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Shelf life enhancement of Guava (*Psidium guajava* L.) fruit using novel coating materials

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Abstract
The present research study was conducted to enhance the shelf life and quality changes of guava fruits at successive interval storage using various coating materials. Guava fruits of winter season harvesting cv. Sardar were treated with T_1 (1% Carboxymethylcellulose+ 4% glycerol+ 40% Aloe vera gel), T_2 (2% Carboxymethylcellulose+ 4% glycerol+ 50% Aloe vera gel), T_3 (almond oil), T_4 (rose oil), T_5 (olive oil) and T_6 (beeswax) along with T_7 (control). Among all the treatments Almond oil has been found to work to increase the shelf life of guava fruits as it reduced the spoilage, physiological loss in weight, maintained firmness, total sugar content, reducing sugar, non-reducing sugar, titratable acidity, TSS, vitamin C and total phenols. Coating of guava fruits with almond oil also scored maximum sensory and organoleptic ratings among all the treatments.

Keywords: Shelf life, enhancement, Carboxymethylcellulose, *Psidium guajava* L.

Introduction
Guava (*Psidium guajava* L.), a prominent member of 300 odd genera of the Myrtaceae family, is one of the most widely cultivated tropical fruits on earth. A tropical plant having the spreading type of growth, guava is a prolific bearer that makes it popular among fruit growers around the globe. The hardy nature of the guava plant makes it suitable for cultivation in sub-tropical areas as well. Guava is a seasonal fruit found within the tropical climatic zone areas of the planet. Guava is considered to be a nutritionally rich fruit that satisfies most of the fruit requirements of the consumers. It has been rightly named as 'Poor man's fruit' as it can provide the required nutrition at an affordable price. It is a superb supply of dietary fibre, pectin, vitamin A, phosphorus presenting the second-largest nutrition content C of all of the fruits. Also, it is rich in iron, thiamine, niacin, riboflavin, and carotene (Mangaraj *et al*. 2014) [10]. Health benefits and nutritional attributes qualify guava fruit to be one of the most important tropical fruit (Morton, 1987) [13].

Guava is one out of the most nutritious and delicious fruits, cherished by buyers for its restoring flavour and superb taste (Adentuji *et al*. 2012) [1]. All over the globe, the buyers are enthusiastic about the diet of high-calibre, with no blend added substances, and a comprehensive period of availability (Jawadul *et al*. 2014). Postharvest adversities are a significant issue considering speedy rot during transport and storage. Efforts should be made to improve the shelf life of fruits and increase their storage ability (Adentuji *et al*. 2012) [1]. For the ease of commercialization and enhanced availability, it is essential to preserve the natural plant products like fruits after their harvest (Krishna and Rao, 2014) [8]. Guava being a climacteric fruit ages rapidly and can be stored effectively for 2-3 days only at room temperature. However, the use of coatings that are palatable and non-detrimental to health can help enhance the availability of guava for longer spells. There are a couple of kinds of palatable coatings, for instance, sugar, protein, lipid and a mix of all of these materials. (Wijewardane, 2013) [19]. Keeping the perishable nature of the guava fruit in mind, a study was executed to evaluate the effect of different palatable coatings on the extension in the shelf life of guava fruit under ambient storage conditions.

Material and Methods
The present study was conducted in the post-graduate laboratory of the Department of Horticulture, Lovely Professional University, Punjab during the year 2020-21. Freshly harvested healthy fruits of guava cv. Hissar Surkha having uniform size and free from any kind of visual deformity and disease were procured from the identified orchard and brought to the laboratory on the day of harvesting.

