Scientia Horticulturae 246 (2019) 769–776

Contents lists available at ScienceDirect

Scientia Horticulturae

journal homepage: www.elsevier.com/locate/scihorti

Application of *Aloe vera* coating delays ripening and extend the shelf life of papaya fruit

T.K. Mendy[a], A. Misran[a,*], T.M.M. Mahmud[a], S.I. Ismail[b]

[a] Department of Crop Science, Faculty of Agriculture, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia
[b] Department of Plant Protection, Faculty of Agriculture, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia

ARTICLE INFO

Keywords:
Postharvest
Concentration
Storage
Decay

ABSTRACT

The use of gel from *A. vera* for fruit coating has been shown to enhance shelf life of fruits. In the present study, papaya fruits were coated with *A. vera* and its effect on quality attributes, shelf life and antioxidant activity were evaluated during storage at 3 days interval for 15 days. Fresh and food grade *A. vera* gel (at 0, 15, 25 and 50%, v/v) were used to coat papaya fruits for 15 days at room temperature (28 ± 2^{0}C). Papaya fruits coated with the two types of *A. vera* showed no significant different in delaying ripening, suppressed fungal growth and maintained the quality of papaya fruits after 15 days of storage especially at 50% gel concentration. *A. vera* coated fruits were able to reduce loss in weight and firmness and maintained higher soluble solid concentration (SSC), pH, titratable acidity (TA), ascorbic acid (AA), total carotenoids content, total phenolic content (TPC), total flavonoids content (TFC) and DPPH scavenging activity as compared to uncoated papaya fruits that decayed within 12 days of storage. Evidences from present study indicate that coating fruits with *A. vera* can effectively extend the shelf life of papaya fruit.

1. Introduction

Despite the significant increase in food production, according to Food Agricultural Organisation (FAO), one third of the food produced for human consumption in the world is loss or wasted. There are many different reasons why this losses occur but one of this reasons is the loss in postharvest stages and marketing systems (Prusky, 2011). The losses are severe in developing countries where there is no proper postharvest storage and marketing facilities. Food losses do not only reduce food availability for human consumption but also cause a negative impact to society through several costs used on production. Hence reducing food losses is tremendously important as it can increase the amount of food available for human consumption and enhance global food security (Kader, 2005; Prusky, 2011).

Postharvest losses can increased after harvest, when there is an increase in the rate of natural deterioration such a high temperature, low atmospheric humidity, physical injury and diseases. The cost of controlling postharvest losses is a deciding factor in the adoption of various postharvest loss control measure. However with emergence in edible coatings, which is an affordable, efficient and remarkable way of extending the shelf-life of commodities (Valencia-Chamorro et al., 2018), most of the postharvest losses of fruits and vegetable can be minimized.

About 60 countries produce papaya with the bulk of production coming from many developing tropical countries. Asia is the world leading papaya producer, accounting for approximately 52.55% of world production from 2008 to 2010. However there are several constraints that hinder the expansion of export for this fruit because of the short storage life, susceptibility to postharvest diseases, high shipment cost and fungicides that could be harmful to consumers (Rahman et al., 2008). In Malaysia 'sekaki' papaya fruit is considered as the leading cultivar of papaya fruits for both domestic consumption and export market. However papaya fruits exported to Singapore market declined by 17.91% between 2002 and 2009 and the 90.31% of papaya fruits exported to Singapore was from Malaysia and the rest from Philippines and Thailand (UN Comtrade, 2012

Edible synthetic coatings (mainly polyethylene based which is a petroleum) such as paraffin, mineral oil, oxidized polyethylene, and plastics are produced from a limited supply of fossil fuels. Ammonia is also commonly used in these synthetic coatings meant for fresh fruits, but it has certain disadvantages. Ammonia-based micro emulsions are difficult to prepare because it is highly volatile and unpleasant, toxic and can cause false alarms in packing houses that use odor as a warning (Hagenmaier, 2004). Postharvest treatments with conventional synthetic waxes and/or chemical fungicides such as imazalil, thiabendazole, sodium ortho-phenylphenate or other active ingredients have created important problems for the food industry such as health and

* Corresponding author.
E-mail address: azizahm@upm.edu.my (A. Misran).

