeb Kashiri *et al.*, 2017; Nuanmano *et al.*, 2015). WPI is thought to limit the losses of phenolics and radical scavenging activity by preventing oxygen catalyzed reactions in the product. Antioxidant activity decreased during storage at both temperatures. This reduction is due to degradation or oxidation of components that are sensitive to environmental conditions (Kalt, 2005).

Color and browning index

The average change in L*, hue angle, chroma and browning index values of cereal bars stored at 25 and 37 ºC is given in Table 3. The bars coated with WPI had the highest L* value, and no significant differences were detected between the other samples at 25 ºC. On the other hand, control and WPI coated bars had the highest L* values at 37 ºC. The coating with WPI may have increased the brightness of the product. L* values of the bars coated with SA and CMC were statistically similar. There was a continuous reduction in L* during the storage period at both temperatures. As expected, reduction of L* value is faster at 37 ºC compared to 25 ºC. This reduction was expected since non-enzymatic browning reactions occurred during storage cause darkening of samples (Rhim & Hong, 2011). Koyuncu and Savran (2002) stated that WPI provides a bright surface to the product. Olivas and Barbosa-Cánovas (2005) concluded that edible coating limits the browning reactions by acting as a barrier in fresh-cut fruits and thus prolongs the storage time.

The hue angle values show a qualitative evaluation of food products, and 0 shows reddish and 90 shows yellowish color. The hue angle of the coated bars was similar and higher than the control samples at 25 ºC (Pathare *et al.*, 2013). Interestingly, the hue angle of control samples was the highest (but statistically similar with WPI coated and SA coated samples) at 37 ºC. This finding may be sourced from reactions in edible coating materials at high storage temperature. There was a decrease in the hue angle value at both storage temperatures during storage, probably due to non-enzymatic browning reactions. Similarly, changes in Hue angle of sliced red guava fruits coated with CMC was also reported in a previous study (Forato *et al.*, 2015).

Table 3. Colour and browning index of cereal bars[1]

Variation sources		L*		Hue angle		Chroma		Browning index	
		25 ºC	37 ºC	25 ºC	37 ºC	25 ºC	37 ºC	25 ºC	37 ºC
Coating	Control	55.71 ± 0.50^{b}	54.35 ± 0.58^{a}	78.13 ± 0.32^{b}	78.48 ± 0.31^{a}	18.47 ± 0.22^{a}	18.58 ± 0.37^{b}	45.96 ± 0.57^{a}	45.19 ± 0.89^{c}
	SA	55.45 ± 0.49^{b}	51.99 ± 0.93^{b}	79.56 ± 0.19^{a}	77.72 ± 0.58^{ab}	18.21 ± 0.17^{ab}	18.59 ± 0.35^{b}	44.72 ± 0.70^{a}	49.95 ± 1.53^{b}
	CMC	55.90 ± 0.67^{b}	51.55 ± 1.24^{b}	79.27 ± 0.28^{a}	77.14 ± 0.87^{b}	17.91 ± 0.25^{ab}	17.41 ± 0.17^{c}	44.09 ± 0.92^{a}	47.74 ± 2.14^{bc}
	WPI	58.04 ± 0.74^{a}	54.14 ± 1.07^{a}	79.81 ± 0.29^{a}	78.56 ± 0.47^{a}	17.81 ± 0.38^{b}	21.27 ± 0.48^{a}	40.82 ± 0.86^{b}	55.81 ± 2.78^{a}
Storage	Initial	58.08 ± 1.00^{a}	58.08 ± 1.00^{a}	79.91 ± 0.48^{a}	80.00 ± 0.48^{a}	18.81 ± 0.37^{a}	18.81 ± 0.37^{a}	41.78 ± 0.79^{b}	41.78 ± 0.79^{c}
	1. Storage time	57.68 ± 0.71^{a}	54.97 ± 0.46^{b}	79.37 ± 0.30^{ab}	79.19 ± 0.36^{ab}	18.59 ± 0.11^{a}	18.77 ± 0.39^{a}	42.90 ± 0.71^{ab}	45.10 ± 1.15^{bc}
	2. Storage time	56.65 ± 0.60^{ab}	51.85 ± 0.86^{c}	79.25 ± 0.33^{ab}	78.40 ± 0.39^{bc}	18.41 ± 0.06^{a}	18.73 ± 0.70^{a}	44.02 ± 0.89^{ab}	48.41 ± 2.49^{bc}
	3. Storage time	56.30 ± 0.41^{ab}	50.88 ± 0.73^{c}	79.22 ± 0.37^{ab}	77.49 ± 0.57^{c}	18.23 ± 0.17^{ab}	19.12 ± 0.65^{a}	43.95 ± 0.83^{ab}	52.78 ± 2.30^{a}
	4. Storage time	55.00 ± 0.54^{bc}	51.68 ± 0.74^{c}	78.79 ± 0.40^{ab}	77.14 ± 0.45^{c}	17.69 ± 0.23^{b}	18.76 ± 0.82^{a}	44.87 ± 1.21^{ab}	53.90 ± 2.40^{a}
	5. Storage time	53.94 ± 0.55^{c}	50.59 ± 1.15^{c}	78.63 ± 0.44^{b}	75.64 ± 0.91^{d}	16.86 ± 0.35^{c}	19.58 ± 0.99^{a}	45.87 ± 1.78^{a}	56.09 ± 2.91^{a}

