Journal of Pure and Applied Agriculture (2020) 5(3): 26-32
ISSN (Print) 2617-8672, ISSN (Online) 2617-8680
http://jpaa.aiou.edu.pk/
RESEARCH PAPER

Responses of persimmon (*Diospyros kaki*) fruits to different fruit coatings during postharvest storage at ambient temperature

Muhammad Jalal Khan[1], Qasim Ayub[1]*, Ijaz Hussain[1], Abid Mehmood[2], Nida Arif[1], Saad Mehmood[1], Qammer Shehzad[3], Sarmad Khalid[1] and Naveed Ul Haq[3]

[1]Department of Horticulture, The University of Haripur, Haripur, Pakistan
[2]Department of Agronomy, The University of Haripur, Haripur, Pakistan
[3]Department of Food Science and Technology, The University of Haripur, Haripur, Pakistan

*****Corresponding author: Qasim Ayub (qasimayub.alizai@gmail.com)

Received: 8 January 2020; Accepted: 17 July 2020; Published online: 30 September 2020

Key Message: The current study aimed to assess the effects different fruit coatings on shelf life and quality of persimmon fruits. It was concluded that the application of *Aloe vera* gel and wax successfully enhanced the post-harvest quality of persimmon fruits.

Abstract: Horticultural crops are a key source of food and nutrition for human beings since the beginning of time. Storage of horticultural crops after harvesting and marketing has numerous distinctive characteristics due to the unique properties of the crops. Due to high perish-ability, seasonal dependence and bulky harvest in a season, horticultural crops require special care and attention, for delaying ripening and senescence during the transportation of product to distinct markets require proper skills. Edible coating have been long used to preserve the quality of horticultural products and many studies have proved the beneficial effects of these coating, so the current study is carried out to investigate the effects of different edible coating (wax, *Aloe vera* and glycerin) on post-harvest storage of persimmon (*Diospyros kaki*) fruit at ambient temperature condition. Current study was conducted at Horticulture Lab, The University of Haripur KP. The experiment was established in CRD (Complete Randomized Design) along with two factors i.e. coating material (wax, *Aloe vera* and glycerin) and storage durations (0, 03, 06, and 09 days). Results reveal that maximum reduction in weight (7.1%), fruit firmness (2.1), pH (5.9) and TSS (20.4) were observed in (glycerin) whereas, highest reduction in weight (8.2%), fruit firmness (2.1), TSS (20.4), pH (9.0) where observed at 9th day. Therefore it can be concluded that glycerin failed to improve the quality of fruits and shelf life of stored persimmon fruits whereas *Aloe vera* gel and wax have considerably increased the studied parameters.

Keywords: *Aloe vera* gel, Ambient temperature, Edible coating, Fruit coating, Persimmon, Postharvest, Shelf life, Storage duration, Wax

To cite this article: Khan, M. J., Ayub, Q., Hussain, I., Mehmood, A., Arif, N., Mehmood, S., Shehzad, Q., Khalid, S., & Haq, N. U. (2020). Responses of persimmon (*Diospyros kaki*) fruits to different fruit coatings during postharvest storage at ambient temperature. *Journal of Pure and Applied Agriculture, 5*(3), 26-32.

Introduction

The persimmon (*Diospyros kaki*) is an important member of the family Ebenaceae. *Diospyros* word is derived from Greek language which means “the food of gods”, this clearly demonstrates the importance of persimmons and its use from ancient times (Chang et al., 2017). Several historic documentation from China prove that persimmons are being domesticated and cultivated from 3,000 years, and during 7th and 14th century persimmons was widely cultivated in Japan and South Korea respectively. The cultivation of persimmons in Europe was started between 18th and 19th century. Commercial production of persimmon in America was started during 19th century and an increase in area and production was noted during 20th century particularly in United Sates and Brazil, whereas Australian and New Zealand persimmon production was started during the early 20th century (Guan et al., 2020). According to FAO data China, Spain, Korea, Japan and Brazil are the top producers of persimmon. During the last decade a sudden surge in persimmon production was noted, with record production of 5.75 million tons during 2017, in which China stands at the top accounting for more than 70% of total world production (Food and Agriculture Organization [FAO], 2019). The persimmon was introduced in Khyber Pakhtunkhwa during 1940. The varieties cultivated in Pakistan are like Hychia and Fuyu with Pistillate flowers. The climate of the province is well suited for the cultivation of persimmons. It is a commonly grown Hazara division, Chakwal and Malakand. Total area under persimmon cultivation is 3156 ha with net production of 26879 tones (Government of Pakistan [GOP], 2015-16).

