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Extending the Shelf Life of Persimmon "*Diospyros kaki*" by Edible Coating

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ABSTRACT

Persimmon *(Diospyros kaki* J.) is a subtropical fruit with short postharvest life. The effect of pectin and guar gum based edible coatings was studied under certain conditions of plasticizer, antioxidants and antimicrobial agents. Two concentrations of pectin (1 and 2%) and guar gum coatings (0.5and1%) were applied. Fruits were dipped in coating solutions for 1 minute, followed by air drying at room temperature and stored at 4±1˚C and 70 - 75 % RH for 30 days. Changes in shelf life, weight loss, firmness, TSS, pH, TTA, V.C, total phenol contents, PPO, BI, microbial growth and sensory properties were evaluated. The results showed that shelf life of fruit was significantly increased by edible coating treatments. Application of pectin and guar gum decreased weight loss, physical changes and retained more firmness, total antioxidant activity and total phenolic compounds compared to the control (non-coated). All the treatments effectively reduced the populations of microbial growth. Significant differences were recorded in fruit between the two concentrations of pectin and guar gum coating. These results demonstrated that the coatings used in application extended the shelf life and maintain quality of harvested persimmon fruit. The sensory evaluation of coated persimmon fruit for colour, odour, taste, texture and overall acceptability confirmed the prementioned findings.

Keywords: Persimmon, Edible coatings, guar gum, pectin

INTRODUCTION

Persimmon *(Diospyros kaki* L.) belonging to family *Ebenaceae* is a popular commercial fruit, and widely consumed both in its natural and dried forms Cho *et al.,* (2007). The fruit is rich in sugars, phenolics, carotenoids, dietary fibers, vitamin C, and minerals, thus it is considered as important neutraceutical fruit, these phytochemicals play an important role in terms of flavour, colour, firmness and pharmaceutical value of the fruit. Carotenoids and phenolics are known for their good antioxidant power, anti-carcinogenic, anti-mutagenic and cardio-protective effects Suzuki *et al.,* (2005). Due to its perishable nature, there is a limited trade exchange for persimmon. With storage, excessive flesh softening, browning, and water-soaked appearance have been observed. Moreover, excessive postharvest softening resulting in jelly-like flesh within couple of days that can make marketing of fruits difficult Harima *et al.,* (2003) and Rasouli, and Khademi, (2014). Many methods are used to increase postharvest shelf life of these fruits like hot water treatments Rasouli, and Khademi (2014). However, the application of high CO_2 levels allows the removal of astringency without affecting fruit firmness Salvador *et al.,* (2007), which enables this fruit to be commercialized as a fresh-cut commodity. Moreover, fruit processing promotes faster deterioration due to tissue damage, which leads to increased physiological activity and major physico-chemical changes, such as enzymatic browning, softening, as well as spoilage and pathogenic microorganisms can also contaminate the product surface, and the nutrients inside the fruit contribute to their growth. On the other hand, browning is the main problem leading to decrease the value of sweet persimmon during process and storage. It was reported that over 30 % of fruit losses occur due to enzymatic browning. Browning influences not only the sensory and quality of sweet persimmon, but also the development of the whole persimmon product. Consequently, the restraint of browning is necessary in this respect. It was documented that the esculent coating carried as antibrowning agents has been found efficient in inhibiting respiration, delaying metabolism and minimizing pericarp browning Zhang and Quantick (1997).

In recent years, the use of edible coatings has emerged as a new, effective, and environmental-friendly alternative mean to extend the shelf life of many products, including fresh-cut fruit and vegetables, by providing a barrier to water loss and gas exchange. Furthermore, functional properties of such products may be enhanced by the addition of food ingredients, such as antioxidants and antimicrobial, to improve appearance, integrity and microbial safety, Valencia-Chamorro *et al.,* (2011). Pectin-based edible coating containing 10 g kg^{-1} citric acid (CA) and 10 g kg^{-1} calcium chloride ($CaCl_2$) proved effective among different polysaccharide coatings in controlling the enzymatic browning of fresh-cut 'Rojo Brillante' persimmon. This effect was attributed to the capability of pectin to form strong insoluble polymers upon the reaction with multivalent metal cations like calcium Oms-Oliu *et al.,* (2008). Antimicrobial pectin coatings and antioxidant aqueous solution significantly controlled enzymatic browning and reduced the total aerobic mesophilic bacteria of fresh-cut 'Rojo Brillante' persimmon during storage at 5°C, Overall, the coatings containing 2 g kg^{-1} PS or 4 g kg^{-1} SB proved to be the most effective to maintain the visual quality of persimmon slices Sanchis *et al.,* (2015).

Microbiological stability on the other hand is a critical factor to maintain the commercial marketability of fresh-cut product. Incorporating antimicrobial compounds into edible coatings is becoming an important practice for the potential development of novel treatments for fresh-cut fruit. The use of these substances has its advantages over the direct application of antibacterial agents onto foods because edible films can be designed to slow down the diffusion of antimicrobials from food surfaces. The effectiveness of different antimicrobial substances, such as lysozyme, nisin (NI), organic acids, essential oils and their derivatives incorporated into edible films against several pathogens has proven satisfactory Rojas-Graü *et al.,* (2009) and Valencia-Chamorro *et al.,* (2011). On the other hand, potassium sorbate (PS), sodium benzoate (SB) and NI are widely used as safe antimicrobial food additives, although they have been less studied as edible coating ingredients to control microbial growth in fresh-cut fruit. Nevertheless, some studies have proved the antimicrobial activity of a cellulose-based edible coating amended with 1 g kg^{-1} SB or PS in fresh-cut apple and potato Baldwin *et al.,* (1996).