[1] Mean ± std error of 12 observations for coating and 8 observations for storage. Different letters in same column shows significant difference (P <0,05). Initial. 1. 2. 3. 4. 5. storage times represent 0. 14. 28. 42. 56 and 70 days of storage for 25 ºC and 0. 7. 14. 21. 28 and 35 days of storage for 37 ºC respectively.

Chroma (C*), which ranges in 0 to 100, is considered as a quantitative attribute of color (Pathare *et al.*, 2013). Chroma values of the cereal bars were determined in a narrow range of 16.86-21.27 (Table 3). At 37 ºC, WPI coated samples had higher chroma values and followed by control, SA coated, and CMC coated samples. While it was decreased throughout the storage at 25 ºC, no significant change was observed at 37 ºC. This distinctive result is mainly sourced from increasing chroma values of WPI coated samples during storage at 37 ºC (data not shown). Therefore, it could be said that high storage temperature causes a reaction that increases the chroma of WPI.

When the browning index values of the bars stored at 37 ºC were examined, it was determined that the highest browning index value belongs to the bars coated with WPI. This may be due to the promotion of non-enzymatic browning reactions by enrichment of bars with protein and high storage temperature. Many studies have shown that browning reactions accelerated with the increase in the amount of protein in sugary products (Broersen *et al.*, 2004; Jiang, 2013; Mesa *et al.*, 2008). On the other hand, the WPI coating of cereal bars provided the least browning index values among the samples stored at 25 ºC. Therefore, this study clearly shows that the effect of coating material on the browning index is highly dependent on storage temperature. According to the results of this study, WPI coating prevents browning reactions at room temperature while it promotes the browning reactions at higher storage temperatures. In a previous research on the mushroom coating with SA, coating prevented the browning reactions that occur during storage of product (Jiang, 2013). As expected, the browning index values at both storage temperatures increased due to browning reactions that occurred during the storage period (Rattanathanalerk *et al.*, 2005).

Texture

Textural properties of cereal bars (hardness, resilience, cohesiveness, springiness and chewiness) are shown in Table 4. The bars coated with WPI had the highest hardness at both temperatures. On the contrary, CMC coated bars had the lowest hardness, which may be due to the softening of the product because of the interaction of cereal bars and CMC. According to the results, the most suitable film material which can be used to maintain the hardness value of cereal bars was determined as SA since the hardness value of the bars were similar throughout the storage period. Similarly, in a previous study, it has been shown that coating sliced fuji apples with SA prevented softening of the product (Rojas-Graü *et al.*, 2008). In another study, it was determined that the changes in the hardness were prevented during storage of mushrooms coated with SA (Jiang, 2013). At both storage temperatures hardness of cereal bars gradually increased during the storage period. At the end of the storage period, 2.6 and 3.2-fold increment of hardness was observed in comparison to initial values at 25 and 37 ºC, respectively. This finding could be related to the hardening of the product due to moisture loss or tightening of the structure because of cohesive forces. Likewise, with the present study, the hardness of fruit bars coated with WPI increased during the storage period (Bilbao-Sainz *et al.*, 2018).