The fruits were washed with distilled water to remove any kind of foreign material attached to the surface of the fruits and then dried at room temperature. The fruits were divided into different batches to provide different coating treatments. The experiment was conducted in a completely randomized design (CRD), different types of readily available coating materials were used for the study. The experiment was divided into seven treatments consisting of treatments T_1- 1% CMC + 4% Glycerol + 40% *Aloe vera* gel coating, T_2- 2% CMC + 4% Glycerol + 50% Aloe vera gel coating, T_3- Almond oil coating, T_4- Rose oil coating, T_5- Olive oil coating, T_6- Bee wax, T_7- Control. The coated fruits were stored in the post-graduate laboratory of the Department of Horticulture, Lovely Professional University under ambient storage conditions. The fruits after being subjected to different coating treatments were judged for their quality and shelf-life evaluation after every 4-day interval. Fruits from each treatment were evaluated using standard procedures for quality and shelf life estimation. The data generated during the investigation was subjected to statistical analysis using SPSS V. 21 software to determine homogenous sets of observations.

Results and Discussion

The study revealed significant findings for the effect of different novel coatings on the quality and shelf life enhancement in guava fruit (Table 1). During the storage period, it was observed that minimum spoilage percentage (20%) was recorded for treatment T_3 (almond oil coating), followed by treatment T_2 (2% CMC + 4% Glycerol+ 50% Aloe vera gel) which recorded a spoilage percentage of 36.67 per cent. Maximum spoilage percentage among guava fruits was recorded under control treatment (60%). In a research study, it was claimed that the coatings help in delaying the process of spoilage in Mediterranean cucumber for increasing the life span and quality retention (Moalemiyan and Ramaswamy, 2012) [12]. Maximum firmness (10.07 kg/cm^2) followed by was recorded in treatment T_3 on the 8th day after storage (Table 2). The minimum firmness value (5.00 kg/cm^2) was observed in T_7 (Control). Firmness showed a decline phase till a further period of storage. On the 16th day after storage, the maximum firmness (9.03 kg/cm2) was recorded in treatment T_7 (Almond oil coating) while it was found that the minimum value of firmness (2.17 kg/cm^2) was recorded in treatment T_7 where fruits were coated with distilled water. During the research, the effect of growth retardants, gamma-irradiation and coatings on shelf-life of winter guava by using coconut oil, liquid paraffin and mustard oil during storage was observed and it was reported that treated fruits with coconut oil were having enhanced storage life (Chauhan *et al.* 2014) [4].

Loss in weight showed an increasing trend in all the treatments. The minimum PLW (2.32%) was observed in treatment T_3 (almond oil coating) followed by treatment T_2 (2% CMC+ 4% Glycerol+ 50%) having a value of 2.96 per cent (Table 3). An enhancement in the trend was observed in the observations recorded under PLW till the further period of storage. On the 16th day after storage, the significant minimum value (4.29%) was recorded in treatment T_3 (almond oil coating) followed by T_4 (rose oil coating) having a value of 5.03 per cent. The maximum PLW value (6.73%) was recorded in treatment T_7 (control). Bhowmick *et al.* (2015) [3] examined the effectiveness of covering material on postharvest life of ber and found that the application of various concentrations of chitosan, guar gum and gum recorded the minimum amount of PLW.

The total sugar content of guava fruits showed an increasing trend during the initial days of storage but gradually declined as the storage period extended (Table 4). Maximum total sugar content (8.96%) at 8 days of storage was observed under treatment T_3 (Almond oil coating) followed by treatment T_6 (8.76%) and treatment T_4 (8.67%). However, as the storage period advanced, the total sugar content among the guava fruits became non-significant with the maximum total sugar content being recorded for the treatment T_3 (6.13%). Minimum total sugar content was recorded for the control treatment during all the storage days. Reducing sugars showed a decreasing trend as the storage period advanced (Table 5). On the 16th day of storage, maximum reducing sugars were observed under treatment T_3 (2.77%) followed by treatment T_1 (2.74%) and treatment T_2 (2.72%). Minimum reducing sugar content (1.91%) was recorded under control treatment T_7. Similar findings were claimed by Singh *et al.* (2017) [16] during an investigation by using almond oil, grape seed oil, mustard oil, olive oil and coconut oil at ambient conditions and cold storage on guava fruits which recorded significant values of sugars. Non-reducing sugars content among stored guava fruits first showed an increasing trend till the 8th day of storage and then followed a decreasing trend thereafter (Table 6). On the 8th day of storage, maximum non-reducing sugars content was recorded under treatment T_7 (4.23%) followed by treatment T_1 (3.83%).

