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Preserving postharvest storage quality of fresh-cut cactus pears by using different bio-materials

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Abstract

Background: Cactus pear (*Opuntia ficus-indica* (L.) Miller) is an important food source for human beings but its consumption and marketability are limited due to the presence of spines and glochids on the fruit surface. Fresh-cut, ready-to-eat cactus pears have higher preference than the whole fruits. However, fresh-cut fruits have tissue wounding and quick deterioration, which decrease the marketability of the products. Therefore, present study was aimed to improve the storage quality of ready-to-eat cactus pears with the application of environmentally friendly bio-materials.

Methods: Fruits of present study were hand collected by a traditional way from a farm located in Yayla village of Northern Cyprus. Fruits were then peeled to prepare fresh-cut prickly pears for further experiments. Fruit peeling was carried out in three steps: (i) slicing off and discarding the both ends of the prickly pears, (ii) making one long vertical slice down the body, and (iii) peeling back the skin by sliping our finger into the slice and preparing a peeled prickly pear without skin. The six treatments of present study are: (1) control—dipping the fruits into distilled water, (2) covering the fruits with *Vitis vinifera* leaves, (3) dipping the fruits into jelly, (4) dipping the fruits into *Aloe vera* gel, (5) dipping the fruits into *Portulaca oleracea* extract and (6) dipping the fruits into cactus gel. Totally 108 fruits (replications) were used for each treatment and 18 fruits from each treatment were selected for quality analysis with 3-days interval (3, 6, 9, 12, 15 and 18 days). Fruits of each treatment (6 from same treatment) were placed into an open plastic box (dimensions: 20 * 13 * 5 cm; material: PET) and was covered with a stretch film (LLDPE, 10 µm) for storage. The fruit boxes were stored at storage rooms adjusted to 5 ± 1 °C and 55 ± 5% relative humidity.

Results: Results showed that, all treatments have varying positive effects on the prevention of weight loss. Among them, the highest positive effect was received from *A. vera* gel treatment (0.98%), and is followed by cactus gel (1.15%), *V. vinifera* leaf (1.39%) and jelly (1.61%) at the end of the experiments (18 days). *A. vera* gel and cactus gel were also found to have highest influence on the prevention of off-odor and decay incidence; and to protect the sensory and visual quality of the ready-to-eat cactus pears.

Conclusions: Results suggested that the postharvest storage duration of ready-to-eat cactus pears might be extended from 9 to 15 days with the use of *Aloe vera* gel or cactus gel.

Keywords: Weight loss, Decay, *Aloe vera* gel, *Portulaca oleraceae* extract, *Vitis vinifera* leaf, Cactus gel, Jelly

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Background

Cactus pear (*Opuntia ficus-indica* (L.) Miller) is an important food source for human beings and is appreciated for its flavor and juiciness (Piga et al. 2000; Cefola et al. 2014), while plant parts are extremely useful for livestock forage in terms of drought tolerance and high biomass generation per unit of water (Márquez-Berber et al. 2012). The demand for the cactus fruit is increasing mainly because of the reported nutritional and functional significance (Tesoriere et al. 2004). The chemical composition of cactus pear fruit is reported to be similar with papaya, nectarine and oranges with about 85% water content and 10–15% carbohydrates. It is also an important source of ascorbic acid (25–30 mg 100 g^{-1}) (Cantwell 1995). Cactus pears are non-climacteric and have very low ethylene production rate after harvest (Amaya-Cruz et al. 2019). Cactus pears are very sensitive to marketing conditions (20 °C, 60–70% R.H) and have a few days of shelf life due to decay and weight loss; and the harvest time has significant influence on the chemical composition of the prickly pear fruits (Juhaimi et al. 2020). Cold storage is an important way of postharvest quality preservation for fresh fruits, but it is known that temperatures below 9–10 °C increases the susceptibility of cactus fruits to chilling injury (Granata and Sidoti 2002). Film packaging, controlled atmosphere (2% O_2 and 2–5% CO_2), modified atmosphere packaging, cauterization process and hot water treatment are reported to extend postharvest life of cactus pears (Ochoa-Velasco and Guerrero-Beltrán 2016; Hahn-Schlam et al. 2019).

Presence of spines and glochids on the fruit surface reduces the commercialization of the cactus fruits (Cefola et al. 2014). Due to the hassle of peeling the cactus fruits, ready-to-eat (fresh-cut) cactus fruits have higher demand in the market than the whole fruits (Timpanaro and Foti 2014). Peeling causes tissue wounds and accelerates fruit deterioration and discoloration (Goldman et al. 2004). Discoloration is an important postharvest problem for fresh-cut cactus pears which is caused by oxidation of the phenolic compounds catalyzed by the enzymatic actions of polyphenoloxidase (PPO). This also leads fruits to have off-flavors and causes losses in nutritional quality (Whitaker and Lee 1995; Goldman et al. 2004). There is very little published information about the postharvest storage quality of ready-to-eat (RTE) cactus pears. Passive modified atmosphere (Piga et al. 2003; Allegra et al. 2016) and cold storage at 2–4 °C (Añorve Morga et al. 2006) were reported to preserve postharvest storage quality of RTE cactus pears until about 9 and 12 days, respectively. Food scientists pay attention on the studies for developing new technologies to improve postharvest quality of fresh-cut fruits to meet consumer preferences (Cefola et al. 2014). Chemical treatments, surface coatings, calcium salt applications, modified atmosphere packaging and gamma radiation are the most known approaches for postharvest quality retention (Troyo and Acedo 2019). Chemicals, i.e. fungicides, which are widely used throughout the world for the preservation of the postharvest quality of fresh produce, began to lose their acceptability due to their possible negative effects on human health and environment (Sharma et al. 2009). Current trend in postharvest research is the use of bio-materials (Silvestre et al. 2011; Kahramanoglu 2020) i.e. chitosan (Tesfahun 2018) and *Aloe vera* gel (Anjum et al. 2020; Kahramanoğlu et al. 2019), essential oils (Kahramanoglu 2019), plant extracts (Chen et al. 2019), acids (Jiang et al. 2015), calcium salts (Zudaire et al. 2019) and edible coatings (Troyo and Acedo 2019). In one of the studies with fresh-cut fruits, Benítez et al. (2015) evaluated the effects of very different treatments (*A. vera*, chitosan and sodium alginate) on the shelf life quality of fresh-cut kiwifruit. In the mentioned study, researchers noted that the sodium alginate, *A. vera* and chitosan act as a gas barrier and reduce the respiration rate of the fruits. The *A. vera* treatment was noted to maintain fruit textural and biochemical quality. On the other hand, it was noted that the microbial decay can be controlled by the application of *A. vera* and chitosan, where on the contrary sodium alginate treatment increased the microorganism counts. The effects of these treatments were reported to have different effects on the quality parameters and the highest overall quality was noted from the *A. vera* coatings. Cactus pears are also high in soluble sugar and low in acidity which makes them highly susceptible to microbial spoilage. In line with the background information, current study was conducted to test the storability of fresh-cut peeled cactus pears treated with different bio-materials: *A. vera* gel, *Portulaca oleraceae* extract, *Vitis vinifera* leaf, cactus gel and jelly. Five different bio-materials were selected in the present study to have a broad range of results and to increase the chances of success in postharvest storability of fresh-cut cactus pears.