In general, application of edible coatings significantly delayed weight loss, decay percentage, colour changes, firmness loss, carotenoid accumulation and maintained higher concentration of total phenolics and antoxidant capacity in coated persimmon fruits. Moreover, sensory evaluation results confirmed the overall acceptability of persimmon fruit during storage Saha *et al.,* (2015).

The aim of this work was study the effect of polysaccharides edible coatings based on pectin and guar gum with a combination of antioxidants and antimicrobial agents on controlling enzymatic browning and microbial growth of sweet persimmons stored at 4±1°C for 30 days.

MATERIALS AND METHODS

Materials and Methods:

Preparation of sample:

Persimmon (*Diospyros kaki* Japanese persimmon) at commercial maturity was obtained from the local market. Before the experiments, fruit was selected for size and absence of physical and microbial damage. Fruits were washed with tap water, and the fruits were rinsed with disinfectant solution (calcium hypochlorite 2%). This was followed by air during for 3min, and randomly divided into 5 groups, which corresponded to 4 coating treatments, and 1 water dipped control.

Coating used: Pectin and guar gum were purchased from Mifad Company, Badr city Egypt.

Coating treatments: Fruits groups were assigned to the following coating treatments: T1 [non-coated (control)]. T2 [1% pectin (P)], T3 [2% pectin (P)], T4 [0.5% guar gum (GG)], T5 [1% guar gum (GG)], 0.1 ml tween-80 was added as an emulsifier and glycerol (50% w/w based on P and GG powder respectively) was added as plasticizer in all the above solutions and the solutions were heated gradually to 85 °C while stirring for 40 min, followed by cooling to room temperature, then 0.1 ml cinnamon oil was added as an antioxidant and potassium sorbate (0.1%) was also added as an antimicrobial in coating solutions, then the solution was filtrated. Experiment was conducted in three replications.

Application of coating on fruits:

The fruits were dipped in each of the prementioned solutions of different coatings for 1 min. and kept for air drying at room temperature for 30 min. Both coated and non-coated fruits were placed and stored on polyethylene teraphthalet (PET) punnets. All samples were stored in a refrigerator at 4±1°C and 70-75% relative humidity (RH). Relative humidity was estimated by Hygrometer. Samples were withdrawn every 3 days of storage for chemical, physical, microbial analyses and organoleptic evaluation.

Physical and chemical analyses:

- Weight loss was measured as the percentage weight loss from the initial weight of fruits A.O.A.C., (2000).

- Total soluble solid (TSS) was determined in the juice by the refractometric method at room temperature using a manual refractometr (R R 12, Nr 05116, 0-35% at 20 °C, Made in Poland) according to the method given in the A. O. A. C., (2000).

- Firmness of the whole fruits was measured using a hand dynamometer model FDP 1000 with a thump (2 mm) in gf (gram- force). The data ware transformed into Newton units using standard factor (1 gram- force = 0.00980665 Newton).

- pH: pH meter was used for pH measurement of the extracted juices as the method described in A.O.A.C., (2000).

- Total titratable acidity (TTA) of juices was determined in the extracted juices as described in A.O.A.C., (2000).

- **Ascorbic acid (V.C)** was determined using 2,6 dichloro-phenolindophenol titrimetic method as described in A.O.A.C., (2000). The results were expressed in milligrams ascorbic acid per 100 ml of fruit juice.

- Brown index (BI): It was measured using a procedure described by Jiang, *et al.,* (2012).

- Total phenolic content: It was measured using a procedure described by Swain and Hallis (1955).

- **Polyphenol oxidase (PPO) activity:** The total soluble enzyme activities were measured spectrophotometrically in the prepared supernatant Hafez, (2010) using the model UV-160A spectrophotometer (Shimadzu, Japan). Polyphenol oxidase (PPO) activity was determined according to the method described by Malik and Singh (1980).

Microbial analysis: Total bacterial count (TC) and yeasts and moluds (Y&M) were determined according to methods described in the DIFCO manual DIFCO, (1977).

Sensory evaluation: It was carried out by seven trained panelists at 0, 5, 10, 15, 20, 25 and 30 days of storage period Ramadhan *et al.,* (2011). The shelf life of persimmon fruits was calculated by counting the days up to which the fruits remain still acceptable for marketing.

RESULTS AND DISCUSSION

Weight loss: There was a significant difference (p<0.05%) was found between control (untreated) fruits and the coated fruits (T2, T5, T3 then T4). 1% pectin was not as effective as guar gum and 2% pectin in controlling weight loss that might be due to its concentration used this might increase the anaerobic conditions within the fruit resulting in greater weight loss Gol, *et al.,* (2013). loss in weight of persimmon fruits increased in all treatments with the progressive increase in storage time (Table 1). Edible coatings act by creating modified atmosphere around fruit surface which resulted in reduction in weight loss during entire storage period which might help in maintaining the quality of 'Hachiya' persimmon fruit Saha, *et al.,* (2015).

