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RETENTION of PHYSICAL QUALITY of BANANAS by HEMICELLULOSE COATING

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Abstract

In order to maintain color and texture, plant-origin edible coatings are advantageous to foodstuffs as an air and moisture barrier. In this study, hemicelluloses extracted from corn peels were used as the coating material on bananas stored at 4 °C. At the end of storage, no fungal decay was detected on coated bananas, whereas 20% of uncoated bananas (control) were infected. Samples coated with 1, 1.5 and 2% hemicellulose (HC) lost 3.6, 3.3 and 3.1 of their total weight, respectively, whereas the control group lost 5.1% of total weight. Hemicellulose coating also protected firmness of bananas (701.1 gf for coated and 509.6 gf for uncoated samples). Color measurements showed that lightness and yellowness of the coated bananas were preserved with negligible losses while uncoated samples turned brown at unacceptable level. Thus, this study showed that hemicelluloses can be alternatively used as the coating material on surface of fruits.

Keywords: Hemicellulose coating, edible coating, preservation, fruit quality, banana

HEMİSELÜLOZ KAPLAMA ile MUZLARIN FİZİKSEL KALİTESİNİN KORUNMASI

Özet

Renk ve tekstür gibi duyusal özelliklerin korunması amacıyla kullanılacak bitkisel kaynaklı yenilebilir kaplama maddeleri besin maddelerinde hava ve nem engelleyici yönleriyle avantajlıdırlar. Bu çalışmada, mısır kabuğundan özütlenen hemiselüloz 4 °C'de buzdolabında depolanan muzlarda kaplama maddesi olarak kullanılmıştır. Depolama sonunda, kontrol olarak kullanılan ve kaplanmamış muz örneklerinin %20 sinde küf oluşumu gözlenirken kaplanmış muz örneklerinde hiçbir küf oluşumu görülmemiştir. %1, 1.5 ve 2 hemiselüloz (HC) ile kaplanmış muzlarda ağırlık kaybı sırasıyla % 3.6, 3.3 ve 3.1 iken, kontrol grubu toplam ağırlığının %5.1'ni kaybetmiştir. Hemiselüloz kaplama ayrıca muzların sertliğini (701.1 gf kaplanmış örnek ve 509.6 gf kaplanmamış örnek için) de korumuştur. Renk ölçümleri, kaplanmamış muzların kahverengine dönüştüğünü gösterirken, kaplanmış muzlarda açıklık ve sarılık değerleri ihmal edilebilir kayıpla korunmuştur. Böylece, bu çalışma hemiselülozların alternatif olarak meyve yüzeylerinde kaplama maddesi olarak kullanılabileceğini göstermiştir.

Anahtar kelimeler: Hemiselüloz kaplama, yenilebilir kaplama, muhafaza etme, meyve kalitesi, muz

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INTRODUCTION

Until recently, majority of the studies have focused on utilization of hemicelluloses as a food fiber or renewable source for fuel and energy production. Nowadays, the potential of hemicelluloses to compete with the commercial coatings such as gums and carboxymethyl derivatives of chitosan, cellulose, and starch are sought in foods due to gel-forming and film-forming properties (1, 2). Coating is an emerging technology to preserve quality of fresh fruits and vegetables; however, current applied technologies may be expensive or not all widely available (3, 4). Therefore, edible hemicellulose coatings can be a cost-effective alternative to prevent physical damage, to reduce microbial growth, and to enhance appearance (5, 6). During ripening of bananas, textural changes also take place rapidly and this causes excessive tissue softening and subsequent spoilage. Hence, heavy loss is observed every year. As a result, coating can preserve texture and contribute to economy by minimizing discharge of fruits. Hemicellulose coatings also have desirable oxygen permeability values compared to other biopolymers such as amylopectin, amylose, and chitosan (7).

The current literature contains a number of coating studies on different foods but the use of hemicellulose is still limited. Heteroxylan coatings were claimed to be superior to cellulose-based coatings for seeds and candy (7). Kittur et al. (8) coated banana and mango using polysaccharide derivatives (PSD) such as chitosan and carboxymethyl derivatives of chitosan, cellulose, and starch in comparison to Waxol. The PSD's were reported to be better than Waxol in terms of retarding color changes, firmness, and weight losses. Sanwal and Payasi (3) treated banana fruits with garlic and onion extracts, chemicals and their combinations. Garlic extract plus sodium metabisulphite solution was reported as the best practice to prolong the shelf life of banana. The PSD-based coatings were also applied successfully in other fruits such as strawberry (chitosan) (9), fresh cut papaya (chitosan, pectin) (10), and apple (chitosan) (4). In addition to coating, hemicellulose components were utilized to produce packaging films (11-15) and used as a food ingredient to enhance chemical and functional properties, namely fish (16), bread (17), and meat (18).