Materials and methods

Materials

Cactus fruits (*Opuntia ficus-indica* (L.) Miller) of present study were hand-collected from a local farm located in Yayla village of Northern Cyprus. Traditional, homemade tool called "coppo" was used to harvest fruits carefully. A 500 ml plastic bottle was cut from mid-point and tied on a long stick. On 4th of August 2019, ripe yellowish red fruits were harvested by using coppo (Fig. 1.a.). The tool was dressed on the fruit, and the stick was turned by hand to twist of the fruit from the plant. The test materials of present study are: (1) control—dipping fruits into distilled water, (2) *Vitis vinifera* leaf—hand collected from local orchard with cv. 'Sultani', (3) jelly—purchased from a local shop with a brand of "Jello", (4) *Aloe vera* gel—collected from Yayla village, (5) *Portulaca oleraceae* extract—collected from Yayla village and (6) cactus gel—collected from the same plants of the fruit samples.

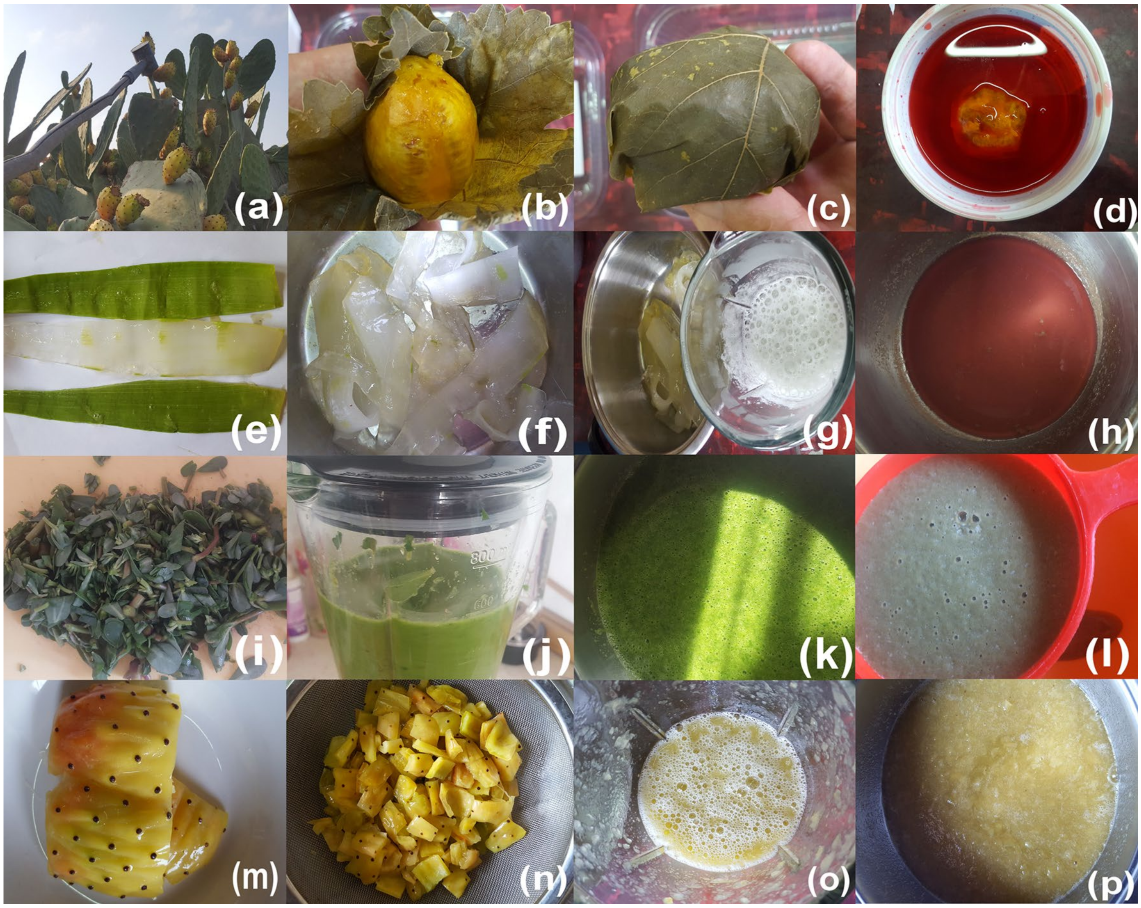

Fig. 1 Materials and methods of the experiments: **a** a view from harvesting cactus pears with traditional coppo; **b**, **c** covering of fresh-cut cactus pears with *Vitis vinifera* leaves; **d** dipping fresh-cut cactus pears into jelly; **e**–**h** preparation of the *Aloe vera* gel; **i**–**l** preparation of *Portulaca oleraceae* extract; and **m**–**p** preparation of cactus gel

Methods

After harvest, fruits were immediately brought to laboratory, selected to eliminate unripe and damaged fruits, and then professional workers peeled the fruits carefully. The fresh-cut fruits of present study were prepared by peeling the fruit skin. The peeling was performed in three steps: (i) slicing off and discarding the both ends of the prickly pears, (ii) making one long vertical slice down the body, and (iii) peeling back the skin by sliping our finger into the slice and preparing a peeled prickly pear without skin. Experimental studies were conducted with six treatments, which was listed above. Studies were planned to continue for 18 days and quality parameters of the fruits were analyzed with 3-day interval (3, 6, 9, 12, 15 and 18 days). 108 fruits (replications) were used for each of the six treatments (listed above) and 18 fruits from each treatment were selected for quality analysis (18 fruits * 6 measurement point = 108 fruits).After peeling, fruits were subjected to the treatments listed above. The descriptions of the treatments are:

1. First treatment was control. For this treatment, the fruits were dipped into distilled water at 24 ± 1 °C for 10 s and then air dried for 30 min and then moved to storage conditions.
2. The second treatment was covering the fruits with *Vitis vinifera* leaf. The fruits were dipped into distilled water for 10 s as in control treatment, air dried for 30 min and then covered with *Vitis vinifera* leaves by using 2 leaves for each fruit (Fig. 1b, c) and moved to storage conditions.
3. The third treatment was jelly. The ingredients of jelly are edible gelatin, sugar, citric acid, natural or natural identical color and flavor. The jelly material was prepared according to the instructions. Totally 80 g of jelly was dissolved in 560 ml of warm water and after 20 min, it was transferred into freezer adjusted at 4 °C in cold storage. The duration required for freezing is about 3 h. Therefore, it was kept 2 h in cold room and then transferred to ambient conditions and fresh-cut cactus pears were dipped into the half-fro-

zen jelly for 10 s (Fig. 1d). Thus the fruits were taken out and transferred to the storage conditions.