Table 1. Effect of edible coating treatments on weight loss (%) during storage of persimmon fruits

Coating types	Storage period (days)										
	0	3	6	9	12	15	18	21	24	27	30
T1	0.00	$^{A}2.41^{e}$	$^{A}3.29^{d}$	$^{A}4.25^{c}$	$^{A}6.43^{b}$	$^{A}7.69^{a}$	ND	ND	ND	ND	ND
T2	0.00	$^{B}1.45^{h}$	$^{B}2.64^{g}$	$^{B}3.02^{f}$	$^{B}4.40^{e}$	$^{B}4.87^{d}$	$^{A}5.90^{c}$	$^{A}6.19^{b}$	$^{A}6.98^{a}$	ND	ND
T3	0.00	$^{D}1.03^{j}$	$^{D}1.92^{i}$	$^{D}2.18^{h}$	$^{D}3.20^{e}$	$^{D}3.92^{f}$	$^{C}4.35^{e}$	$^{C}4.96^{d}$	$^{C}5.70^{c}$	$^{B}6.11^{b}$	$^{B}6.63^{a}$
T4	0.00	$^{E}0.96^{j}$	$^{E}1.45^{i}$	$^{E}1.56^{h}$	$^{E}2.41^{g}$	$^{E}2.93^{f}$	$^{D}3.50^{e}$	$^{D}4.31^{d}$	$^{D}4.92^{c}$	$^{C}5.20^{b}$	$^{C}5.78^{a}$
T5	0.00	$^{C}1.22^{j}$	$^{C}2.19^{i}$	$^{C}2.73^{h}$	$^{C}3.61^{g}$	$^{C}4.06^{f}$	$^{B}5.13^{e}$	$^{B}5.76^{d}$	$^{B}6.26^{c}$	$^{A}6.91^{b}$	$^{A}7.74^{a}$

Means of treatments having the same right case letter (s) (capital letters within a column are not significantly different (p > 0.05).
Means of storage periods having the same left case letter (s) (small letters within a row) are not significantly different (p > 0.05).
T1→uncoated samples (control) T2→Pectin 1% T3→Pectin 2% T4→Guar gum 0.05% T5→Guar gum 1% ND→Not determined because of spoilage.

Fruit Firmness: Firmness of the uncoated fruits and fruits coated with T2 significantly decreased (p<0.05) with storage as compared to fruits coated with other the coatings (Table 2). Firmness of the fruit coated with 1% pectin (T2) was higher (2.10 N) at 24th days of storage than non-coated which spoiled after15th days of storage. T5, T3 coated fruit had values of 2.20 N and 2.62 N respectively, at the end of storage. T4 coated samples were significantly the best in firmness retention in all storage period. Our results are in agreement with those obtained by Saha, *et al.*, (2015). The edible coating perhaps inhibits increase in water soluble pectic substances; thereby delays fruit softening process. More details were given by Proctor and Peng (1989).

TSS: Total soluble solid (TSS) significantly increased for both uncoated and coated samples (Table 3) as a result of storage time for 30 days of permission fruits. This finding might be due to moisture loss during storage and degradation of insoluble components to soluble ones during ripening. The increment of TSS in uncoated samples at the end of storage was significantly higher than those of coated samples. The lowest increment of TSS was found in T4 coated samples (21.80%) followed by T3 and T5 (22.30% & 22.50%) (no significance different between both of them during most of storage period), then T2 coated samples (24.50%) at 24th days of storage compared with uncoated samples (26.30%) at 15th days of storage.

Table 2. Effect of edible coating treatments on firmness (N) during storage of persimmon fruits

Coating	Storage period (days									
types	0	3	6	9	12	15	18	21	24	27	30
T1	$^{A}6.96^{a}$	$^{C}5.30^{b}$	$^{B}4.20^{c}$	$^{D}3.23^{d}$	$^{C}2.91^{e}$	$^{C}2.30^{f}$	ND	ND	ND	ND	ND
T2	$^{A}6.90^{a}$	$^{B}6.00^{b}$	$^{A}5.49^{c}$	$^{C}4.39^{d}$	$^{B}4.01^{e}$	$^{B}3.73^{f}$	$^{C}3.17^{g}$	$^{C}2.79^{h}$	$^{C}2.10^{i}$	ND	ND
T3	$^{A}6.89^{a}$	$^{AB}6.33^{b}$	$^{A}5.68^{c}$	$^{AB}5.09^{d}$	$^{A}5.00^{d}$	$^{AB}4.23^{e}$	$^{B}3.75^{f}$	$^{B}3.28^{g}$	$^{B}3.08^{gh}$	$^{B}2.83^{gh}$	$^{B}2.62^{h}$
T4	$^{A}6.91^{a}$	$^{A}6.56^{a}$	$^{A}5.94^{b}$	$^{A}5.23^{c}$	$^{A}5.03^{cd}$	$^{A}4.64^{de}$	$^{A}4.57^{de}$	$^{A}4.44^{e}$	$^{A}3.59^{f}$	$^{A}3.30^{f}$	$^{A}3.10^{f}$
T5	$^{A}6.97^{a}$	$^{AB}6.14^{b}$	$^{A}5.45^{c}$	$^{BC}4.64^{d}$	$^{B}4.34^{de}$	$^{B}4.09^{e}$	$^{C}3.25^{f}$	$^{BC}3.20^{f}$	$^{B}3.02^{f}$	$^{B}2.53^{g}$	$^{C}2.20^{g}$

- ND → Not determined because of spoilage. - See legend to Table (1) for details.