https://doi.org/10.1016/j.scienta.2018.11.054
Received 3 August 2018; Received in revised form 15 November 2018; Accepted 16 November 2018

environmental issues associated with chemical residues or the proliferation of pathogenic resistant strains (Palou et al., 2015). Many countries are increasingly restricting the use of agrochemicals and exports markets are demanding fruits with residue levels even lower than those established by official regulations. Research should now be focused on providing coating where conventional chemical fungicides are not available (Palou et al., 2015). Natural coatings made from natural ingredients such as polysaccharides, lipids and proteins represent an environmentally ideal package since they are biodegradable, can be consumed with the packaged product and the main ingredients are produced from renewable resources (Khan et al., 2013). Edible coating have been used as a coating on papaya fruits and the results showed that it was able to prolong the shelf life of papaya fruits by reducing diseases index and maintaining the quality of papaya fruits during storage at room temperature (Marpudi et al., 2011; Brishti et al., 2014).

Aloe vera is a short-stemmed succulent plant of the Asphodelaceae (Liliaceae) family grown in the dry regions of Africa, Asia, Europe, and America. The stems have a high capacity of retaining moisture especially in very warm dry climates, and therefore it can survive very harsh circumstances where most other vegetation could not (Misir et al., 2014). *Aloe vera* has been used by different cultures as a medicinal plant for centuries. The antifungal activity of *A. vera* has been well documented both in *in vitro* and *in vivo* study. *A. vera* is found to reduce the respiration rate and microbial spoilage (Benítez et al., 2013) as well as lead to firmness retention and increase the level of certain phenolic compounds (Martínez-Romero et al., 2013). It has been reported that *A. vera* was able to reduce spore survival by 15%–20% for *Penicillium*, *Botrytis* and *Alternaria* (Saks and Barkai-Golan, 1995), and accordingly *A. vera* gel was also able to reduce by 22%–38%, the mycelium growth of other plants pathogenic fungi such as *Rhizoctonia, Fusarium* and *Colletotrichum* (Gonzalez-Aguilar et al., 2010). The effectiveness of *Aloe vera* as an antifungal fruit coating against most fungal pathogens has been demonstrated in stone fruits (Guillén et al., 2013), avocados (Bill et al., 2014), papaya (Marpudi et al., 2011) and berry fruits, notably blueberries (Vieira et al., 2016) and strawberries (Sogvar et al., 2016). In mandarins, Jhalegar et al. (2014) suggested that *Aloe vera* have the potential to control green and blue mold decay.

The experiment was carried out to assess the comparison of antifungal potential of locally processed *A. vera* gel (Fresh *A. vera*) and commercial processed *A. vera* (Food grade *A. vera*) as a coating in extending the postharvest shelf life and quality of papaya fruits.

2. Materials and methods

2.1. Plant materials

2.1.1. Papaya fruit

Sekaki papaya fruit of index maturity stage 2 (green with slight yellow colour) were obtained from Meng Choon Plantation in Kota Tinggi, Johor, Malaysia. Papaya fruits with no visible sign of mechanical damage were selected and standardized based on their uniform shape, size, and colour. Prior to treatment, papaya fruits were washed in tap water to removed dirt and debris. They were then surface sterilised with ethanol 70% for 1 min followed by clorox 10% for 3 min and rinsed three times with distilled water then allow to air dry.

2.1.2. Aloe vera gel

Fresh *A. vera* leaves (*A. barbadensis* Mill) from 2 year old plants was supplied by PPABio Sdn Bhd., Johor Bahru, Johor, Malaysia. The *Aloe vera* leaves (weighting between 345.02 g to 569.33 g and 10 kg in total quantity) were immediately shipped to the laboratory in Crop Science Department, Faculty of Agriculture, Universti Putra Malaysia under cold conditions (4 -10 °C). Food grade *A. vera* (aloeshafy™) was supplied by PIJ Manufacturing Sdn Bhd.The ingredients used in processing the gel were *Aloe vera* (bardadensis Miller), sodium erythorbate ($C_6H_7NaO_6$) and acid citric ($C_6H_8O_7$).