4. The fourth treatment of the experiments is *Aloe vera* gel. Firstly, the leaves were harvested and the outer leaf rind was removed. The Aloe gel lying underneath was ground in a blender and the resulting mixture was filtered to remove fibers. The liquid was then pasteurized at 70 °C for 45 m (Fig. 1e–h). Hereafter, the resulting gel was cooled immediately and ready to use. Then, 10% of gel was used in the present study by dissolving it in distilled water in a ratio of 1:9 (w/v). Fruits were dipped into the solution and kept 10 s. Next, air dried for 30 min and transferred to storage conditions.
5. The fifth treatment of the experiments was *Portulaca oleraceae* extracts. After collecting the plants, the above ground plant parts were chopped into small particles (< 2 cm) and ground in a blender. Herein, the mixture was filtered and resulting solution was dissolved in distilled water in a ratio of 1:1 (w/v). The liquid was then pasteurized at 70 °C for 45 m (Fig. 1i–l). Same procedure was used for the application and storage as in *Aloe vera* gel.
6. The final treatment of the present study is the cactus gel. The peel of the fruits of present study was used for the preparation of the cactus gel. The spines and glochids of the peels were removed carefully and the resulting material was chopped into small particles (< 2 cm) and ground in a blender. Next, the mixture was filtered and resulting solution was dissolved in distilled water in a ratio of 1:1 (w/v). The liquid was then pasteurized at 70 °C for 45 m (Fig. 1m–p).

Storage condition for all treatments is: covering with stretch film (LLDPE, 10 µm) and keeping at 5 ± 1 °C. After dipping the fruits into mentioned solutions, fruits were air dried for 30 min (except jelly treatment) and then 6 fruits (from same treatment) were placed into an open plastic box (dimensions: 20*13*5 cm; material: PET) and it was sealed up with a stretch film to provide a passive atmospheric packaging. Finally, the fresh-cut fruit boxes were immediately transferred to the storage rooms (6 m*3 m*3 m) adjusted to 5 ± 1 °C and 55 ± 5% relative humidity.

At the mentioned measurement points (3, 6, 9, 12, 15 and 18 days), 18 fruits from each treatment were taken out from storage rooms to measure quality parameters. First of all, fruit weight was measured with a digital scale sensitive to ± 0.01 g and weight loss was calculated for each replication by using the initial weight data. SSC (% Brix) was measured with a hand refractometer (REF 103/Index Instruments Ltd.). Hereafter, the overall sensory quality of the fresh-cut prickly pear fruits during the storage was then assessed by a panel of six trained person (3 women and 3 men; aged from 22 to 67 years). The sensory evaluation was performed according to the taste, aroma, texture and visual quality of the fruits. The nine-point scale of Aguayo et al. (2014) was used to determine sensory quality. This scale simply described as, 1 = extremely poor (dislike), 2 = dislike very much, 3 = dislike moderately (poor), 4 = dislike slightly, 5 = limit of acceptability (neither like nor dislike), 6 = like slightly, 7 = like moderately (good), 8 = like very much and 9 = like extremely (excellent).

The severity of off-odor during the storage was determined with the Odor Index (OI) according to the 0-4 scale. The description of the scale is as 0 represents excellent fruits with no off-odor; 1 equals to slight off-odor; 2 represents moderate off-odor; 3 used for moderately severe off-odor; and 4 represents severe off-odor. The OI index was then calculated using the following formula: $\text{OI index} = \{\sum[(\text{OI scale}) \times (\text{number of fruit at that OI})]\}/(4 \times \text{total number of fruit in each treatment})$. The fruits with an OI index of 0.4 or higher were considered as unacceptable for consumers.

Decay Incidence (DI) was observed according to the four-point scale formula of Cao et al. (2011). All fruits of each replication were visually evaluated according to the scale where 0 referred no decay, 1 equaled to slight decay (≤ 25%), 2 mentioned moderate decay (25% < 50%) and 3 referred severe decay (> 50%). After scoring the fruits according to above given scale, following formula was used to calculate Decay Incidence. $\text{DI} = \{[(1 \times \text{N1}) + (2 \times \text{N2}) + (3 \times \text{N3})] \times 100/(3 \times \text{N})\}$. In this formula, N represents the total number of fruit measured and N1, N2 and N3 were used to indicate the numbers of fruit showing the different severities of decay.

Visual appearance of the fruits was determined according to the 1-5 scale of Amodio et al. (2007). The description of the scale is as 5: Excellent, no defect; 4: good, minor effect; 3: fair, moderate defect (limit of marketability); 2: poor, major defect (limit of edibility); and 1: inedible. The arithmetic mean of the scores was used to calculate the overall score of each treatment.

Data analysis

The effects of above mentioned six treatments at the given storage durations were determined by subjecting the raw data (Additional file 1) separately to the analysis of variance (ANOVA). Furthermore, separation of means was carried out with Tukey's Honestly

Significant Difference (HSD) test at P = 0.05. SPSS 22.0 was used in present study to perform statistical analysis.

Results

Effects on weight loss

Effects of test materials on the weight loss of ready-to-eat cactus pears are given in Fig. 1. It is clear from the figure that the untreated control fruits had higher weight loss (0.78%) even in 3 days of storage than the others (0.13–0.50%). Among the test materials, cactus gel and jelly treatment found to have highest effect in the first 3 days of storage and fruits had very low weight loss (0.13–0.14%). Covering fruits with *V. vinifera* leaves and *A. vera* gel treatment found to have third and fourth highest influence on the weight loss prevention with a rate of 0.36% for both (Fig. 2). During ongoing storage, the positive effect of cactus gel and jelly decreased and the highest positive effect was determined from *A. vera* gel. However, all of the bio-materials were found to effective when comparing with control treatment. At the end of the experiments (18 days of storage), the highest weight loss was measured from control treatment (2.83%) and was followed by *P. oleraceae* extracts (2.31%). No statistical difference was determined among these two treatments. On the other hand, the lowest weight loss (thus the highest influence) was obtained from the *A. vera* gel treatment with only 0.98% weight loss. This treatment was followed by cactus gel (1.15%), *V. vinifera* leaf (1.39%) and jelly (1.61%) and no statistical difference was found among these three treatments.