Table 4. Textural properties of cereal bars[1]

Variation sources		Hardness(N)		Resilience		Cohesiveness		Springiness		Chewiness(N,s)	
		25 ºC	37 ºC	25 ºC	37 ºC	25 ºC	37 ºC	25 ºC	37 ºC	25 ºC	37 ºC
Coating	Control	100.06 ± 14.23^{bc}	111.65 ± 12.80^{c}	10.86 ± 0.61^{b}	11.65 ± 1.03^{b}	0.32 ± 0.01^{c}	0.31 ± 0.01^{c}	54.76 ± 1.95^{b}	53.81 ± 2.99^{b}	17.20 ± 1.82^{b}	18.66 ± 3.12^{c}
	SA	126.46 ± 11.24^{ab}	150.98 ± 19.40^{b}	16.33 ± 0.88^{a}	17.30 ± 1.00^{a}	0.41 ± 0.01^{a}	0.41 ± 0.01^{a}	58.74 ± 1.28^{ab}	61.39 ± 1.29^{a}	28.26 ± 1.77^{a}	38.64 ± 5.53^{b}
	CMC	76.07 ± 10.73^{c}	74.24 ± 10.28^{c}	11.26 ± 0.63^{b}	12.62 ± 0.95^{b}	0.35 ± 0.01^{b}	0.36 ± 0.01^{b}	56.89 ± 1.36^{ab}	63.55 ± 2.51^{a}	13.87 ± 2.08^{b}	15.53 ± 3.06^{c}
	WPI	142.55 ± 15.43^{a}	203.15 ± 28.19^{a}	16.15 ± 0.79^{a}	19.68 ± 1.63^{a}	0.41 ± 0.01^{a}	0.43 ± 0.02^{a}	62.36 ± 2.75^{a}	62.84 ± 2.77^{a}	31.27 ± 3.08^{a}	54.48 ± 7.76^{a}
Storage	Initial	64.58 ± 7.83^{d}	64.58 ± 7.84^{c}	10.87 ± 0.85^{c}	10.87 ± 0.85^{d}	0.33 ± 0.02^{c}	0.33 ± 0.02^{c}	53.49 ± 3.03^{a}	53.49 ± 3.03^{b}	12.96 ± 2.45^{b}	12.96 ± 2.45^{c}
	1. Storage time	86.80 ± 10.93^{cd}	101.56 ± 14.83^{bc}	12.15 ± 0.96^{bc}	13.35 ± 1.11^{cd}	0.35 ± 0.01^{bc}	0.36 ± 0.02^{bc}	57.79 ± 0.81^{a}	55.98 ± 2.99^{b}	17.43 ± 2.73^{b}	$23.10\pm4.94b^{c}$
	2. Storage time	100.58 ± 13.67^{bcd}	121.22 ± 19.76^{b}	13.65 ± 1.02^{ab}	14.59 ± 1.33^{bc}	0.38 ± 0.02^{ab}	0.38 ± 0.02^{bc}	57.57 ± 3.64^{a}	59.93 ± 2.40^{b}	24.02 ± 3.44^{a}	25.90 ± 5.16^{bc}
	3. Storage time	120.22 ± 17.29^{bc}	135.19 ± 16.55^{b}	14.26 ± 1.11^{ab}	15.35 ± 1.57^{bc}	0.38 ± 0.02^{ab}	0.39 ± 0.02^{ab}	58.56 ± 1.80^{a}	61.45 ± 2.68^{ab}	25.43 ± 4.25^{a}	32.18 ± 6.88^{bc}
	4. Storage time	128.20 ± 15.80^{b}	183.68 ± 31.75^{a}	15.45 ± 1.60^{a}	17.56 ± 1.81^{ab}	0.39 ± 0.02^{a}	0.39 ± 0.02^{ab}	59.53 ± 1.76^{a}	62.00 ± 2.19^{ab}	27.51 ± 2.79^{a}	44.72 ± 9.64^{a}
	5. Storage time	167.33 ± 18.11^{a}	203.81 ± 38.58^{a}	15.52 ± 1.40^{a}	20.14 ± 2.37^{a}	0.40 ± 0.02^{a}	0.42 ± 0.02^{a}	62.18 ± 2.54^{a}	69.51 ± 3.60^{a}	28.55 ± 3.90^{a}	52.12 ± 11.24^{a}