Table 3. Effect of edible coating treatments on TSS (%) during storage of persimmon fruits

Coating	Storage period (days)									
types	0	3	6	9	12	15	18	21	24	27	30
T1	$^{A}18.20^{f}$	$^{A}19.50^{e}$	$^{A}20.80^{d}$	$^{A}22.10^{c}$	$^{A}24.20^{b}$	$^{A}26.30^{a}$	ND	ND	ND	ND	ND
T2	$^{A}18.20^{i}$	$^{B}18.80^{h}$	$^{B}19.30^{g}$	$^{B}19.60^{f}$	$^{B}20.70^{e}$	$^{B}21.30^{d}$	$^{A}22.20^{c}$	$^{A}23.60^{b}$	$^{A}24.50^{a}$	ND	ND
T3	$^{A}18.10^{h}$	$^{C}18.30^{h}$	$^{C}18.90^{g}$	$^{CD}19.30^{f}$	$^{C}19.50^{f}$	$^{C}19.80^{e}$	$^{B}20.00^{e}$	$^{BC}20.30^{d}$	$^{B}20.80^{c}$	$^{A}21.90^{b}$	$^{A}22.30^{a}$
T4	$^{A}18.00^{h}$	$^{C}18.20^{h}$	$^{C}18.90^{g}$	$^{D}19.20^{f}$	$^{C}19.50^{e}$	$^{C}19.70^{e}$	$^{C}19.70^{e}$	$^{C}20.20^{d}$	$^{C}20.50^{c}$	$^{B}21.30^{b}$	$^{B}21.80^{a}$
T5	$^{A}18.10^{j}$	$^{B}18.60^{i}$	$^{BC}19.10^{h}$	$^{BC}19.50^{g}$	$^{C}19.70^{fg}$	$^{C}19.90^{ef}$	$^{B}20.00^{e}$	$^{B}20.50^{d}$	$^{B}21.00^{c}$	$^{A}21.80^{b}$	$^{A}22.50^{a}$

- ND → Not determined because of spoilage. - See legend to Table (1) for details.

pH: The data presented in Table (4) showed that pH values of uncoated and coated samples increased slightly as a function of storage time. The increment of pH values of coated samples was lower compared to the control. Significant differences were recorded between coated and uncoated samples. T3, T4, T5 coated samples were the best for maintenance of pH during 30 day of storage period ($p \geq 0.05$).

TTA: Table (5) shows the changes in total titratable acidity (TTA) during storage of persimmon fruits. TTA decreased during storage all samples. Significant differences were recorded between coated and uncoated (control) samples. T4 coated samples had significantly the highest (0.160%) followed by T3 and T5 (0.157% and 0.155%) respectively, at 30 day of storage period in maintenance of TTA value.

Table 4. Effect of edible coating treatments on pH during storage of persimmon fruits

Coating	Storage period (days)									
types	0	3	6	9	12	15	18	21	24	27	30
T1	$^{A}6.10^{f}$	$^{A}6.39^{e}$	$^{A}6.49^{d}$	$^{A}6.59^{c}$	$^{A}6.78^{b}$	$^{A}6.91^{a}$	ND	ND	ND	ND	ND
T2	$^{A}6.13^{i}$	$^{A}6.38^{h}$	$^{AB}6.48^{g}$	$^{A}6.53^{f}$	$^{B}6.59^{e}$	$^{B}6.61^{d}$	$^{A}6.69^{c}$	$^{A}6.75^{b}$	$^{A}6.83^{a}$	ND	ND
T3	$^{A}6.12^{k}$	$^{A}6.33^{j}$	$^{B}6.42^{i}$	$^{B}6.43^{h}$	$^{C}6.46^{g}$	$^{C}6.54^{f}$	$^{AB}6.64^{e}$	$^{AB}6.65^{d}$	$^{B}6.68^{c}$	$^{A}6.73^{b}$	$^{A}6.83^{a}$
T4	$^{A}6.13^{g}$	$^{A}6.33^{f}$	$^{B}6.42^{e}$	$^{B}6.44^{e}$	$^{C}6.44^{e}$	$^{C}6.52^{d}$	$^{B}6.61^{c}$	$^{C}6.62^{c}$	$^{B}6.66^{bc}$	$^{A}6.71^{b}$	$^{A}6.80^{a}$
T5	$^{A}6.16^{h}$	$^{A}6.36^{g}$	$^{AB}6.46^{f}$	$^{B}6.46^{e}$	$^{C}6.48^{e}$	$^{AB}6.56^{d}$	$^{A}6.76^{c}$	$^{B}6.69^{bc}$	$^{B}6.69^{bc}$	$^{A}6.75^{b}$	$^{A}6.84^{a}$

- ND → Not determined because of spoilage. - See legend to Table (1) for details.

Table 5. Effect of edible coating treatments on TAA (%) during storage of persimmon fruits (expressed as % of citric acid)

Coating	Storage period (days)									
types	0	3	6	9	12	15	18	21	24	27	30
T1	$^{A}0.173^{a}$	$^{C}0.168^{b}$	$^{C}0.162^{c}$	$^{D}0.157^{d}$	$^{C}0.151^{e}$	$^{C}0.146^{f}$	ND	ND	ND	ND	ND
T2	$^{A}0.175^{a}$	$^{B}0.172^{b}$	$^{B}0.168^{c}$	$^{C}0.166^{d}$	$^{B}0.163^{e}$	$^{B}0.160^{f}$	$^{B}0.157^{g}$	$^{C}0.156^{h}$	$^{C}0.153^{i}$	ND	ND
T3	$^{A}0.175^{a}$	$^{A}0.175^{a}$	$^{A}0.173^{ab}$	$^{AB}0.172^{bc}$	$^{A}0.170^{c}$	$^{A}0.167^{d}$	$^{A}0.163^{e}$	$^{B}0.161^{ef}$	$^{B}0.159^{fg}$	$^{B}0.158^{g}$	$^{AB}0.157^{g}$
T4	$^{A}0.175^{a}$	$^{A}0.175^{a}$	$^{A}0.173^{a}$	$^{A}0.173^{a}$	$^{A}0.170^{b}$	$^{A}0.168^{b}$	$^{A}0.165^{c}$	$^{A}0.165^{c}$	$^{A}0.163^{c}$	$^{A}0.163^{c}$	$^{A}0.160^{d}$
T5	$^{A}0.175^{a}$	$^{AB}0.174^{a}$	$^{A}0.171^{a}$	$^{B}0.170^{a}$	$^{A}0.168^{ab}$	$^{A}0.166^{bc}$	$^{A}0.163^{cd}$	$^{B}0.160^{de}$	$^{B}0.157^{ef}$	$^{B}0.156^{fg}$	$^{B}0.155^{g}$