Effects on soluble solids concentration

At the day of harvest, the soluble solids concentration (SSC) of the cactus pears was measured as 11.84%. During the first 3 days of storage, the SSC content of the all samples showed slight increase (Fig. 3.). It was measured as between 11.91% and 12.10% at 3 days after storage and began to show a slight decrease afterwards. It was measured as between 11.89% and 12.06% at 6 days after storage. Until the measurements done at 9th day of storage, there was not statistically significant difference among the treatments. Hereafter, the untreated control fruits found to have lower SSC as compared with treated fruits. At the end of the experiments (18 DAS), the highest SSC was noted from cactus gel treatment with 10.83%, as was followed by *A. vera* gel and *P. oleraceae* extract with 10.17%, jelly (10.03%) and *V. vinifera* leaf (9.91%). The SSC values of these four treatments were found to have no significant difference from each other. However, these values were less than the SSC of the fruits treated with cactus gel and slightly higher than the control fruits (9.65%). Results showed

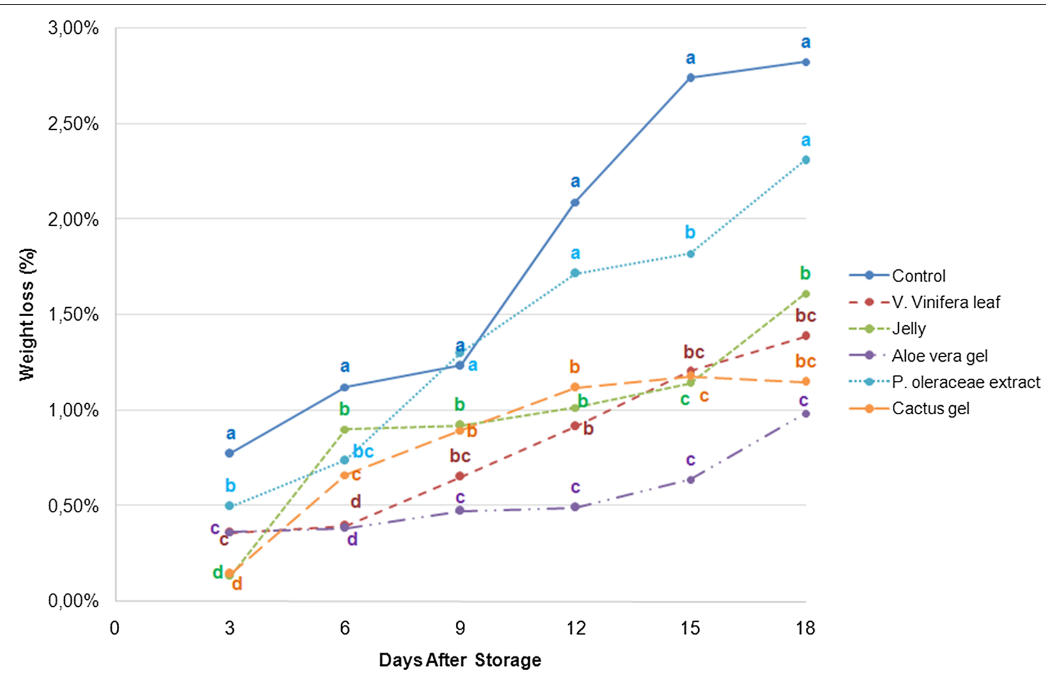

Fig. 2 Effects of different bio-materials on the weight loss of ready-to-eat cactus pears during 18 days of storage. Values followed by the same letter or letters at the same day of storage duration are not significantly different according to Tukey's HSD at P = 0.05

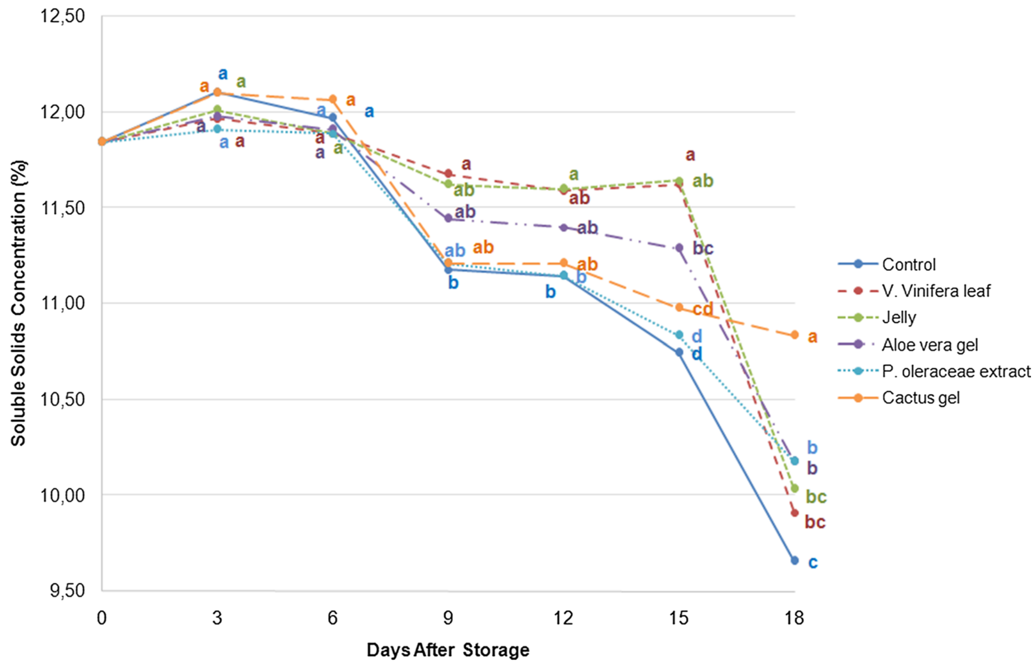

Fig. 3 Effects of different bio-materials on the soluble solids concentration of ready-to-eat cactus pears during 18 days of storage. Values followed by the same letter or letters at the same day of storage duration are not significantly different according to Tukey's HSD at P = 0.05

that all treatments have considerable and varying effect on the prevention of SSC as in weight loss.