Persimmon trees are deciduous and medium size (8-12 m) tall. The leaves are ovate, elliptic to ovate, acuminate apex, pubescent beneath, glabrous and shining above. Persimmons are climacteric fruit, and maturation of persimmon depends upon postharvest respiration rate and production of ethylene gas (Yaqub et al., 2016). In contrast to other climacteric fruits, ethylene and respiration rates are much lower. In comparison with other climacteric fruits, persimmon produces less ethylene and has a lower respiration rate, but maturity is not affected by these factors and the entire procedure of maturation is perfectly controlled (Kluge & Tessmer, 2018). Like other fruits and vegetables, the color of fruits is used to describe the harvesting and maturity index (Denoya et al., 2020). During the whole process of ripening, the peel color of persimmon fruits changes from green at unripe period to bright red at the end stage of its ripening (Bordiga et al., 2019). The fruit growth starts with rapid cell division in the region of Mesocarp, which is then followed by cell elongation and increase in intercellular spaces, which help the fruit to improve its size during all developmental stages. Along with these, different persimmon cultivars show different accumulation of tannins in the cell vacuole during fruit development, which causes diversified sizes and astringency in every cultivar (Kluge & Tessmer, 2018). The fruit is a berry which varies in size, shape, color and quality, and the average fruit weight of the berry range from 120 to 180 g (Matheus et al., 2020).

Fruits along with vegetables have very much importance in human nutrition and diet and are considered as a wealthy source of many bioactive compounds like fibers, antioxidants and many phytochemicals. Persimmon is a rich source of vitamin-c, many important minerals, polyphenols, steroids and carotenoids (Karaman et al., 2014). These compounds help to prevent many diseases and have many beneficial effects on human health (Dauchet, 2006). The bioactive compounds and phytochemicals prevents stiffness of arteries, decreases oxidation of LDL (Low Density Lipoproteins), triggers immune system, regulates metabolism, prevents cancer and acts against inflammation (Miller et al., 2004). These bioactive components also cause reduction in stiffness of arteries and stops LDL (low-density lipoproteins) oxidation. Many phytochemicals present in persimmon possess anti-mutagenic properties which continuously regulate and trigger the human immune system and result in normal working of metabolism, also act as chemo preventive and as anti-inflammatory agent. Persimmons are widely used in many food products, some of most common products are; juices (El-Hawary et al., 2020), vinegar (Hidalgo et al., 2012) , wine (Kim et al., 2019) , dehydrated fruit, chips (Milczarek et al., 2018), ice cream (Karaman et al., 2014), creamy sweets (Bolzan & Pereira, 2017), and jam (Querido et al., 2013). It is important to note that many of these products produce waste, as the key ingredient in the manufacturing of these products is fruits pulp, while other fruit parts like seed, peel and peduncle are discarded.