2.2. Treatment of papaya fruit

Treatment was performed by extracting the fresh *A. vera* based on the methods of Brishti et al. (2014) with a little modification. Fresh *A. vera* gel in this present test was filtered using muslin cloth and filter paper (Whatman, grade 1 and diameter of 90 mm). Fresh *A. vera* and food grade *A. vera* gel were then diluted with autoclaved distilled water to provide a working concentration of 15%, 25% and 50% (v/v). Control treatment had only autoclaved distilled water and no *A. vera* gel added. Tween 80 (0.03% v/v) was added to control treatment and each final concentration of fresh *A. vera* and food grade *A. vera* gel to facilitate coating (Mahmud et al., 2008).

The sterilised papaya fruits were coated with fresh and food grade *A. vera* at concentration (0%, 15%, 25% and 50%) with three replication for each concentration. Papaya fruits were dipped for 3 min in fresh and food grade *A. vera* gel concentrations then allowed to air dry for 1 h at room temperature before they were stored in cartons (29 cm height, 42 cm length and 28 cm width). Fruits dipped in distilled water without *A. vera* were treated as control. Three replication for control and each concentration of fresh and food grade *A. vera* were weighted and stored separately at completely randomized design to monitor the weight loss during the storage period. The cartons were placed randomly on the table surface at room temperature 28 ± 2 °C and 68–70% relative humidity for 15 days. Data on postharvest quality parameters based on fresh weight of papaya fruits were taken every 3 days starting with day 0. Percentage increase and decrease presented on the result were calculated based on the highest value (within the storage period) for that particular parameter from the initial value of day 0 or the final value at the end of storage multiply by 100.

2.3. Effect of Aloe vera coating on postharvest quality of papaya

2.3.1. Determination of physiological weight loss

Papaya fruits with three replicates in each treatment were weighed using an electronic balance (EK-600H, Japan) on the first day of storage before been stored in cartons. Every three days after storage they were taken out and weight then returned into their various cartons for subsequent weighing. This was done up to the last day storage. Percentage weight loss for each storage interval was determined by:

$$\%Weight\ loss = \frac{[Papaya\ weight\ at\ SDa] - [Papaya\ weight\ at\ SDb]\ \ x100}{[Papaya\ weight\ atSDa]}$$

SD = Storage duration at 3, 6, 9, 12 and 15 day
SDa = Initial weight after treatment
SDb = Final weight at each storage interval (3, 6, 9, 12 and 15)

2.3.2. Firmness of papaya fruit

Papaya firmness testing was measured using an Instron Universal Testing Machine (Model 5543P5995, Instron Crop. Minneapolis, USA). The equipment has a 6 mm diameter probe with 5 kg load that can penetrate 40 mm in the fruit in any direction at crosshead speed of 500 mm min^{-1}. Papaya fruits firmness was measured with three replicates on each slice. Three slice of height about 3 cm and width 10 cm each were used for firmness testing from each papaya fruit. The data on firmness testing was collected every three days during storage period, starting with day 0. The firmness were expressed as Newton (N), using the Instron Merlin Software version M12-13664-EN.

2.3.3. Determination of soluble solid concentration

Soluble solids concentration was determined by the method of (Ali et al., 2011a, 2011b) using a digital refractometer (ATAGO, Japan). The readings were standardized at room temperature (28 °C) by adding 0.28% and multiplied by dilution factor to obtained original reading of the papaya juice.

% SSC = [readings of the refractometer * dilution factor] + 0.28.

$$Dilution\ factor = \frac{1 + volume\ of\ water\ (ml)}{Weight\ of\ sample\ (g)} = \frac{1 + 80ml}{20g} = 5$$

2.3.4. Determination of titratable acidity (TA)

Titratable acidity was determined by the methods of Ali et al. (2011a,2011b) with modification. This was calculated as percentage of citric acid using the following equation.

$$\textbf{Citric acid}\ (\%) = \frac{mlNaOHx0.1MNaOHxvolumeofproduct\,(100ml)\ x64(equivalentweightofcitricacid)x100}{Weightofsample\,(20g)xvol.\ ofsamplefortitration\,(5ml)x1000}$$

2.3.5. Determination of pH

pH was determined using a pH meter (Model GLP 21).The juice from soluble solid concentration was used to determine pH. The pH meter was calibrated with buffers at pH 7.0 and 4.0 prior to be used.