Effects on visual appearance

Along with the weight loss and SSC results, visual appearance is at utmost importance for the postharvest

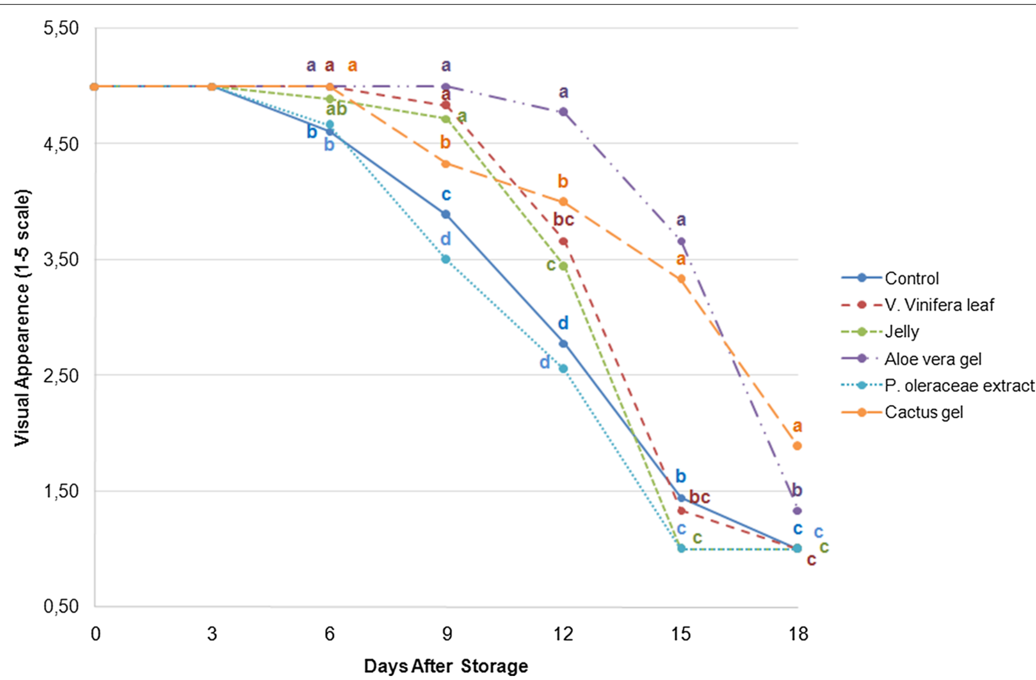

Fig. 4 Effects of different bio-materials on the visual appearence of ready-to-eat cactus pears during 18 days of storage. Values followed by the same letter or letters at the same day of storage duration are not significantly different according to Tukey's HSD at P = 0.05

quality of fresh and fresh-cut produce. While food safety issues are of great importance for consumers, visual appearance is still the first impression and highly influences the choice of consumers. Results of present study are in accordance with those results where the *A. vera* gel was found to have second highest influence on the prevention of visual quality after cactus gel (Fig. 4).

Fruits treated with *P. oleraceae* extract were found to have fewer score, even than the control treatment during the storage. Similarly, fruits treated with jelly found to have very low visual quality scores. According to the results obtained, all fruits, even the untreated control fruits had acceptable marketability quality for 9 days of storage. Twelve days after storage, fruits treated with *P. oleraceae* extract (2.55) and control (2.78) found to have lower quality scores than the limit of marketability. Visual quality scores of fruits treated with jelly and *V. vinifera* leaves was higher at 12 DAS, but decreased to 1.00 and 1.33 at 15 DAS, respectively. The fruits treated with *A. vera* gel and cactus gel had acceptable visual quality for

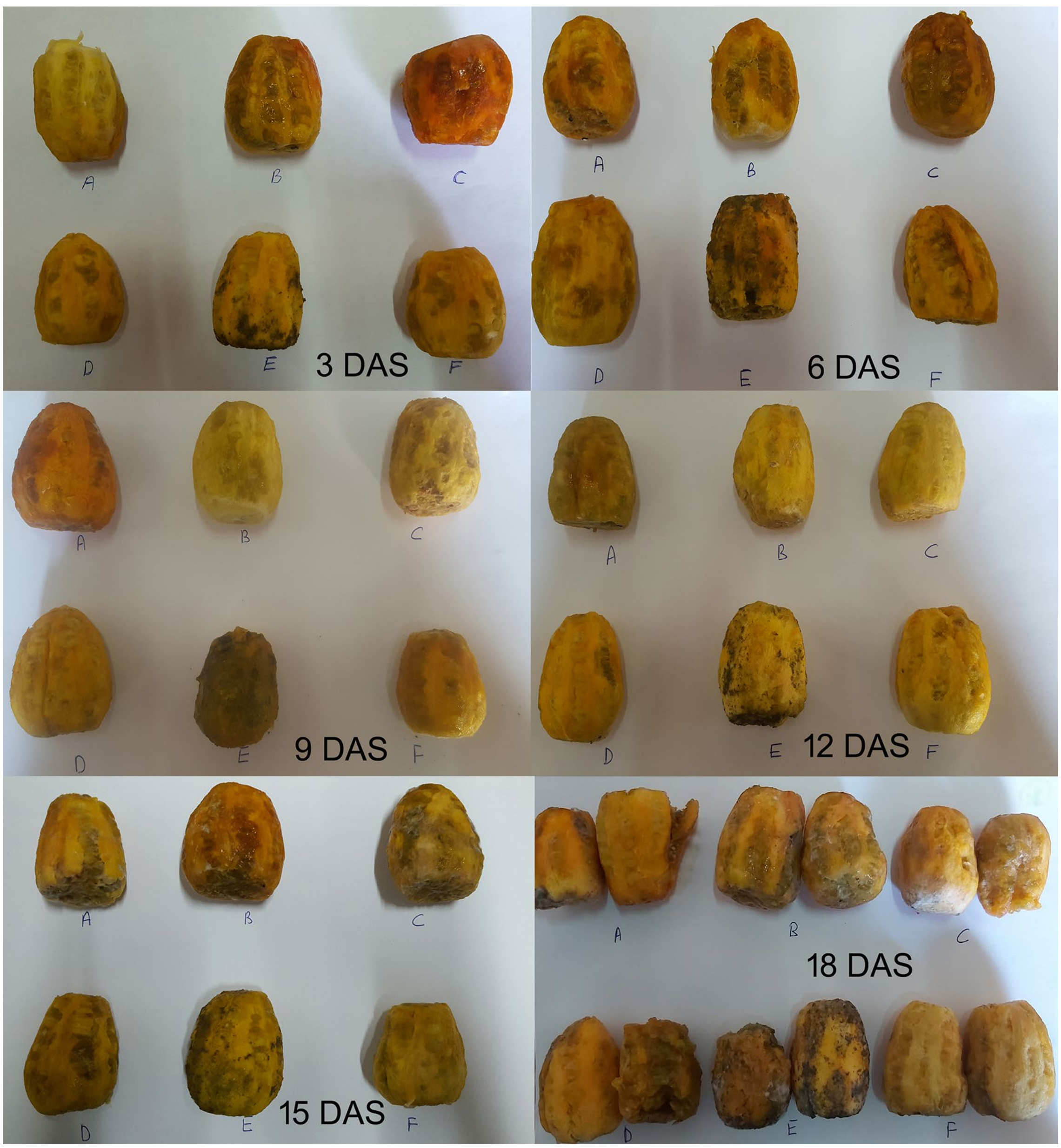

Fig. 5 Visual appearance of cactus fruits during storage [DAS: Days After Storage; **a** Control; **b** Coverage with *Vitis vinifera* leaves; **c** Jelly treatment; **d** *Aloe vera* gel; **e** *Portulaca oleraceae* extract; and **f** cactus gel]