Post-harvest storage is a key factor in preventing economic losses during storage and transportation. Perishable nature of persimmon fruit decreases its post-harvest life and causes substantial losses during storage and handling. After harvesting, fruits and vegetables undergo many biochemical and physiological changes which produce permanent and harmful changes in shelf life and quality of fruits. Among these processes post-harvest transpiration, respiration and production of ethylene gas are key contributors in degradation and senescence of product (Mostafavi & Zaeim, 2020). Ethylene production is a unique characteristic associated to the climacteric fruits, which is commonly produced under stress conditions, but ethylene production is also partially associated with the changes in fruit's flavor, color and texture. Along with other factors water loss and decrease in moisture content of fruits increase during the storage mainly because of transpiration and respiration (Chu et al., 2020). Post-harvest water losses can also generates changes in metabolic process and alteration in enzymatic activation, which causes rapid senescence, dwindled nutritional content, and escalated chances of chilling injuries and microbial attacks, whereas respiration involves in oxidative disintegration of organic compounds into their simpler forms, including water and carbon dioxide, coupled with energy production (Chen et al., 2019). All these biological factors depend upon many factors like type of fruits, cultivar, stage of harvesting, environmental and physical condition of storage and the chemical constituents of the fruit coating. Many studies indicates the fact that bioactive compounds, antioxidant and antimicrobial activity in many climacteric fruits, like in persimmons, changes greatly and these changes do not generally depends upon variety, method of cultivation, availability of nutrients, temperatures and light but chiefly depends post-harvest handling practices (Charles et al., 2017). Hence during the previous years, many studies are being conducted in order to establish sustainable, effective and workable post-harvest techniques, which not only enhance the shelf life of fruits and vegetables but also preserve and improve the biochemical and nutritional profile of the product (Pataro et al., 2015). This could result in lesser food loss and increased market prices of fruits and vegetables by providing superior nutritional and health benefits.

Among these different methods the uses of edible and non-edible fruit coatings have gained the interest of many scientists and many studies have proven the benefits of these coatings on the number of fruits and vegetables. Edible fruit coating helps to improve the shelf life and help to retain the fruit quality during storage. Edible coatings are emerging as a new approach for lengthening the shelf life and improving quality of fruit. Many fruit coatings are edible and consist of different types of polymers such as polysaccharide, protein and lipid. Edible coatings preserve the quality of fruits by creating an obstacle between fruit surface and atmosphere which prevents gaseous exchange and reduces the ripening and moisture loss and hence fruits are able to keep their odor and essence (Olivas & Barbosa, 2005). Fruit coating also consists of several active compounds like anti-microbial, texture retaining and anti-browning compounds along with various nutrients and flavors, which increases the safety, quality and nutritional content of fruits (Rojas et al., 2007). Addition of certain essential oils increases the shelf life and helps in better utilization and processing of fruits (Sung et al., 2013).

Persimmon being a climacteric fruit; with high perishability and respiration rate after harvesting, cause considerable economic losses in terms of fruit quality. Keeping in view the nutritional and economic importance of persimmon the experiment was carried out to investigate the benefits of different fruit coating to increase the shelf life and to maintain quality of fruits after harvesting.

Material and Methods

This research study was carried out in Horticulture Lab, The University of Haripur KP, during November 2019.

Fruits collection and storage condition

Unripe persimmon fruits were collected from the fruit market of Haripur. Fruits were then washed with tap water to eliminate dirt and microbial contamination. Wounds, Injured and insect or pest affected fruits were excluded. Washed and dried fruits were then treated with different edible coatings i.e. Control (without coating), Wax, Glycerin and *Aloe vera*. Fruits were dipped for 10 minutes in for thorough application of all treatments on fruits. Each treatment was replicated thrice. After treatment fruits were kept at ambient temperature for 9 days. Data regarding different parameters were recorded at regular intervals of 3 days (0, 3, 6 and 9 days).

Parameters studied

During the course of the study parameters regarding weight loss percent (%), fruit firmness (kg/cm^2), total soluble solids (Brix^0), pH and organoleptic tests were conducted. Fruit weights loss (%) were measured by using digital weight balance. Initial weight of fruits was recorded and every three days interval and total loss was determined by using following formula as described by (Konopacka & Plocharski, 2004):

$$\text{Fruit weight loss \%} = \frac{\text{Initial weight - Final weight}}{\text{Initial weight}} \times 100$$