2.3.6. Determination of ascorbic acid (AA) content

Ascorbic acid was determined by the method of (Wall, 2006). 20 g of papaya fruit sample was homogenized with 80 ml of 3% metaphosphoric acid ($HPO_{3)}$ using a blender for 1 min at high speed. The ascorbic acid was calculated as in the equation below.

Ascorbic acid (mg / 100 g) = ml dye used x dye factor x volume of product (100 ml) x 100 / Weight of sample (20 g) x volume of sample for titration (5 ml)

2.3.7. Determination of total carotenoid content

Total carotenoid was done by the method of Soto-Zamora et al. (2005) with modification. Papaya pulp (5 g) was grounded in mortar with 10 ml of extraction solution (hexane: acetone: ethanol; toluene at 10:7:6:7). The extracts were transferred in to test tubes after which 1 ml of methanolic KOH was added and heated in a water bath at 56 °C for 20 min for saponification. It was immediately cooled at room temperature before 10 ml of 10% sodium sulfate was added and stirred for 1 min. After the phase separation the upper phase was used for carotenoid analysis using spectrophotometer at 450 nm.

2.3.8. Determination of total phenolic content (TPC), total flavonoid content (TFC) and DPPH scavenging activity of papaya fruits

The extraction for antioxidant was done by the method of (Musa et al., 2012). Papaya fruits were cut into small pieces about 1 cm, after been peeled and then blender to produce uniform slurries. This was done with fresh peeled papaya to preserve the antioxidant compound in it. The slurries (1.5 g) each were grinded in a mortal with 50% methanol and transferred into 15 ml universal bottles. All the samples were then centrifuged using table top centrifuge (Kubota 2100) at 4000 *g* for 10 min. The supernatants were collected and stored in -20 °C for further analysis of TPC, TFC and DPPH scavenging activity.

The total phenolic content was done by the modified method of (Abu Bakar et al., 2009) with modification. The samples were kept for 2 h at room temperature before the absorbance was taken at 765 nm wavelength with spectrophotometer (Fisher Thermo Scientific Multiskan Go Model 151, United Kingdom). The result were expressed as mg of Gallic acid equivalent per 100 g of fresh sample (mg GA/100 g).

Flavonoid content was determined by the modified colorimetric method of (Addai et al., 2013). The solution was well mixed by a shaker and the absorbance was read at 510 nm using a spectrophotometer (Fisher Thermo Scientific Multiskan Go Model 151, United Kingdom). The result was expressed as milligrams of quercetin equivalent (QR) per 100 g of fresh sample (mg QR/100 g).

2, 2-diphenyl-1-pycrylhydrazyl radical scavenging activity (DPPH) was determined by the modified method of (Addai et al., 2013) with a slight modification. About 1 ml of papaya samples was mixed thoroughly with 3 ml freshly prepared DPPH solution and kept in the dark for 30 min at room temperature before the absorbance was read at 517 nm using UV-VIS spectrophotometer (Fisher Thermo Scientific Multiskan Go Model 151, United Kingdom). The percentage of DPPH scavenging activity was determined by the following equation.

% DPPH = Absorbance sample- Absorbance control sample *100 / Absorbance control sample

2.3.9. Diseases incidence and severity

Diseases incidence and severity was observed and recorded within storage period (15 day) and ranked as 1–5 where:

0 – is healthy fruits without any lesion.

1 – 1%–25% fruits surface covered with lesion.

2 – 26%–50% of fruits surface covered with lesion and soft rot.

3 – 51%–75% of fruits surface covered with water soaked lesions and necrosis around the lesions.

4 – 76%–100% of the fruits surface covered with water soaked lesion.

Diseases incidence = [(number of infection categories / number of infected fruit falling to this category)*100] / maximum no. of infection categories

2.4. Experimental design and statistical analysis

The study involved a three-factorial arrangement of treatments in a Completely Random Design (CRD) with two types of *Aloe vera* (fresh and food grade) x four different concentration (0%, 15%, 25%, and 50%, v/v) x storage durations (0, 3, 6, 9, 12 and 15 day), with three replications. Data obtained were subjected to analysis of variance (ANOVA) using LSD test at $p \leq 0.05$ significant level for mean comparisons. Data were analysed using Statistical Analysis System (SAS version 9.4 Cary, NC, USA).