[1] Mean ± std error of 12 observations for coating and 8 observations for storage. Different letters in same column shows significant difference (P <0,05). Initial. 1. 2. 3. 4. 5. storage times represent 0. 14. 28. 42. 56 and 70 days of storage for 25 ºC and 0. 7. 14. 21. 28 and 35 days of storage for 37 ºC respectively.

Two different groups were observed in the present study according to the resilience of samples. Resilience values of the bars coated with WPI and SA were similar and higher than those of other samples. There is an increase in the resilience value of cereal bars during storage. Mahboobeh Kashiri *et al.* (2016) reported that the films obtained from WPI had a positive effect on the texture because of improved mechanical strength. Additionally, alginate-based films increased mechanical resistance and improved the active properties of products due to their excellent colloidal properties (Dhanapal *et al.*, 2012).

The highest cohesiveness was determined in the bars coated with either WPI or SA at both temperatures. On the contrary, control samples had the lowest cohesiveness values. The higher cohesiveness of the coated bars is related to the formed tight structure at the surface of the product and the adherence of coating materials to the product. An increase in cohesiveness occurred during storage at both temperatures probably due to increasing interactions of ingredients.

The springiness of coated bars was determined to be higher than control samples at both storage temperatures. Therefore, it can be claimed that the edible coating of bars has retained their textural properties. Calva-Estrada *et al.* (2019) reported that protein-based edible coating enhanced the texture of products and ensured the stable textural properties during storage. An increase, although statistically insignificant at 25 ºC, was observed at both storage temperatures.

The bars coated with WPI had the highest chewiness values and followed by SA coated, control and CMC coated bar, respectively. These results were expected since the chewiness value is a function of hardness, springiness and cohesiveness (Gerçekaslan *et al.*, 2007). In a previous study on fresh-cut fruits, WPI coating maintained chewability and hardness of products during storage (Rossi Marquez *et al.*, 2017). As expected, chewiness value was 2,2 and 4,0-fold increased throughout the storage at 25 and 37 ºC, respectively.

CONCLUSION

In this study, the changes of physical and chemical properties of cereal bars during storage was tried to prevent or limit by the edible coating of product using different biopolymers (SA, CMC and WPI). Control and coated cereal bars were stored at two different temperatures (25 and 37 ºC). The edible coating had a low impact on the chemical composition of cereal bars. It has been found that coated samples had significantly higher moisture content because of high initial moisture content and provided resistance to moisture loss. Edible coating of cereal bars provided higher content of total phenolics compare to control samples. However, radical scavenging activity of control bars was found to be higher than coated samples. This unexpected result could be related to the product of non-enzymatic browning reactions that have radical scavenging activity. According to the color result, coated samples had higher L* values since biopolymers gave brightness to the product. It must be noted that the effectiveness of coating materials on color protection was depended on storage temperature. Indeed, WPI coated samples had the lowest browning index values at 25 ºC, while those had the highest values at 37 ºC. Coating of cereal bars with SA prevented the negative changes in the textural properties of the product during storage. Overall, the results showed that coating with SA limited undesirable changes in cereal bars during storage at room and elevated temperatures. However, additional studies using composite coatings of SA with lipophilic biopolymers such as beeswax, carnauba wax etc. are needed to improve the storage stability of cereal bars.

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CONFLICT OF INTEREST

The authors declared no conflict of interest.

AUTHORS' CONTRIBUTIONS

Vildan EYİZ – Data collection, literature review, writing the article
İsmail TONTUL – Idea/Concept, Supervision, critical review
Selman TÜRKER – Idea/Concept, Supervision, critical review

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