These studies indicate that hemicellulose coating has limited use in foods. To our knowledge, there is no study on hemicellulose coating of banana fruits. The use of corn-peel-hemicelluloses for food coating will also yield reduced cost of the fruit. Therefore, the aim of the present work was to assess usage of hemicelluloses extracted from corn peels as a coating material to retard darkening of fresh banana, which is the most traded fruit worldwide and susceptible to environmental conditions.

MATERIALS and METHODS

Raw Materials

Corn peels for hemicellulose extraction and ripe bananas (*Musa acuminata*) for coating were purchased from local markets located in Ankara. Corn peels were dried at 70°C in an oven for 24 h and ground to approximately 1.0 mm of particle size using laboratory miller (Thomas-WILEY Laboratory Mill, Model 4). Before use, bananas were washed with distilled water and air dried.

Edible Coating Material

To prepare the coating solution, hemicellulose as a polysaccharide derivative and Tween-80 as an emulsifier were used. Hemicellulose extraction is described in details elsewhere (19). Briefly, corn peels were treated with 10% alkali solution (NaOH) at 30 °C for 24 h. Then, hemicellulose was separated by precipitation and filtration. Isolated hemicelluloses were dried in oven at 40 °C for 24 h and ground in mortar to get small and uniform particle size.

Coating Formulations and Application

To prepare 100 ml of coating solution (1-2% total solids), respective amounts of hemicellulose was dissolved in distilled water to give 1.0, 1.5, and 2.0 g of hemicelluloses per 100 ml of solution. Then, Tween-80 (0.2 ml) was added to emulsify and improve the wettability. The solution was homogenized for 10 min by a blender and stirred for 30 min by a laboratory stirrer. If any insoluble remained, they were separated by vacuum filtration (8).

Banana fruits (*Musa acuminata*) were randomly distributed into four groups and each group was assigned 10 samples. Each fruit was washed and dried. First group was control and not coated. The other groups consisted of (a) 1%; (b) 1.5%; and (c) 2% hemicellulose solutions sprayed on the fruits. The fruits were then air-dried after coating application and subsequently stored at 4 °C in the refrigerator to speed up darkening and limit experimental period with 4 days. The treatments were replicated twice for reliable results.

Quality Evaluation

Fungal decay was visually inspected daily during storage, as done by others (9). Results were expressed as the percentage of infected fruits, based on counts of bananas with mycelial development. Weight loss was expressed as the percent loss of the initial total weight. Results of measurements from 10 fruits were averaged and reported. Firmness was measured with T 18 Basic (IKA®-Werke GmbH & Co.KG, Staufen, Germany) equipment and defined as the maximum penetration force (gram force). Banana's external color was evaluated with Datacolour 110TM (HITEX Services, Inc. Easton, PA, USA) according to CIE L*a*b* coordinates where L*is lightness, a* is a chromacity coordinate defining greenness (-) to redness (+), and b* is another chromacity coordinate defining blueness (-) to yellowness (+). Sensory analysis involved visual acceptance only because this work was focused on the darkening of bananas at refrigerator condition, and carried out by 20 untrained panelists. The 7-point hedonic scale was used to evaluate the sensory analysis. Acceptability level was determined as 4 because huge color difference started just after score 4. Fruit scores below 4 were considered unacceptable.

Statistical Analysis

One-way analysis of variance (ANOVA) was used to perform statistical analysis of the results and Tukey test was used for pair-wise comparison at p=0.05 using the statistical software MINITAB® 15.1 (Minitab Inc. State College, PA, USA).

RESULTS

Visible Fungal Decay

Signs of fungal decay were observed on uncoated bananas (control) after 4 days of storage at 4 °C whereas no fungal decay was detected on bananas coated with 1, 1.5, and 2% hemicellulose (HC) solutions. About 20% of control bananas were infected by molds.

Weight Loss

Because moisture evaporation and respiration through the fruit skin can be detected with weight loss, it was monitored for 4 days as a measurable quality attribute of coating. Results given in Figure 1 showed that all samples lost weight during storage; however, the rates of weight loss determined from the slope values were significantly greater for uncoated fruits than that of coated fruits ($P<0.05$).