marketability with the scores of 3.67 and 3.33, 15 days after storage. Hereafter, at the 18 DAS, fruits of all treatments found to have inedible fruits with very low visual quality scores (1.00–1.89). The visual appearance of the cactus pears can be seen from the Fig. 5.

Effects on off-odor

The aroma of fresh and fresh-cut fruits and vegetables is an important quality attribute for consumer acceptability. Results of present study showed that the tested bio-materials have significant varying effect on the weight loss and on the off-odor too. Similar with the other results, fruits treated with *A. vera* gel and cactus gel found to have no off-odor in 6 days of storage. Nine days after storage, all treatments found to have off-odor (Fig. 6.). The highest off-odor scores were noted from the fruits treated with *P. oleraceae* extract and control with scores of 0.36 and 0.44, respectively (very close or higher than acceptable limit = 0.40). In terms of off-odor scores, fruits treated with *A. vera* gel, cactus gel, jelly and *V. vinifera* leaf have acceptable quality for 12 days of storage, but the off-odor increase afterwards to a minimum score of 0.42 in 15 days of storage.

Effects on microbial spoilage

Results of present study also showed that all of the tested bio-materials (except *P. oleraceae* leaves) are effective in controlling decay. The reducing effect of *P. oleraceae* extracts on the weight loss and other quality parameters might also be associated with the reduced effect on the control of decay. At 9 days of storage, control fruits found to have 35.17% decay, while the decay at the fruits treated with *A. vera* gel was only 0.00% (Fig. 7.). Fruits treated with *A. vera* gel, V. vinifera leaves and cactus gel were found to have a decay score of ≤ 20.00% with the rates of 7.43%, 16.67% and 20.40%, respectively. At the end of the experiments, *A. vera* gel was found to be the most effective material for preventing microbial spoilage.

Effects on sensory quality

One of the most important results of present study is about the sensory quality of the fresh-cut prickly pear fruits. The results about the sensory quality are in accordance with the visual quality and off-odor results. The sensory quality of the fresh-cut fruits began to decrease 6 days after the storage (Fig. 8.). According to the results obtained, the sensory quality of the fruits treated with *P. oleraceae* extracts and the control were found to decrease below the limit of acceptability (5) in 9 days of storage. Other treatments were found to have higher and acceptable sensory quality until the end of the 12th day of storage. Hereafter, the sensory quality of fruits in all

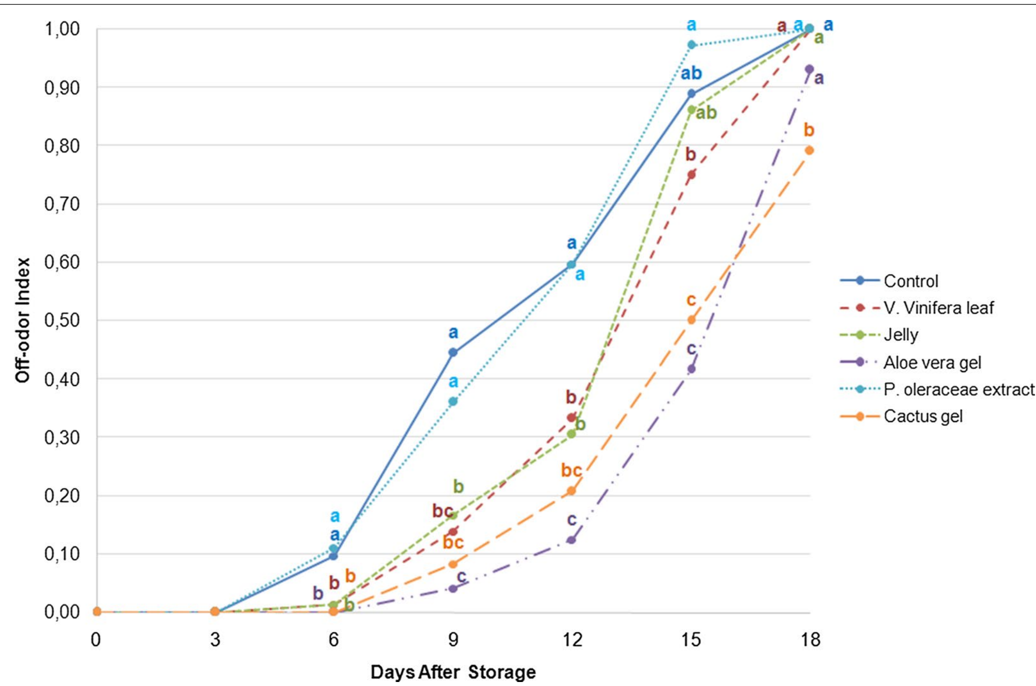

Fig. 6 Effects of different bio-materials on the off-odor of ready-to-eat cactus pears during 18 days of storage. Values followed by the same letter or letters at the same day of storage duration are not significantly different according to Tukey's HSD at P = 0.05