Persimmon fruit firmness of persimmon fruits were calculated by using Magness Tylor (MT) probe and expresses as the highest amount of force needed to insert 11mm MT probe in pulp of the fruit after the skin of fruit is removed, up to 8mm deep (Instron Model 4303, 100 mm/min crosshead speed). The obtained results were expressed in kg/cm^2 (Konopacka & Plocharski, 2004). Total soluble solid (Brix^0) content of fruits was calculated by Handhold Refractometer (Zeiss, ATAGO NAR-3T model, Japan) at each interval of storage according to method described by Konopacka & Plocharski (2004). The pH of fruits was measured according to Association of Official Analytical Chemists [AOAC], (2005); juice of selected fruits from each replication was extracted by the help of hand juice extractor and pH of juice was recorded by using digital pH meter. Organoleptic evaluation of the fruits was performed as described by Kim et al. (2009). The fruits were given to the 5 faculty members of Department of Horticulture and Department of Food Science and Technology, The University of Haripur for sensory evaluation. The members were asked to rank the fruits on the rank of 1-10 for different fruit characters like taste, color, aroma, texture and overall look of the fruit. The applied ranking protocol was fruit with 9-10 rating was considered excellent, 6-8 was marked as good, 3-5 was marked poor and fruits with 0-2 rating were rejected. Hence a rating of 5 was considered to be an acceptability limit.

Experimental design and statistical procedures

Present experiment was laid down in Completely Randomized Design with two factors i.e. coating material (Control, Wax, Glycerin, *Aloe vera* gel and storage durations (0, 3, 6, and 9). Data obtained for different parameters were then subject for Analysis of Variance (ANOVA) at $p<0.05$ as described by Steel et al. (1980) using a computer based software, Statistix 8.1.

Results and Discussion

Weight loss (%)

Results regarding weight loss indicate a highly significant difference ($p<0.001$) between all treatments and storage durations. A decreasing trend was noted regarding weight loss of persimmon fruits (0.00 to 8.2%) during the storage interval. Maximum reduction in weight loss (7.51%) was recorded in glycerin whereas lowest weight loss (1.9%) was recorded in control. The highest reduction in weight loss (8.2%) was recorded at 9th day of storage followed by (5.8%) and (2.7%) at 6th day and 3rd day, respectively. Regarding the interaction of fruit coating and storage days, the maximum weight loss (14.4%) was recorded at 3rd day in those fruits which are treated with glycerin meanwhile lowest weight loss(0.0%) was recorded in 0 day under control, wax, *Aloe vera* and glycerin coatings followed by (3.6%) at 3rd day under control conditions. The results are in-line with findings of Alam et al. (2017). The weight loss during storage periods is key element which describes the shelf life of fruit. During storage many factors like water loss form fruit surface, degradation of plant cell wall, higher respirations and ethylene production causes weight loss. Moisture content of fruits is directly related to temperature, tissue water gradient and atmospheric pressure, all these components define the storability of fruits at ambient temperature. The increased weight loss over the period of time in our study can be attributed to these factors as the fruits are more exposed to the environmental conditions resulting in the higher reduction of weight. Also, the weight loss during storage can be due to gradual decreases of moisture content of stored fruits coupled with higher metabolic activity at cellular level over the interval of time decreasing the weight of fruits (Peyro et al., 2017).

Table 1 Effect of fruit coating and storage duration on weight loss (%) of persimmon fruit

Coating material	Storage duration (Days)				Means
	0	3	6	9	
Control	0.00j	1.67i	2.40h	3.60g	1.92d
Wax	0.00j	1.92i	4.47f	3.62d	3.15c
Aloe vera	0.00j	2.55h	5.70e	8.72c	4.24b
Glycerin	0.00j	4.75f	10.90b	4.40a	7.51a
Means	0.00d	2.72c	5.86b	8.23a	

Fruit firmness (kg/cm^2)

Data regarding fruit firmness of persimmon showed that a highly statistically significant difference (p<0.001) was observed among all applied coatings, storage intervals and their interaction (Table 2). An overall decreasing trend was noted regarding fruit firmness of persimmon fruits during the research period (3.5 to 2.1). Maximum reduction in fruit firmness (2.1) was seen in those persimmons fruits which were treated with glycerin whereas lowest fruit firmness (3.5) was noted in fruits which were treated with any fruit coating (control fruits). The highest reduction in fruit firmness (2.1) were observed on 9th day followed by (2.6) and (3.1) at 6th day and 3rd day respectively. The interactive results regarding fruit firmness shows that highest fruits firmness (3.1) was noted at 3rd day in fruits which were treated with glycerin meanwhile lowest fruit firmness (2.1) was seen at 6th day when fruits were treated with no fruits coating. Findings of our experiments were also confirmed by (Iqbal et al., 2016). The overall firmness of the fruits is described by factors like fruit softness, color changes, physiological processes, amount of ethylene produced and fruit ripening (Abreu et al., 2012). Amount of ethylene produced distinguishes the firmness of fruits from immature to mature fruits due to presence of protein polymers (Ghani et al., 2016). Calcium which maintains adjacent chains bonded among themselves, also glycoside chains interconnected among themselves by phenolic compounds. Hydrolytic enzyme activation due to ripening increases firmness that promotes intense solubilization of pectin present in the cell wall, mainly pectin methyl esterase (PME) and polygalacturonases (PG). High esterase activities in the cell wall of persimmon kernel suggest that rapid decrease in firmness (Rawan et al., 2017).