On the 16th day of storage, the maximum non-reducing sugar content was recorded under treatment T_3 (3.19%) followed by treatment T_7 (1.15%). Minimum non-reducing sugar content was recorded under treatment T_6 (0.54%). However, the data on non-reducing sugar content in guava fruits during the storage intervals was non-significant. Similar findings were claimed by Krasniewska *et al.* (2017) [7] during research using the pullulan coating material on highbush blueberry which recorded significant value of non-reducing sugars during the storage period.

Guava fruits under ambient storage conditions showed a decreasing trend in the titratable acidity of the fruits (Table 7). Variation in titratable acidity of the stored guava fruits was observed on the 8th day of storage where maximum acidity value (0.604%) was recorded for the treatment T_3 (almond oil) whereas minimum acidity values were recorded for the treatment T_7 (0.292%). However, on the 16th day of storage, the acidity values for all the treatments were non-significant. Hassanpour (2014) [5] showed in a research study that total phenol content was observed in decreasing phase significantly.

The results were shown in coated berries, the coated fruits were kept in cold storage and showed a decline phase till the further duration of storage.

TSS of the guava fruits under storage showed an increasing trend during the first 8 days of storage however as the storage period advanced, there was a decrease in the TSS value of guava fruits (Table 8). Maximum TSS was reached under treatment T_3 on the 12th day of storage (11.53 ˚Brix) closely followed by treatment T_2 (11.13 ˚Brix). However, on the 16th day of storage, TSS values in all the treatments decreased compared to the previous values. Maximum TSS value on the 16th day of storage was recorded under treatment T_3 (10.48 ^{o}Brix). Minimum TSS value (8.02 ^{o}Brix) was recorded for the control treatment (T_1). In research findings of Jagdeesh and Rokhade (1994) [6] it was claimed that during the first few

days of storage, the TSS tends to show an increase owing to the conversion of starch to sugars but as the level of starch drops down and there is a shortage of substrate to be converted to sugars after few days they observe a decline in the TSS content of the stored fruits wherein the accumulated sugars tend to break down and bring down the TSS levels.

In the data related to vitamin C, it was found that vitamin C showed a decreasing trend under ambient storage conditions (Table 9). On the 8th day of storage, the maximum significant value of vitamin C (143.31 mg/100g pulp) was recorded in treatment T_3 (Almond oil) while the minimum value of vitamin C (123.70 mg/100g pulp) was recorded in treatment T_7 (control). Vitamin C showed decreasing trend till further, on the 16th day of storage, the maximum value (78.98 mg/100g pulp) was recorded in treatment T_3 while the minimum value of vitamin C (71.59 mg/ 100g pulp) was recorded in treatment T_7 (Control). It has been reported in many research findings that there is degradation in the vitamin C content during the storage of fruits. The acid in a coating formulation as an antioxidant lowered the loss of vitamin C **(**Ayranci and Sibel, 2003) [2]. Among all treatments, the maximum significant value of total phenols (451.80 mg GAE/ 100g pulp) was recorded in T_3 (Almond oil coatings) at 8th days of storage while the minimum value of total phenols 447.74 mg GAE/ 100g pulp) was recorded under control (Table 10). The total phenols demonstrated a declining trend till a further period of storage. On the 16th day of storage, it was revealed that the maximum value of total phenols (435.71 mg GAE/ 100g pulp) was recorded under treatment T_3 while the minimum content of total phenols was found to be recorded under treatment T_7 (control) or non-treated fruits. During storage, the total phenol content of guava fruits decreased significantly irrespective of the treatment (Sood *et al.* 2021) [18].