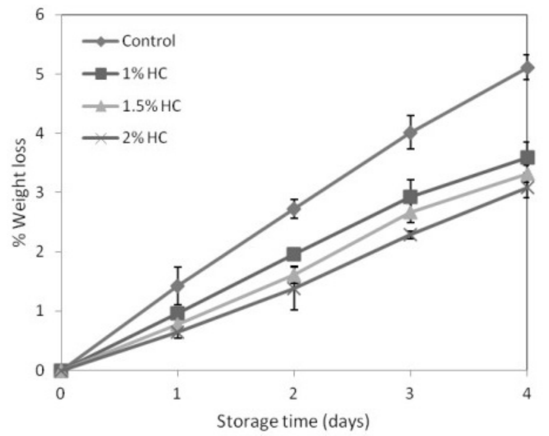


Figure 1. Weight loss of bananas as a function of storage time at 4 °C.

At the end of day 4, the control group lost 5.1% of total weight but samples coated with 1, 1.5, and 2% HC solutions lost 3.6, 3.3, and 3.1% of their total weight, respectively. There was also a slight difference (P>0.05) in the percentage of weight loss within the coated samples, being the least weight loss for 2% coating solution.

Firmness

In Figure 2, firmness values of the control group and samples coated with 1, 1.5, and 2% of HC solutions are presented with respect to storage time. Similar initial values were measured for all samples ($P>0.05$). The coating solutions of 1.5 and 2% HC resulted in significantly higher firmness values than the 1% HC solution and the control group (p<0.05). The firmness values of samples coated with 1.5 and 2% coating solution slightly decreased to 825.5 and 866.3 gf from initial values of 893 and 895 gf, respectively within 4 days. Although there was some decrease in firmness values of 1% HC-coated samples, from 896 to 701.1 gf at the end of 4 days, they were still in good condition compared to uncoated samples, whose values decreased gradually from 894.2 to 509.6 gf. The results indicated that increasing hemicellulose content up to 1.5 % in the coating solutions improved the quality due to higher barrier potential and 1.5 and 2 % HC solutions were found equally effective (*P*>0.05).

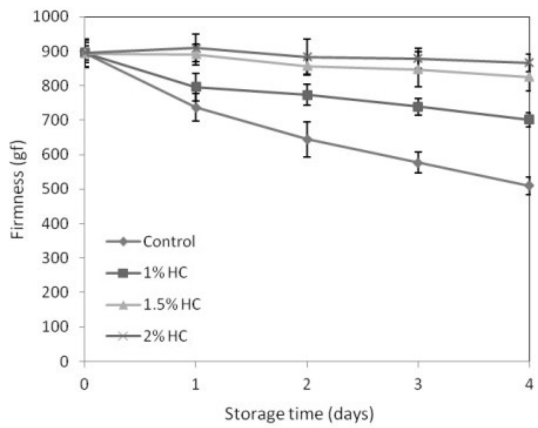


Figure 2. Effect of hemicellulose coatings on the firmness of bananas stored at 4 °C.

External Color

In order to observe quickly the effects of hemicellulose coatings on retention of banana color, hemicellulose coatings were tested under refrigerated storage. The results are shown in Fig. 3a, Fig. 3b and Fig. 3c in terms of changes of L*, a*, and b* values, respectively. The coating application did not affect the initial color coordinates of the fruits. The L* parameter represents lightness and it is an indicator of fruit darkening. In Figure 3a, it was observed that L* values of all samples decreased with storage time. The statistical results showed that the control group was significantly darker than the coated bananas during the storage; however, no significant differences were found among the bananas treated with different concentration of HC solutions. By the end of the fourth day, the control samples lost 30% of their lightness while the decrease in L* values of coated samples with 1%, 1.5%, and 2% of HC solutions were around 14.1, 13.4, and 11.1, respectively. Thus, these results revealed that hemicellulose coating successfully delayed the darkening of banana fruits at 4 °C.