3. Result and discussion

3.1. Postharvest quality test of papaya coated with fresh A. vera gel

3.1.1. Weight loss / firmness/ soluble solids concentration

Table 1 also showed no significant different in the two types of *A. vera* gel coating for weight loss, firmness and soluble solid concentration (SSC). Weight loss in all treatments increased during storage but was better maintained by coated fruits. The weight loss continue to increase with increased storage time for both coated and uncoated fruits and the highest weight loss of 13.19% was recorded for uncoated fruits after 15 days of storage. Papaya fruits firmness reduced with increased storage time. Control fruits showed the highest rate of softening leading to high losses in firmness by the end of storage period as compared to *A. vera* coated fruits (Table 1). *A. vera* coated fruits were able to maintain some degree of firmness up to last day of storage especially for 50% *A. vera* coated fruits. Both fresh *A. vera* and food grade *A. vera* gel coated fruits were able to prevent the loss of weight, reduced firmness on papaya fruits up to three days of storage but uncoated fruits lose about 6.5% of weight and within three days. Soluble solids increased for both coated and uncoated fruits at the beginning of storage period then declined towards the end of storage (Table 1). The highest soluble solids of 10.50% was recorded for uncoated fruits the end of storage period. Soluble solids increased at the beginning of storage then reduced towards the end of storage.

Weight loss is a major determinant in the storage life and quality of papaya fruits (Ali et al., 2011a, 2011b). Seymour et al. (1993) reported that papaya fruits losses water mostly through the peel. The reason why *A. vera* coated fruits had less weight loss than uncoated fruits in this

Table 1
Means of Main and interaction effects of *A. vera* gel (fresh and food grade), concentrations (0%, 15%, 25% and 50%) and storage durations (0, 3, 6, 9, 12 and 15 days) on weight loss, firmness and soluble solids concentrations (SSC) of papaya fruits at room temperature (28 ± 2 °C).

Factors	Weight loss (%)	Firmness (N)	SSC (%)
Aloe vera (A)			
Fresh	5.60 a	36.86 a	9.46 a
Food	5.81 a	36.17 a	9.36 a
Concentration(C) (%)			
0	13.19 a	12.65 d	10.50 a
15	4.85 b	36.12 c	9.97 b
25	2.71 c	44.50 b	8.87 c
50	2.05 d	52.29 a	8.29 d
Storage duration(D) (Days)			
0	0.00 f	71.50 a	7.22 c
3	1.41 e	51.05 b	9.20 b
6	4.09 d	47.47 c	9.88 a
9	6.90 c	39.06 d	10.07 a
12	9.74 b	6.07 e	10.13 a
15	12.07 a	3.93 e	9.97 a
A*C	ns	ns	ns
A*D	ns	ns	ns
C*D	**	**	**
A*C*D	ns	ns	ns

Mean (n = 3) with different letter within the same column are significantly different at p ≤ 0.05 using LSD. Not Significant (ns).

present study could be as a result of *A. vera* gel acting as a barrier to moisture loss and papaya fruit respiration during the storage period (Seymour et al., 1993). Marpudi et al. (2011) also reported similar findings, stating that *A. vera* gel incorporated with papaya leaf extracts (1:1) were able to survive 15 days storage at temperature of 30 ± 3 °C but uncoated fruits decayed within 10 days of storage. In that particular study, he also reported that the marketability of the papaya fruits were found to be better for coated fruits. In this present study, the marketability of papaya fruits was better for coated fruits because uncoated fruits decayed with 12 days of storage. Similar result were reported by Brishti et al. (2014) where the weight loss of uncoated papaya fruits after 12 days storage at room temperature (25 − 29 °C and 68–70%) RH) was 22.5% as compared to 100% *A. vera* gel coated (7.93%). In addition *A. vera* gel coating was also able to act as a physical barrier to moisture loss and reduced dehydration and fruit shrivelling in strawberry fruits (Sogvar et al., 2016). *A. vera* gel was also found to be effective in controlling the loss of water from commodities including sweet cherry (Martínez-Romero et al., 2006) and peach and plum fruits (Guillén et al., 2013).