Sensory evaluation of guava fruits stored under ambient storage conditions is presented in Table 11. The maximum points for sensory attributes (6.8, 6.5, 6.5, 7.2 and 6.8 respectively) were recorded in the group of guava fruits coated with almond oil (T_3) at 16th days of storage followed by the data recorded (6.1, 5.7, 5.2, 5.5 and 6.0 respectively) in treatment T_2 (2% CMC+ 4% Glycerol+ 50% *Aloe vera* gel). While the guava fruits kept under storage in T_7 (control) were found to be recorded the minimum points of organoleptic sensory attributes (3, 1.5, 1.9, 1.5 and 2.0 respectively). The fruits kept under control (T_7) were disliked highly at 16th days of storage as according to fruits kept under almond oil treatment (T_3) were found to be liked at the same period. (Martínez-Romero *et al.* 2006) [11]

Coatings have been proven to provide stability to the fruits under natural storage conditions. Coatings form a layer around the fruit which isolated the fruit internal environment from the external one. In the present study, almond oil came out to be the best coating material for the ambient storage of guava fruits. Other coating treatments also performed well against the untreated fruits. Beneficial effects of coatings have been highlighted by Relhan *et al.* (2021) [15] in Ber wherein coatings proved to retain the quality characteristics and enhanced the shelf life of ber. Similar findings have been reported by Singh *et al.* (2018) [17] that different coatings responded significantly in enhancing the post-harvest life and quality of guava fruits. They proposed a study wherein they treated guava fruits with aloe vera and two antioxidants along with control. The findings revealed that 20% aloe vera gel was found effective in retaining the quality parameters of guava fruits along it also extended the shelf life against the control. Mendal *et al.* (2018) experimented on mango fruit cv. Rangkuai with chitosan, olive oil, wax, carboxymethylcellulose (CMC), aloe gel on shelf life and quality of mango and found that the fruits coated with wax coating enhanced the post-harvest life and quality of mango fruits as the wax coating kept the fruit remained in dark skin colour and pulp was found slightly orange against the control.

Table 1: Effect of coatings on spoilage percentage of guava fruits stored under ambient conditions

Treatment	Spoilage (%)				
	0	4	8	12	16
T_1	0^a	0.00^a	3.33^a	16.67^a	43.33^{ab}
T_2	0^a	0.00^a	10.00^b	13.33^a	36.67^b
T3	0^a	0.00^a	0.00^a	10.00^a	20.00^a
T_4	0^a	0.00^a	3.33^a	33.33^b	50.00^c
T_5	0^a	0.00^a	3.33^a	40.00^b	46.67^c
T_6	0^a	0.00^a	6.67^a	36.67^b	50.00^c
T_7	0^a	6.67^b	23.33^b	46.67^b	60.00^c

Table 2: Effect of different coatings on firmness (kg/cm^2) of guava fruits stored under ambient storage conditions

Treatment	Firmness (kg/cm^2)				
	0	4	8	12	16
T_1	11.68^a	9.30^a	6.40^b	5.43^{bc}	4.00^b
T_2	11.68^a	9.63^d	6.84^b	5.83^c	4.37^b
T_3	11.68^a	11.07^e	10.07^d	9.53^d	9.03^c
T_4	11.68^a	9.00^{bc}	7.43^c	5.73^d	4.13^b
T_5	11.68^a	9.13^{bc}	7.67^c	5.43^{bc}	4.23^b
T_6	11.68^a	8.73^b	6.70^b	5.07^b	3.87^b
T_7	11.68^a	6.27^a	5.00^a	4.43^a	2.17^a

Table 3: Effect of different coatings on physiological loss in weight (%) of guava fruits stored under ambient storage conditions

Treatments	Physiological Loss in weight (PLW%)			
	4	8	12	16
T_1	1.89	3.06	4.54	5.43
T_2	1.80	2.96	3.66	5.21