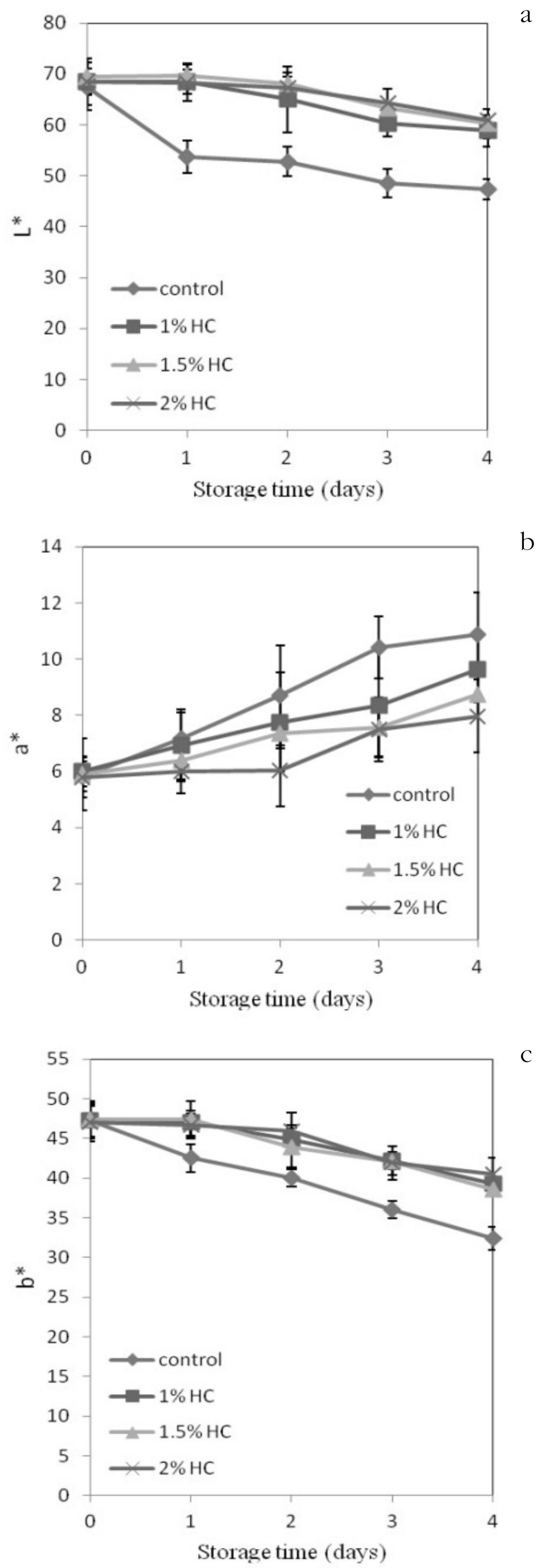
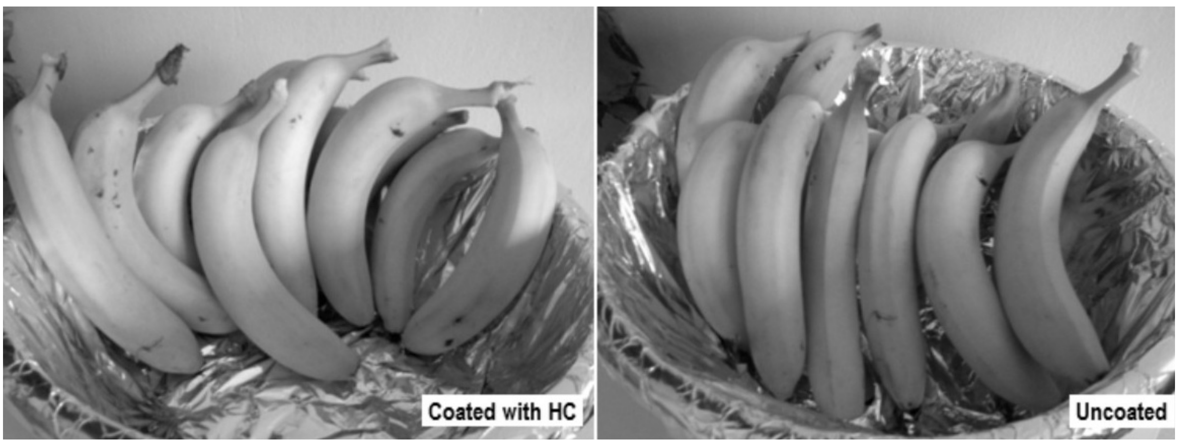


Figure 3. Effect of hemicellulose coatings on L*, a* and b* values of bananas stored at 4 °C.