Table 2 Effects of fruit coating and storage duration on fruit firmness (kg/cm^2) of persimmon fruit

Coating material	Storage duration (Days)				Means
	0	3	6	9	
Control	3.62a	3.22b	2.75e	2.25g	2.96b
Wax	3.57a	3.27b	2.92d	2.50f	3.06a
Aloe vera	3.57a	3.07c	2.52f	2.10h	2.81c
Glycerin	3.55a	2.92d	2.32g	1.82i	2.65d
Means	3.58a	3.12b	2.63c	2.16d	

Total soluble solids (Brixº)

The analysis of variance (Table 1) showed that a highly significant difference (p<0.001) was observed among all treatments. An increasing trend was noted regarding TSS of persimmon fruits (16.4 to 20.4). Maximum increase in TSS (20.4) was seen in glycerin whereas lowest TSS was noted in control. The highest TSS (20.4) was observed in Glycerin coating, followed by (19.0) and (17.8) in *Aloe vera* gel and wax, respectively. Regarding storage days, maximum TSS was observed when Persimmon was stored for 9 days (7.5) followed by 6th day (4.2), while minimum TSS was observed in control treatment (1.9). Concerning the interaction, maximum TSS (22.6) was observed in glycerin stored for 9 days, whereas, minimum and statistically significant results of TSS were recorded in fruits stored for 0 days with coating of wax, *Aloe vera*, glycerin and control. Present findings are in line with those of Bagheri et al. (2015); Naeem (2019) who also reported that values of total soluble solids increased over the storage interval in persimmons fruits. The increasing values of TSS during storage can be attributed to the polysaccharides hydrolysis, like those of starch, and also to the concentration of fruit juice due to water loss or dehydration (Akhtar et al., 2010). Edible fruit coating application to the exterior of fruits increased the barrier between fruit and the external environment which prevents the loss of cellular water and allowed suitable opportunity for biochemical degradation of starch molecules into simpler sugar molecules and influenced the post-harvest changes and senescence process involving sugars, acids, anthocyanins, and texture (Crouch, 2001; Ali et al., 2013; Alwan & Hassan, 2020).

Table 3 Effects of fruit coating and storage duration on total soluble solids (Brixº) of persimmon fruit

Coating material	Storage duration (Days)				Means
	0	3	6	9	
Control	16.4j	17.2i	18.2g	19.2e	16.4d
Wax	16.5j	17.1i	17.5h	21.4b	17.8c
Aloe vera	16.5j	18.1g	19.7d	21.4b	19.0b
Glycerin	16.4j	18.6f	20.5c	22.6a	20.4a
Means	1.9d	3.1c	4.2b	7.5a	

pH

The analysis of variance showed that highly significant difference (p<0.001) was observed for coating materials, storage days and their interaction. Maximum pH (5.99) was recorded in glycerin while minimum pH (5.04) was recorded in the control treatment (without coating). The highest pH (6.19) was noted at 0 days of storage Minimum pH (5.00) was recorded when fruits were stored for 9 days. Concerning the interaction, statistically similar results were recorded in *Aloe vera* and glycerin coatings stored at 0 days whereas, minimum pH (3.75) was observed in glycerin coating stored for 9 days. These results are in agreement with those of Khan et al. (2016). Fruit pH is an important postharvest factor of fruits. pH of the fruit is related to the concentration of organic acids in the fruit extract, which is an important parameter in maintaining the quality of fruits. With increase in storage intervals an increased pH can be attributed to the organic metabolism occurring during the ripening over the storage intervals (Wijewardana et al., 2014).