T_3	0.88	2.32	3.27	4.29
T_4	1.76	3.36	4.65	5.03
T_5	1.94	3.32	4.43	5.70
T_6	1.81	3.46	5.15	6.20
T_7	2.46	3.93	5.38	6.73

Table 4: Effect of coatings on Total sugar content of guava fruits stored under ambient conditions

Treatment	Total sugar (%)				
	0	4	8	12	16
T_1	6.36^{a}	7.38^{ab}	8.63^{c}	5.96^{c}	3.42^{c}
T_2	6.36^{a}	7.37^{ab}	8.53^{b}	6.10^{c}	3.48^{d}
T_3	6.36^{a}	8.34^{c}	8.96^{e}	7.24^{e}	6.13^{e}
T_4	6.36^{a}	7.58^{b}	8.67^{c}	5.97^{c}	3.25^{b}
T_5	6.36^{a}	7.46^{ab}	8.56^{b}	6.64^{c}	3.37^{c}
T_6	6.36^{a}	7.35^{ab}	8.76^{d}	5.45^{b}	3.12^{a}
T_7	6.36^{a}	7.27^{a}	7.98^{a}	4.88^{a}	3.11^{a}

Table 5: Effect of coatings on reducing sugar content of guava fruits stored under ambient conditions

Treatment	Reducing sugar (%)				
	0	4	8	12	16
T_1	3.47^{a}	3.97^{b}	4.60^{a}	3.09^{b}	2.74^{c}
T_2	3.47^{a}	4.12^{d}	4.80^{b}	3.23^{b}	2.72^{c}
T_3	3.47^{a}	4.36^{e}	5.02^{c}	3.36^{b}	2.77^{c}
T_4	3.47^{a}	3.99^{c}	4.81^{b}	2.99^{b}	2.34^{b}
T_5	3.47^{a}	3.91^{b}	4.82^{b}	3.05^{b}	2.57^{b}
T_6	3.47^{a}	4.07^{d}	4.80^{b}	3.02^{b}	2.54^{b}
T_7	3.47^{a}	3.77^{a}	4.51^{a}	2.50^{a}	1.91^{a}

Table 6: Effect of coatings on Non-Reducing sugar content of guava fruits stored under ambient conditions

Treatment	Non-Reducing (%)				
	0	4	8	12	16
T_1	2.75^{a}	3.24^{a}	3.83^{b}	2.72^{ab}	0.65^{ab}
T_2	2.75^{a}	3.09^{a}	3.54^{a}	2.73^{ab}	0.72^{ab}
T_3	2.75^{a}	3.78^{c}	3.74^{b}	3.69^{c}	3.19^{d}
T4	2.75^{a}	3.41^{b}	3.66^{a}	2.82^{b}	0.86^{b}
T5	2.75^{a}	3.34^{b}	3.55^{a}	3.40^{c}	0.76^{ab}
T_6	2.75^{a}	3.12^{a}	3.77^{b}	2.31^{ab}	0.54^{a}
T_7	2.75^{a}	4.34^{d}	4.23^{c}	2.26^{a}	1.15^{c}

Table 7: Effect of coatings on titratable acidity in guava fruits stored under ambient storage conditions

Treatment	Titratable Acidity (%)				
	0	4	8	12	16
T_1	0.628^{a}	0.485^{a}	0.456^{abc}	0.428^{a}	0.398^{a}
T_2	0.628^{a}	0.515^{a}	0.501^{bc}	0.479^{a}	0.457^{bc}
T_3	0.628^{a}	0.604^{a}	0.576^{c}	0.557^{b}	0.549^{c}
T_4	0.628^{a}	0.469^{a}	0.343^{ab}	0.309^{a}	0.274^{a}
T_5	0.628^{a}	0.482^{a}	0.472^{abc}	0.418^{a}	0.387^{ab}
T_6	0.628^{a}	0.504^{a}	0.442^{abc}	0.458^{a}	0.436^{bc}
T_7	0.628^{a}	0.349^{a}	0.292^{a}	0.203^{a}	0.168^{a}