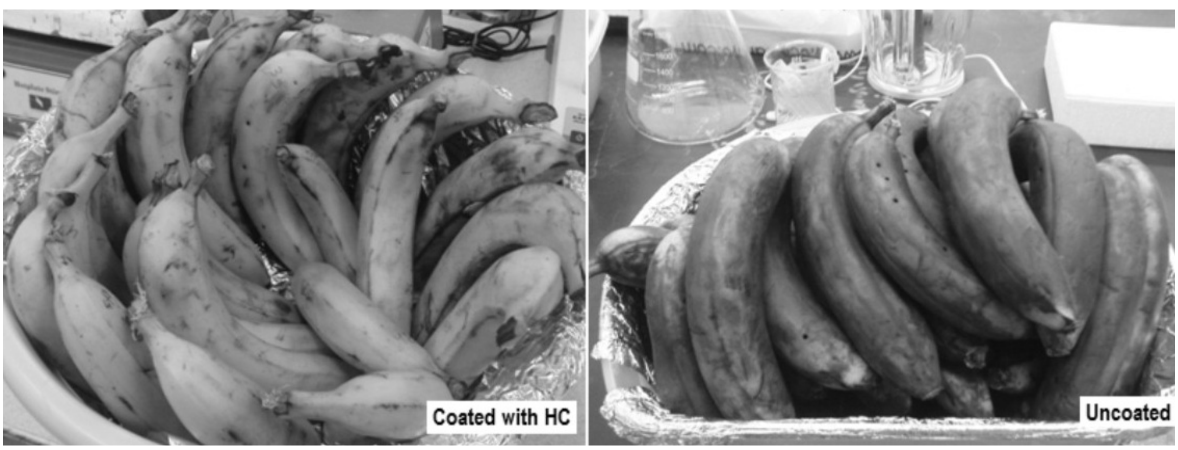
The changes in a* values of banana peel during storage is presented in Fig. 3b. Positive values of a* indicate redness and negatives indicate greenness. For bananas, a decrease in L* and b* values and increase in a* values indicate browning. Even though, a slower increase was observed in a* values of coated fruits (Figure 3b), a significant difference was not observed among the coated and uncoated fruits ($P>0.05$). It meant that only a* value is not enough for interpretation of external color of banana.

The other chromacity coordinate is b* of which positive values represent yellowness and negative values represent blueness. As expected, external color analysis of banana gave all positive values of b* (Figure 3c). Yellowness of all bananas decreased during storage. However, the decrease in yellowness of control bananas was significantly higher than the coated ones among which there was no significant difference in b* values. For coated samples, no decrease in b* value was observed at the end of the first day and after that a slight decrease was observed while rapid and continuous decrease in b* values of control samples was observed.

Moreover, b* values of the coated samples at the end of the fourth day were close to the b* values of uncoated samples on the second day of storage. For example, after four days of storage at 4 °C, b* values of bananas coated with 1, 1.5, and 2% HC solution were 39.3, 39 and 40.5, respectively. These results were similar to b* values of the uncoated bananas, which was 40 at the end of the second day. Thus, bananas coated with 1-2% HC solutions delayed browning up to two times of control samples.



a) initial



b) Final

Figure 4. Initial (a) and final (b) appearances of hemicellulose coated and uncoated bananas.

Table 1 Visual acceptance values of bananas during storage at 4 °C[a]

Storage time (day)	Treatments			
	Control	1% HC[b]	1.5% HC	2% HC
0	6.4 ± 0.5	6.5 ± 0.5	6.6 ± 0.6	6.7 ± 0.5
1	4.4 ± 0.7	6.0 ± 0.7	6.1 ± 0.7	6.4 ± 0.6
2	3.5 ± 0.8	5.8 ± 0.7	5.6 ± 0.6	5.6 ± 0.8
3	2.7 ± 0.8	5.0 ± 0.7	5.2 ± 0.7	5.1 ± 0.7
4	2.3 ± 0.7	3.9 ± 0.8	4.0 ± 0.8	4.1 ± 0.7
5	2.1 ± 0.6	3.2 ± 0.7	3.1 ± 0.7	3.3 ± 0.6

[a] Each value represents the mean value ± standard deviation.
[b] HC, hemicellulose

Visual Acceptance

On each day of storage, coated and uncoated bananas were evaluated visually by 20 untrained panelists as per sensory analysis just before the analytical tests. The results were recorded according to a 7-point hedonic scale and are given in Table 1. Initially (day 0), consumers showed similar preferences for coated and uncoated fruits, which proved that coating application did not alter banana's color and appearance (Figure 4a). Throughout the storage, all bananas lost their visual acceptance. The hemicellulose coating concentration did not significantly affect the visual acceptance of bananas ($P>0.05$). Every coated sample had acceptable scores. At the end of storage, neither coated nor uncoated samples received acceptable scores (<4) but coated samples were still in a better condition as shown in Figure 4b.