- ND → Not determined because of spoilage. - See legend to Table (1) for details.

Ascorbic acid: The present results showed that ascorbic acid contents in all samples significantly decreased during storage. Ascorbic acid losses of coated samples were lower than those of uncoated samples during storage (Table 6). The lowest amount (mg/100g) of V.C was observed in T4 coated samples (19.2) followed by T3, T5 (18.7 and 18.0) at 30 days of storage, and by T2 coated fruits (18.5) at 24th days of storage whereas non-coated fruits had the minimum value (18.0) at 15th days of storage. Delay in changes of antioxidant activities with edible coatings during storage and ripening has also been reported by Ali, *et al*., (2013) in tomatoes. They suggested that edible coatings delayed the biochemical and physiological changes in fruits during storage. The antioxidant capacities of persimmon fruits also depend on other factors like genetic factors, cultivars, environmental conditions, harvesting maturity, time of harvest and their geographical origin Vinha, *et al*., (2012).

Total Phenols: Persimmon fruit is a good source of poly-phenols and antioxidants Veberic, *et al*., (2010) and Vinha, *et al*., (2012). In our study, the control persimmon fruits (T1) showed phenomenal increased (0.859 ug/g) in total phenols at 12th days of storage period (Table 7) followed by T2 coated fruits (0.791) at 18th days of storage period. During entire storage period, T4 coated fruits displayed significantly lower retention (0.727 ug/g) of total phenols at 30 days of storage period followed by T3 and T5 (0.783 and 0.810 ug/g) respectively. Phenolic compounds are responsible for colour, flavour, taste and aroma of the fruit Tomas-Barberan, & Espin (2001) and Vinha, *et al*., (2012). These results agree with Saha, *et al*., (2015) since higher retention of total phenols in coated fruits represented better internal quality of chitosan and guar gum coated fruits as compared to control (non-coated) fruits.

Table 6. Effect of edible coating treatments on V.C (mg/100g sample) of coated and control persimmon fruits during storage

Coating	Storage period (days)										
types	0	3	6	9	12	15	18	21	24	27	30
T1	$^{B}37.0^{a}$	$^{D}34.0^{b}$	$^{C}30.2^{c}$	$^{D}27.3^{d}$	$^{D}23.5^{e}$	$^{E}18.0^{f}$	ND	ND	ND	ND	ND
T2	$^{A}37.4^{a}$	$^{C}34.8^{b}$	$^{B}32.6^{c}$	$^{C}30.0^{d}$	$^{C}27.3^{e}$	$^{D}24.1^{f}$	$^{D}22.5^{g}$	$^{D}20.3^{h}$	$^{D}18.5^{i}$	ND	ND
T3	$^{A}37.5^{a}$	$^{AB}35.5^{b}$	$^{A}33.4^{c}$	$^{B}31.2^{d}$	$^{AB}28.2^{e}$	$^{B}26.0^{f}$	$^{B}24.7^{g}$	$^{B}22.5^{h}$	$^{B}21.0^{i}$	$^{B}19.5^{j}$	$^{B}18.7^{k}$
T4	$^{A}37.5$	$^{A}35.7^{b}$	$^{A}33.4^{c}$	$^{A}31.5^{d}$	$^{A}28.3^{e}$	$^{A}29.4^{f}$	$^{A}25.3^{g}$	$^{A}23.1^{h}$	$^{A}22.0^{i}$	$^{A}20.3^{j}$	$^{A}19.2^{k}$
T5	$^{A}37.5^{a}$	$^{B}35.4^{b}$	$^{A}33.2^{c}$	$^{B}31.2^{d}$	$^{B}28.0^{e}$	$^{C}25.7^{f}$	$^{C}24.0^{g}$	$^{C}22.0^{h}$	$^{C}20.0^{i}$	$^{C}19.1^{j}$	$^{C}18.0^{k}$

- ND → Not determined because of spoilage. - See legend to Table (1) for details.

Table 7. Effect of edible coating treatments on total phenols (ug/g) of coated and control persimmon fruits during storage

Coating	Storage period (days)					
types	0	6	12	18	24	30
T1	$^{B}0.224^{c}$	$^{A}0.680^{b}$	$^{A}0.859^{a}$	ND	ND	ND
T2	$^{A}0.252^{d}$	$^{B}0.375^{c}$	$^{E}0.459^{b}$	$^{A}0.791^{a}$	ND	ND
T3	$^{A}0.252^{f}$	$^{C}0.351^{e}$	$^{B}0.573^{d}$	$^{B}0.663^{c}$	$^{B}0.731^{b}$	$^{B}0.783^{a}$
T4	$^{A}0.252^{f}$	$^{C}0.337^{e}$	$^{C}0.551^{d}$	$^{C}0.645^{c}$	$^{C}0.673^{b}$	$^{C}0.727^{a}$
T5	$^{A}0.257^{f}$	$^{B}0.373^{e}$	$^{B}0.584^{d}$	$^{B}0.675^{c}$	$^{A}0.756^{b}$	$^{A}0.810^{a}$

- ND → Not determined because of spoilage.
- See legend to Table (1) for details.