Table 8: Effect of coatings on TSS of guava fruits stored under ambient storage conditions

Treatment	Total soluble solids (ºbrix)				
	0	4	8	12	16
T_1	8.89^{a}	10.13^{a}	9.33^{a}	9.03^{a}	8.02^{a}
T_2	8.89^{a}	11.37^{a}	11.13^{ab}	10.97^{ab}	9.50^{bc}
T_3	8.89^{a}	11.73^{a}	11.53^{b}	11.27^{b}	10.48^{d}
T_4	8.89^{a}	11.07^{a}	10.80^{ab}	10.60^{ab}	9.83^{cd}
T_5	8.89^{a}	10.90^{a}	10.30^{ab}	10.07^{ab}	8.83^{abc}
T_6	8.89^{a}	10.23^{a}	9.70^{ab}	9.53^{ab}	8.67^{ab}
T_7	8.89^{a}	10.37^{a}	10.13^{ab}	9.90^{ab}	9.00^{abc}

Table 9: Effect of coatings on Vitamin C in guava fruits stored under ambient storage conditions

Treatment	Vitamin C (mg/100 gm pulp)				
	0	4	8	12	16
T_1	172.00^{a}	164.52^{ab}	128.06^{a}	90.42^{a}	77.83^{cd}

T_2	172.00^a	163.04^{ab}	126.18^a	89.66^{abc}	76.96^{bs}
T_3	172.00^a	170.41^c	143.31^b	91.40^c	78.98^d
T_4	172.00^a	165.96^b	126.94^a	89.31^{abc}	76.11^b
T_5	172.00^a	163.67^{ab}	126.01^a	89.85^{abc}	77.06^{bs}
T_6	172.00^a	163.29^{ab}	125.11^a	88.44^{ab}	76.01^b
T_7	172.00^a	161.48^a	123.70^a	87.80^a	71.59^a

Table 10: Effect of coatings on Total phenols in guava fruits stored under ambient storage conditions

Treatment	Total phenols (mg GAE/100 g pulp)				
	0	4	8	12	16
T_1	489.67^a	467.71^a	449.71^{bc}	425.20^a	409.71^a
T_2	489.67^a	468.96^b	448.53^{ab}	432.40^b	423.03^b
T_3	489.67^a	469.80^b	451.80^d	441.19^d	435.71^d
T_4	489.67^a	468.03^a	450.06^c	434.36^b	428.59^{cd}
T_5	489.67^a	467.66^a	449.22^{ab}	433.15^b	426.67^c
T_6	489.67^a	467.82^a	448.62^{ab}	432.26^b	423.05^b
T_7	489.67^a	467.64^a	447.74^a	437.44^c	429.50^c

Table 11: Sensory evaluation for fruits stored under ambient condition at 16th days of storage

Treatments	Organoleptic sensory attributes				
	Colour	Taste	Appearance	Texture	Overall acceptability
T_1	5.3	5.5	4.9	5.1	5.5
T_2	6.1	5.7	5.2	5.5	6.0
T_3	6.8	6.5	6.5	7.2	6.8
T_4	5.4	5.0	4.4	4.3	4.9
T_5	5.5	4.9	5.1	4.8	5.1
T_6	5.1	4.5	4.3	4.1	4.8
T_7	3	1.5	1.9	1.5	2.0

Conclusion

The present research revealed that the almond oil edible coating material could effectively control respiration and act as a barrier to oxygen and thus it extended the life span of guava fruits treated with almond oil. Based on the results obtained it is concluded that the almond oil is effective in enhancing the shelf life, appearance and ripeness of fresh whole fruits like guava. It is seen that the almond oil coating is effective only when it is applied in sufficient amount that is in this experiment the highest number of the coating was single coat only, which turned out to be the most effective in controlling the decay and maintaining the shelf life of fruits kept in storage coated with almond oil.

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