The consumers showed significant preferences for coated bananas ($P<0.05$) after 1, 2, 3, and 4 days, receiving scores between "like extremely" and "neither like nor dislike" on the hedonic scale. On the other hand, uncoated bananas fell below the limit of acceptability by the second day of storage.

DISCUSSION

Low storage temperature and modified atmosphere are common means for preventing partially mold growth and senescence, and extending shelf life of fruits (9). Modified atmosphere method involves use of polyethylene bags for bananas. Optimal temperatures and gas levels for banana range between 13.3 to 14.4 °C, 2 to 5% O_2 and 2 to 5% CO_2, respectively (20). Exposure of bananas to temperatures below 13 °C leads to chilling injury depending on cultivar, maturity, and duration of exposure (20). Chilling injury is a peel disorder, whose major indicator is sub-epidermal discoloration causing the peel to turn dark brown or black (20). Edible coatings, which can also be used to preserve fruits by decreasing moisture loss and respiration, provide similar controlled gas-exchange and antimicrobial property, etc and retard deterioration of bananas (9). In addition, edible coatings might be a cost effective alternative or supplement to modified atmosphere method. Thus, in this study fungal decay, weight loss, firmness, color, and sensory properties were monitored for coated and uncoated bananas to evaluate the potential of hemicelluloses as a coating material on fruit surfaces.

The capacity of chitosan coating to inhibit several fungi on strawberry and banana was previously shown (8, 9). The antimicrobial activity was claimed to be due to cellular damage to mold and interference in the secretion of polygalacturonases. Thus, it is no surprising that hemicellulose coating, which is also a polysaccharide derivative as chitosan, did prevent fungal decay in the coated bananas in this study. Hernandez-Munoz et al. (9) also reported successful fungal inhibition for chitosan coating at 1.5% and partly successful for 1% coating, which resulted in decay on day 6.

Moisture content is one of the key factors that need to be controlled to preserve food quality during storage and its change is related with weight loss in practice. As a preservative action, the coating material acts as a moisture barrier, which seals small wounds, limits water transfer and delays dehydration (7). Because unpeeled bananas were used in coating experiments, they were not susceptible to rapid water losses but prevention of this much water loss (3.1-3.6%) was still important for retaining the quality of the stored bananas.

For fresh fruit and vegetables, texture is a critical quality parameter because textural changes directly affect the acceptance of consumers. Polysaccharide derivatives such as carboxymethyl cellulose, starch, and *N,O*-carboxymethyl chitosan, etc. with addition of lipid component such as glycerol monosterate or palmitic acid as a coating formulation for banana resulted in higher firmness (150-177 kgf) values than the uncoated samples (112 kgf) during storage at room temperature (8). On the other hand, the hemicellulose coating without addition of any enhancer as in this study seems more advantageous with its natural, edible, and water-soluble characteristics.

Color is an important factor that directly affects consumer decision to buy the product or not. At the beginning of ripening, banana peel contains ethylene, which causes ripening from green to yellow. A uniform bright yellow color is the desired quality characteristics for bananas. Because cold temperatures speed up darkening of banana peel, the final color was not as bright as desired but was sufficient to demonstrate the effect of the hemicellulose coating. All tested hemicellulose concentrations were successful in preserving banana's color. Lower levels of darkening and browning were also detected in the sensory analysis results, measured as visual acceptance by the consumers. As a result, hemicellulose coating showed successful promising preservative effect on banana, delaying darkening and prolonging acceptability of banana. Thus, in further studies the preservative effect should be evaluated at different storage temperatures and on different fruits.

CONCLUSION

This study presented the usage of hemicelluloses from a renewable source as an edible coating material. In order to prolong shelf life and maintain important properties such as color and texture, edible coatings from natural sources are often preferred as an air and moisture barrier. Banana was used for the experiments in this study because it is the most traded fruit in the world and may be susceptible to harsh environmental conditions in everyday life. After a storage period of four days at 4 °C, the results indicated that hemicelluloses can be an effective coating material to prevent darkening of bananas. It was shown that lightness and yellowness of the coated bananas were preserved with small losses at the end of storage while uncoated samples were of unacceptable appearance. Moreover, hemicellulose coating kept both textural damage and moisture losses at minimal levels. Thus, it was concluded that hemicelluloses have a remarkable potential to be used on surfaces of various fruits for quality preservation.

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