Brown index (BI): The BI increased with persimmon fruits storage lasted, which suggests an increase in proportion of oxidized phenols during sweet persimmon storage. The changes in degree of browning of sweet persimmons are shown in Table (8). There are significant differences between coated and uncoated samples and between the treatments. Samples T4, T3 and T5 remained constant relatively in this respect.

Polyphenol oxidase (PPO): PPO activity is considered a major factor involved in enzymatic browning which generally results from the oxidation of phenolic substrates and brings about drop of sensory quality. As shown in Table (9), the PPO activity of coated sweet persimmons showed a significant increase during storage compared with the uncoated. PPO activity of T4 coated samples changed gradually during storage, which was inhibited and was only 0.00503 (U/min ug) at the end of storage, while the other treatments T3 and T5 had values of 0.00663 and 0.00693 (U/min ug), respectively. Compared with the treatment of T2 (0.00593) at 18 days of storage. The inhibitory effect on PPO activity in the cinnamon oil is fungistasis, which can protect membrane integrity and avoiding contact between phenolic and PPO. Moreover there is synergistic effect when several browning inhibitors mix together Lee, and Eun, (1999).

Table 8. Effect of edible coating treatments on brown index (BI) (u/ug) of coated and control persimmon fruits during storage

Coating types	Storage period (days)					
	0	6	12	18	24	30
T1	$^{A}0.0827^{c}$	$^{A}0.1867^{b}$	$^{A}0.2917^{a}$	ND	ND	ND
T2	$^{B}0.0687^{d}$	$^{B}0.1507^{c}$	$^{B}0.2367^{b}$	$^{A}0.2417^{a}$	ND	ND
T3	$^{B}0.0657^{f}$	$^{C}0.1037^{e}$	$^{D}0.1657^{d}$	$^{C}0.1777^{c}$	$^{B}0.1927^{b}$	$^{B}0.2137^{a}$
T4	$^{B}0.0657^{f}$	$^{E}0.0976^{e}$	$^{E}0.1067^{d}$	$^{D}0.1777^{c}$	$^{C}0.1867^{b}$	$^{B}0.2097^{a}$
T5	$^{B}0.0667^{e}$	$^{D}0.1097^{d}$	$^{C}0.1857^{c}$	$^{B}0.1967^{b}$	$^{A}0.1987^{b}$	$^{A}0.2157^{a}$

- ND → Not determined because of spoilage. - See legend to Table (1) for details.

Table 9. Effect of edible coating treatments on poly phenol oxidase (PPO) (U/min ug) during storage of coated and control persimmon fruits

Coating types	Storage periods (days) at 4±1 °C and 70-75%					
	0	6	12	18	24	30
T1	$^{A}0.00273^{c}$	$^{b}0.00473^{A}$	$^{A}0.00583^{a}$	ND	ND	ND
T2	$^{A}0.00263^{d}$	$^{B}0.00373^{c}$	$^{B}0.00433^{b}$	$^{A}0.00593^{a}$	ND	ND
T3	$^{A}0.00273^{f}$	$^{C}0.00333^{e}$	^{C}0.00373d	$^{C}0.00393^{c}$	$^{A}0.00573^{b}$	$^{B}0.00663^{a}$
T4	$^{A}0.00273^{d}$	$^{D}0.00273^{d}$	$^{D}0.00273^{d}$	$^{D}0.00333^{c}$	$^{B}0.00393^{b}$	$^{C}0.00503^{a}$
T5	$^{A}0.00273^{f}$	$^{B}0.00373^{e}$	$^{C}0.00393^{d}$	$^{B}0.00333^{c}$	$^{A}0.00593^{b}$	$^{A}0.00693^{a}$

- ND → Not determined because of spoilage. - See legend to Table (1) for details.

Microbial growth: Under the studied conditions, growth of bacteria and yeasts & moulds, was observed during storage in all persimmon fruits, including the control samples dipped in water. The results indicated that all coatings were effective in maintaining low levels of total bacterial count compared to the control. However, the counts of total bacteria significantly increased in control samples during storage (Table 10), T4, T3 and T5 were the best in reducing levels of total bacterial counts. It can be observed from the Table (10) that, all coatings significantly reduced yeasts and moulds growth compared to the control samples. T3 and T4 coatings restricted yeasts and moulds growth during all storage period. Evidence of the antimicrobial properties of organic acids like citric, sorbic, benzoic, lactic or oxalic acids, and organic acid salts like PS and SB, can be frequently found in the literature Valencia-Chamorro *et al.,* (2011). Cinnamon oil can inhibit bacteria, yeasts and moulds growth and subsequent toxin production Bullerman, *et al.,* (1977). Olivas and Barbosa-Canovas., (2005) mentioned that coatings created a modified atmospher that changed the growth rate of spoilage and pathogenic microorganisms.

Sensory evaluation: sensory evaluation of persimmon fruits in terms of colour, odour, taste, texture and overall acceptability among treatments was significantly ($p<0.05$) different at zero time of storage. The fruits treated with T4 received maximum score followed by T5, T3 and T2 (Table

11). Colour, odour, taste and texture of these fruits were relatively maintained to 30 days of storage period due to protective, antifungal and barrier effects of pectin and guar gum as an edible coating, non-coated samples received less scores that due to high shrinkage, less colour, low quality and fungal deterioration after 15th day of storage. These results similar to those of Saha, *et al.,* (2015).