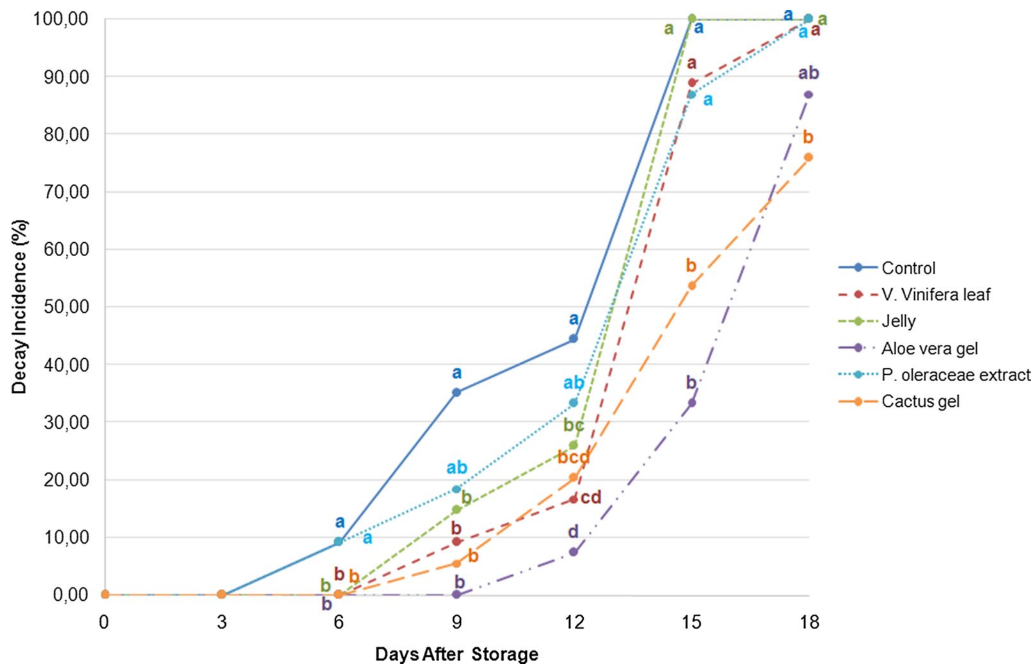

Fig. 7 Effects of different bio-materials on the decay incidence of ready-to-eat cactus pears during 18 days of storage. Values followed by the same letter or letters at the same day of storage duration are not significantly different according to Tukey's HSD at P = 0.05

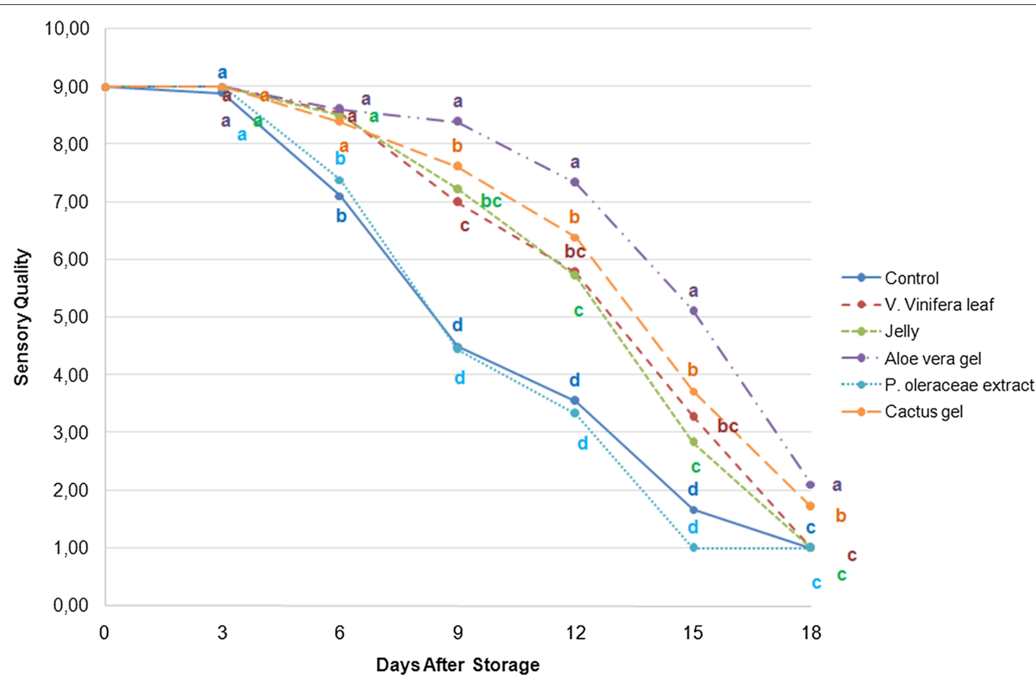

Fig. 8 Effects of different bio-materials on the sensory quality ready-to-eat cactus pears during 18 days of storage. Values followed by the same letter or letters at the same day of storage duration are not significantly different according to Tukey's HSD at P = 0.05

treatments, except *A. vera* gel, decreased below the limit of acceptability. All of those results are in accordance with the other findings, which clearly indicate that the *A. vera* gel treatment improve the postharvest storability of fresh-cut prickly pear fruits and help to keep fruits acceptability for 15 days of storage.

Discussions

In this study, *A. vera* gel provided the highest efficacy in preventing weight loss and protecting visual and sensory quality of fresh-cut cactus pear fruits. Weight loss is mainly a cause of respiration (loss of carbon reserves) and transpiration (loss of water), and *A. vera* gel was highly cited by numerous studies to acts as a barrier, thereby restricting water transfer and prevents weight loss (Achipiz et al. 2013; Kator et al. 2018; Kahramanoglu et al. 2019). Previous studies demonstrated successful results for *A. vera* gel coatings for both fresh and fresh-cut fruits and vegetables, i.e.: pineapples (Adetunji et al., 2012), tomato (Kator et al. 2018), ready-to-eat pomegranate arils (Martínez-Romero et al. 2013), fresh-cut papaya fruits (Kuwar et al. 2015), fresh-cut oranges (Radi et al. 2017), fresh-cut apples (Song et al. 2013) and fresh-cut kiwifruits (Benítez et al. 2015). It is noted by those researchers that *A. vera* gel application provides a barrier to the produce and lower the respiration rate. According to Author's knowledge, there is not any published study about the use of *A. vera* gel for the fresh-cut cactus pears. The second highest effect on the prevention of weight loss at the ready-to-eat cactus pears was obtained from cactus gel. Previously, extracts from other parts of the cactus plants, mainly the cladodes, were tested on different fruits and found to be effective in preventing weight loss (Allegra et al. 2016; Gheribia et al. 2018). The third most successful treatment of present study was found to be covering the fruits with *V. vinifera* leaves. According to the Author's knowledge, it is first time to test *V. vinifera* leaves as a postharvest treatment. Grape leaves have wide use in Mediterranean countries as cooked with rice. Due to the high use of *V. vinifera* leaves in diet, many studies conducted about the health effects, antibacterial, antifungal, antiviral, antioxidant activities, and phenolic and volatile contents of leaves (Fernandes et al. 2013; Pintaća et al. 2019). Orhan et al. (2009) reported that *V. vinifera* leaves have antiviral and antioxidant activities which support their utilization in folk medicine. At the beginning of the experiments (3 DAS) jelly was one of the most effective materials for the prevention of weight loss, but its efficacy decreased in time and found to be the fourth effective material among the tested bio-materials. Gelatin (natural water soluble protein) based coatings were previously reported to be effective in preventing postharvest quality and weight loss (Mellinas et al. 2016; Ortiz-Zarama et al. 2016), but it was a first report for the jelly. The reduced effect of jelly in present study might be a cause of sugar in the jelly or the application method. Further studies by freezing the fresh-cut fruits in jelly would provide higher efficacy than the present methodology. Gol and Rao (2013) reported that 10% gelatin coating reduces the weight loss at mango fruits and improves the postharvest quality. The final bio-material of present study was *P. oleraceae* extracts. *P. oleracea* is an annual herbaceous plant, distributed in many parts of the world (Zhou et al. 2015) and has been used as a traditional medicine against gastrointestinal diseases, headaches, some kind of inflammation, ulcer, sexual desire, eruptions of blood, burning of the stomach, and etc. (Iranshahy et al. 2017). The un-expected low efficacy of the *P. oleraceae* extracts might be a cause of the negative effects of extracts on the decay and future studies are necessary with different preparation methods and/or combination with some other bio-materials.