Table 4 Effects of fruit coating and storage duration on pH of persimmon fruit

Coating material	Storage duration (Days)				Means
	0	3	6	9	
Control	6.15^{ab}	6.07^{bc}	5.95^{cd}	5.80^{ef}	5.04^{d}
Wax	6.15^{ab}	5.95^{cd}	5.75^{fg}	5.45^{h}	5.70^{c}
Aloe vera	6.22^{a}	5.92^{de}	5.62^{g}	5.02^{i}	5.82^{b}
Glycerin	6.25^{a}	5.85^{def}	4.32^{j}	3.75^{k}	5.99^{a}
Means	6.19^{a}	5.95^{b}	5.41^{c}	5.00^{d}	

Organoleptic evaluation

Data taste was significantly affected by both coating and storage durations as it is clear from the table-5 that significant variations were present among treatments, storage duration and the interaction. Fruits which were treated with *Aloe vera* gel showed the highest rating of taste (7.99) followed by Wax (7.82) and Glycerin (7.70) whereas least taste fruits were those of control treatment (7.04). The fruits at first day of storage showed highest taste (8.19) followed by fruits stored at 3rd (7.95) and 6th day (7.41), meanwhile lowest quality fruits were those which were stored up to 9th day (7.00). The interaction of fruit coating and storage duration reveals that maximum values for taste (8.25) were obtained from those persimmon fruits which were treated with *Aloe vera* gel on the first day of storage whereas least values (5.75) were obtained by *Aloe vera* gel at 9th day. In broader sense odor, color and taste are main sensory aspects which create the perception of quality and gain the acceptability by the consumers. So the control of these sensory attributes is very compulsory and its importance can't be undermined. Post-harvest process causes increased sugar content due to breakdown of polysaccharides and decrease in acidity of fruit juice (Tabatabaekolor et al., 2016). Taste retains higher acid concentration (Mazahir et al., 2018). Acids like citric acid, malic and quinic acid impart a major effect on flavor and taste of the fruits. The process of ripening changes these organic acids and sugars competently and enhances the taste and flavor. Talukder et al. (2020) reported that, improved metabolic activity during the storage changes the acidity inside tissues of fruits, hence organoleptic characteristics maintaining by the physicochemical properties of the treatments retained.

Table 5 Effects of fruit coating and storage duration on organoleptic evaluation of persimmon fruit

Coating material	Storage duration (Days)				Means
	0	3	6	9	
Control	8.15^{ab}	8.07^{bc}	7.95^{cd}	7.80^{ef}	7.04^{d}
Wax	8.22^{a}	7.92^{de}	7.62^{g}	7.02^{i}	7.82^{b}
Aloe vera	8.25^{a}	7.85^{def}	6.32^{j}	5.75^{k}	7.99^{a}
Glycerin	8.15^{ab}	7.95^{cd}	7.75^{fg}	7.45^{h}	7.70^{c}
Means	8.19^{a}	7.95^{b}	7.41^{c}	7.00^{d}	

Conclusion and Recommendation

The results of present study indicate that edible fruit coating have significant effects on quality and shelf life of persimmon. Results revealed that *Aloe vera* gel and Wax have significantly increased all studied parameters and maintained the quality of fruits during post-harvest storage, whereas glycerin failed to enhance any shelf life and quality of fruits. Hence from this study it can be recommended that to increase the shelf life and quality of persimmon *Aloe vera* and Wax can be use under ambient temperature conditions and economic losses due to post-harvest degradation of fruits and be minimized.

Author Contribution Statement: Muhammad Jalal Khan and Qasim Ayub conducted and carried out this research study. Ijaz Hussain planned, designed and supervised this research study. Nida Arif, Saad Mehmood and Sarmad Khalid helped in conducting the research project. Abid Mehmood analyzed the data. Naveed ul haq and Qammaer Shehzad edited the manuscript. All the authors read and approved the manuscript to be published.

Conflict of Interest: The authors declare that they have no conflict of interest.

Acknowledgments: The authors are thankful to Department of Horticulture, The University of Haripur for providing facilities and platform for this research study.

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