Table 10. Effect of coating types of persimmon on the total bacterial count, (A) and yeast and mould count (B) Log (CFU/g)*

Coating types	Storage period (days) (A)						
	0	**5**	**10**	**15**	**20**	**25**	**30**
T1	$^{A}3.36^{c}$	$^{A}3.87^{d}$	$^{A}4.24^{b}$	$^{A}5.36^{a}$	ND	ND	ND
T2	$^{AB}3.30^{d}$	$^{A}3.69^{e}$	$^{B}3.90^{c}$	$^{B}4.15^{b}$	$^{A}4.46^{a}$	ND	ND
T3	$^{BC}3.26^{f}$	$^{A}3.59^{f}$	$^{C}3.69^{e}$	$^{C}4.08^{d}$	$^{C}4.15^{c}$	$^{A}4.30^{b}$	$^{B}4.48^{a}$
T4	$^{D}3.01^{d}$	$^{B}3.27^{d}$	$^{C}3.60^{c}$	$^{E}3.77^{c}$	$^{D}4.11^{a}$	$^{B}4.23^{b}$	$^{C}4.41^{a}$
T5	$^{C}3.23^{f}$	$^{A}3.62^{e}$	$^{C}3.73^{d}$	$^{D}3.90^{c}$	$^{B}4.28^{b}$	$^{A}4.32^{b}$	$^{A}4.50^{a}$
Coating types	Storage period (days) (B)						
	0	5	10	15	20	25	30
T1	$^{A}2.15^{d}$	$^{A}2.85^{c}$	$^{A}3.26^{b}$	$^{A}3.96^{b}$	ND	ND	ND
T2	$^{B}2.00^{e}$	$^{AB}2.76^{d}$	$^{B}2.88^{c}$	$^{B}3.15^{c}$	$^{A}3.36^{a}$	ND	ND
T3	$^{B}1.95^{f}$	$^{C}2.37^{e}$	$^{C}2.73^{d}$	$^{C}3.05^{d}$	$^{C}3.17^{c}$	$^{A}3.26^{b}$	$^{B}3.43^{a}$
T4	$^{C}1.85^{g}$	$^{D}2.12^{f}$	$^{D}2.45^{e}$	$^{D}2.95^{e}$	$^{D}3.11^{c}$	$^{B}3.23^{b}$	$^{C}3.40^{a}$
T5	$^{B}1.95^{f}$	$^{B}2.63^{e}$	$^{C}2.78^{e}$	$^{C}3.08^{e}$	$^{B}3.23^{c}$	$^{A}3.28^{b}$	$^{A}3.80^{a}$

- ND → Not determined because of spoilage.
***→ Colony forming unit/gram - See legend to Table (1) for details.**

Table 11. Mean sensory scores of permission fruits as affected by coating types during storage

Storage (days)	Attributes	T1	T2	T3	T4	T5
0	Colour	$^{A}9.72$	$^{A}9.72$	$^{A}9.74$	$^{A}9.80$	$^{A}9.81$
	Odour	$^{A}9.79$	$^{A}9.86$	$^{A}9.89$	$^{A}9.91$	$^{A}9.82$
	Taste	$^{A}9.81$	$^{A}9.93$	$^{A}9.82$	$^{A}9.91$	$^{A}9.86$
	Texture	$^{A}9.94$	$^{A}9.91$	$^{A}9.90$	$^{A}9.92$	$^{A}9.88$
	Overall acc.	$^{A}9.87$	$^{A}9.92$	$^{A}9.92$	$^{A}9.92$	$^{A}9.91$
5	Colour	$^{C}7.10$	$^{B}9.04$	$^{B}9.10$	$^{A}9.29$	$^{B}8.99$
	Odour	$^{D}7.31$	$^{C}8.76$	$^{B}8.99$	$^{A}9.40$	$^{B}8.88$
	Taste	$^{D}8.13$	$^{C}8.69$	$^{B}8.85$	$^{A}9.09$	$^{BC}8.77$
	Texture	$^{E}8.09$	$^{D}8.39$	$^{B}8.73$	$^{A}9.14$	$^{C}8.56$
	Overall acc.	$^{D}6.99$	$^{C}8.52$	$^{B}9.11$	$^{A}9.35$	$^{B}9.09$
10	Colour	$^{D}6.18$	$^{C}7.99$	$^{B}8.90$	$^{A}9.20$	$^{B}8.84$
	Odour	$^{E}6.90$	$^{D}8.10$	$^{B}8.81$	$^{A}9.31$	$^{C}8.68$
	Taste	$^{E}7.21$	$^{D}8.38$	$^{B}8.75$	$^{A}9.14$	$^{C}8.63$
	Texture	$^{E}6.11$	$^{D}7.74$	$^{B}8.45$	$^{A}8.73$	$^{C}8.30$
	Overall acc.	$^{D}6.49$	$^{C}7.89$	$^{B}8.99$	$^{A}9.30$	$^{B}8.99$
15	Colour	$^{D}5.42$	$^{C}7.40$	$^{AB}8.68$	$^{A}8.78$	$^{B}8.59$
	Odour	$^{E}6.30$	$^{D}7.24$	$^{B}8.59$	$^{A}8.74$	$^{C}8.29$
	Taste	$^{D}6.20$	$^{C}7.53$	$^{B}8.50$	$^{A}8.66$	$^{B}8.42$
	Texture	$^{E}5.10$	$^{D}6.99$	$^{B}8.30$	$^{A}8.46$	$^{C}8.10$
	Overall acc.	$^{E}5.33$	$^{D}6.65$	$^{B}8.20$	$^{A}8.52$	$^{C}7.99$
20	Colour	ND	$^{C}6.99$	$^{AB}8.60$	$^{A}8.64$	$^{B}8.51$
	Odour	ND	$^{D}7.21$	$^{B}8.20$	$^{A}8.36$	$^{C}8.09$
	Taste	ND	$^{C}7.11$	$^{A}8.34$	$^{A}8.40$	$^{B}8.20$
	Texture	ND	$^{C}6.48$	$^{A}8.00$	$^{A}8.10$	$^{B}7.88$
	Over all acc.	ND	$^{C}6.13$	$^{A}8.81$	$^{A}8.90$	$^{B}8.50$
25	Colour	ND	ND	$^{A}8.16$	$^{A}8.21$	$^{A}8.10$
	Odour	ND	ND	$^{B}7.78$	$^{A}7.90$	$^{C}7.60$
	Taste	ND	ND	$^{A}7.99$	$^{A}8.01$	$^{A}7.92$
	Texture	ND	ND	$^{A}7.69$	$^{A}7.72$	$^{B}7.45$
	Overall acc.	ND	ND	$^{B}7.99$	$^{A}8.10$	$^{A}7.91$
30	Colour	ND	ND	$^{B}7.99$	$^{A}8.52$	$^{B}7.95$
	Odour	ND	ND	$^{B}7.52$	$^{A}7.91$	$^{B}7.49$
	Taste	ND	ND	$^{A}7.73$	$^{A}7.78$	$^{A}7.71$
	Texture	ND	ND	$^{B}7.32$	$^{A}7.51$	$^{B}7.30$
	Overall acc.	ND	ND	$^{B}7.61$	$^{A}7.77$	$^{B}7.59$