Additional to the prevention of weight loss, *A. vera* gel was also found to maintain fruit SSC. This is in agreement with the previous studies which reported that *A. vera* gel reduces the speed of the changes in soluble solids concentration at different fruits and vegetables, i.e. strawberry (Sogvar et al. 2016), tomato (Chrysargyris et al. 2016), fresh-cut papaya fruits (Kuwar et al. 2015) and fresh-cut oranges (Radi et al. 2017). Parven et al. (2020) reported that the coating of papaya fruits with *A. vera* gel provides favorable conditions for the prevention of fruit SSC.

There is limited available information in the published literature about the impacts of tested bio-materials on visual quality. Only *A. vera* gel was noted previously to have positive impact on visual quality (Mohebbi et al. 2014; Sophia et al., 2015; Song et al. 2013) which are in accordance with the results of present study. In a very recent study by Parven et al. (2020), *A. vera* gel coating was reported to delay colour development during storage which improved the visual quality of the papaya fruits. Ali et al. (2019) reported that the lotus root slices coated with *A. vera* gel have better overall visual quality as compared with the uncoated control fruits during storage. They reported that the uncoated control slices lost marketability in 4 days of stoage, slices coated with *A. vera* gel had markedly higher visual quality until 8 days of storage. Similar results were previously noted by Supapvanich et al. (2016) and it was suggested that it could possibly due to reduced enzymatic browning of fruit surface.

Rather than visual quality, the development of off flavor was also an important characteristic in present study. The aroma of fresh and fresh-cut fruits and vegetables is an important quality attribute for consumer acceptability (Cefola et al. 2014). Composition of the volatile compounds released from the produce determines the aroma of the produce. Wounding of tissues accelerates respiration and removes natural diffusion barriers, with associated increases in rates of other biochemical reactions resulting with changes in color, texture, odor, flavor and nutritional quality. Lack of oxygen in the surrounding atmosphere also causes anaerobic respiration which results in off-odors (Forney, 2016). Although the information about the biosynthesis mechanisms is still limited, it is known that the postharvest practices significantly affect it (Defilippi et al. 2009). Previous studies suggested that the suppression of respiration plays an important influence on the prevention of off-odor on fresh produce (Dang et al. 2008). In agreement with this knowledge, results of present study showed that the bio-materials of present study have significant varying effect on the weight loss (estimated to have on respiration) and on the off-odor too. Similar with the other results, fruits treated with *A. vera* gel and cactus gel found to have no off-odor during the first 6 days of storage. Present results for *A. vera* gel are in accordance with the reports of Dang et al. (2008) who noted that the application of *A. vera*-based coatings reduce aroma volatile biosynthesis in the fruit pulp of mango. Finally, *A. vera* gel, *V. vinifera* leaves and cactus gel were found to have a decay score of ≤ 20.00% in present study. There is no published literature about the *V. vinifera* and cactus gel, whereas high potential of *A. vera* gel on the prevention of microbial spoilage was previously noted for other fruits and vegetables, i.e. tomato (Chrysargyris et al. 2016), citrus (Jhalegar et al. 2014), raspberry (Hassanpour et al. 2015), and ready-to-eat pomegranate arils (Martínez-Romero et al. 2013).

Reduction of the microbial decay is indispensable for prolonging the safe storage of fresh-cut products (Li et al. 2018). The observed percentage of the decay incidence in present study suggested that the *A. vera* gel coating provides moderate to high control over the postharvest diseases. The positive effect of *A. vera* gel for the prevention of disease severity is not new, and the results of present study are in agreement with the findings of several studies (Martínez-Romero et al. 2006; Benítez et al. 2015; Kahramanoglu et al. 2019; Mendy et al. 2019; Rasouli et al. 2019; Parven et al. 2020). *A. vera* gel coating was previously noted to exhibit satisfactory inhibition of mycelial growth and spore germination (Mendy et al. 2019). Similarly, Ali et al. (2019) noted that the *A. vera* gel coating decreases the aerobic bacteria at the lotus root slices during storage.

Sensory quality of fresh-cut fruits and vegetables is most important characteristic influencing the consumer satisfaction (Ragaert et al. 2011). In this study, *A. vera* gel, cactus gel, *V. vinifera* leaf covering and jelly coating were all found to maintain sensory quality above the acceptable limit for 12 days; and the *A. vera* gel was effective for 15 days of storage. In the studies of Benítez et al. (2015) similar results were reported for *A. vera* gel coating for maintaining the sensory quality of the kiwifruits. Similarly, Martínez-Romero et al. (2006) suggested that the natural look sweet cherry fruits can be kept 16 days in cold room with the application of *A. vera* gel coating.

Conclusions

Results of present study suggested that the postharvest storage duration of the ready-to-eat cactus pears might be extended with the use of different bio-materials. The *Aloe vera* gel and cactus gel were found to be highly effective in protecting weight loss, sensory quality, visual quality, occurrence of microbial spoilage, development of off-odor and changes in soluble solids concentration. Results are also promising for jelly and *V. vinifera* leaves but further studies need to be undertaken especially about the application methodology.

Supplementary information

Supplementary information accompanies this paper at https://doi.org/10.1186/s43170-020-00008-5.

Additional file 1. Raw data, mean and standard deviation for all quality parameters.

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Authors' contributions
İK and SU conceptualized the study. All authors design the experiment. İK and SU performed the experiments and collected the data. İK and VO analyzed the data and prepared the figures. İK and CW were the major contributor in writing the manuscript. All authors read and approved the final manuscript.

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