- ND → Not determined because of spoilage.
- See legend to Table (1) for details.

Shelf life: Shelf life of fruits coated with 0.5%, 1% guar gum and 1% pectin was extended to 30 days followed by 1% pectin coated fruits (20 days). In contrast, non-coated (control) fruits deteriorated within 15 days. Edible coatings are a simple, environmentally friendly and relatively inexpensive technology that can be used to extend the shelf life of tropical fruits and vegetables under proper storage and temperature control Park, (1999). All the coated fruits according to sensory evaluation appeared fresh, shiny for relatively longer period of time than the control (non-coated) persimmon fruits.

CONCLUSION

The results of the present study showed that edible coatings can be effectively used to extend the shelf life of persimmon fruits. The 2% pectin and 0.5%, 1% guar gum based edible coatings proved more beneficial than 1% pectin for reducing weight loss, maintaining fruit firmness, and quality of persimmon fruits during storage.

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إطالة العمر التخزينى لثمار الكاكى بإستخدام الأغطية الغذائية

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الكاكى ثمار حساسة ومرغوبة لدى المستهلك نظراً لما تحتوية من سكريات ومواد فينولية وفيتامين C وكاروتينات وألياف ومعادن، ونظراً لأن عمرها التخزينى قصير لذلك تم إستخدام الاغطية الغذائية لإطالة العمر التخزينى لها والمحافظة على الخواص الكيماوية والفيزيائية والميكروبية والحسية لأطول فترة ممكنه. تم إستخدام البكتين و صمغ الجوار كمواد تغطية طبيعية مع زيت القرفه كمضاد أكسدة ومضاد ميكروبى طبيعى. تم تقسيم العينات إلى 5 مجموعات T1 هى العينات غير المعاملة (الكنترول)، T2 البكتين (1%)، T3 البكتين (2%)، T4 صمغ الجوار (0.5%)، T5 صمغ الجوار (1%). تم تخزين العينات المعاملة والكنترول فى الثلاجة على 1±4 °C و 75%-70 رطوبة نسبية. تم سحب عينات على فترات زمنية مختلفة لتقدير الفقد فى الوزن، الصلابة، المواد الصلبة الكلية الذائبة TSS،pH، الحموضة الكلية التنقطية TTA، فيتامين C، المواد الفينولية الكلية، معامل التلون البنى BI، نشاط إنزيم بولى فينول أوكسيديز PPO، الحمل الميكروبى والخواص الحسية. أظهرت النتائج أن مواد التعبئة والتغليف كان لها تأثيراً معنوياً على التركيب وصفات الجودة التى تم دراستها لثمار الكاكى. وجد أن متوسط قيم الفقد فى الوزن، TSS، pH، المواد الفينولية الكلية، BI، PPO والحمل الميكروبى تزداد بإستمرار خلال فترات التخزين ولكن معدل الزيادة كان أقل منه فى العينات المغطاة مقارنه بالعينات غير المغطاة (الكنترول). كما أظهرت النتائج أن متوسط قيم TTA، فيتامين C، الصلابة تقل بزيادة فترة التخزين وكان معدل الإنخفاض فى العينات المغطاة أقل منه فى عينات الكنترول. أوضحت النتائج أن أفضل المعاملات كانت هى العينات المعاملة ب T4 يليها T3، T5 ومع تخزينها حتى 30 يوماً تم إحتفاظها بخواص حسية جيدة ثم العينات المعاملة ب T2 والتى تم تخزينها حتى 20 يوما مقارنة بالعينات غير المغطاة (الكنترول) والتى تم تخزينها حتى 15 يوما والتى فسدت بعد ذلك.