In this present study *A. vera* coated fruits were able to maintain some degree of firmness loss but uncoated decayed within 12 days. The loss of firmness in papaya fruits is an important factor in determining the edibility of the fruits and their postharvest shelf life. Pulp softening is believed to be directly affected by the production of ethylene during ripening (Brummell and Harpster, 2001). It has been reported that pulp softening might be as a result of significant changes in papaya cell wall pectin (Lazan et al., 1995; Manrique and Lajolo, 2004). Texture of papaya fruits is an important quality factor in consumer's acceptability of the fruit and it directly associated with papaya fruit firmness (Misir et al., 2014). Similar findings were reported by Brishti et al., (2014) where 100% *A. vera* coating was able to reduce papaya fruit firmness as compared to control fruits that decay after 12 days storage at room temperature (25 − 29 °C and 82–84% RH). In addition *A. vera* coating was also able to reduced firmness losses of table grades during cold storage (1 °C, 95% RH) compared to control that loss about 50% in firmness after 21 days of cold storage and 4 days at 20 °C (Misir et al., 2014).

One of the major component of soluble solids in papaya fruits is the sugar which gave a rough measurement of pulp sweetness. It is also one of the most appreciated characteristics of ripe papaya fruits (Gomez et al., 2002). A reduction in respiration rate slow down the fruit metabolites resulting in lower rate of increment in soluble solids of coated papaya fruits and delaying ripening process. High increased in soluble solids is believed to be as a result of high metabolism of fruits and senescence process (Hassanpour, 2015). This could be seen in this present study with uncoated fruits recording rapid increased soluble solid concentration as the fruits reached senescence. *A. vera* gel has been reported to modify internal atmosphere of storage fruits and vegetables thereby prolonging their shelf life (Valverde et al., 2005; Serrano et al., 2005b). The findings in this present study are supported by the reports of Embuscado and Huber, (2018) who reported that edible coating prevent moisture loss by controlling the exchange of important gases like oxygen, carbon dioxide and ethylene that are involved in respiration process. The prevention of moisture loss by controlling respiration in this present study slowed down the papaya fruit metabolism in coated fruits thereby delaying ripening and the rapid increased of soluble solids. In contrast the uncoated fruits were able to ripen normal registering the highest soluble solids (10.50%) at the end of storage period. It was also reported by Martínez-Romero et al. (2006) and Valverde et al. (2005) that sweet cherry fruits and table grapes coated with *A. vera* maintained high level of soluble solids at the end of the storage period because of the control in respiration process. Moreover it has been reported that the values of soluble solids in papaya ranges from 7.4 to 19.0 ° Brix and the soluble solid concentration in this study is within that range (Paull et al., 1997; Wall, 2006 and Zaman et al., 2006). *A. vera* coated fruits in this present study have higher level of soluble solids than uncoated at the end of the storage period

3.1.2. Titratable acidity (TA) /pH/Ascorbic acid (AA) and carotenoid content

There was no significant in the two types of *A. vera* for titratable acid, pH and ascorbic acid and carotenoid content after 15 days of storage. Titratable acidity in papaya fruits in this present study increased up to 9 day then began to decline towards the end of storage period (Table 2). Uncoated fruits recorded the lowest titratable of 0.58% while 50% concentration had 0.62% at the end of storage period (Table 2). There was an increased in the titratable acidity at the beginning of storage then a decline towards the end of storage period (Table 2). The highest titratable acidity was recorded for 25% concentration (0.66%) by the end of storage period. Titratable acidity increased during the beginning of storage then decline towards the end of storage period. The highest record of titratable acidity was on day 9 of storage (Table 2).

This findings are in line with Lazan et al. (1995) and Bron and Jacomino, (2006) in which TA in papaya fruits increased towards the ripening stage then a decrease. The rapid reduction in TA for uncoated fruits in this study during storage period could be as a result of the metabolic changes in fruits due to the reduction of organic acids because of high respiratory process (Wills and Widjanarko, 1995). *A. vera* coating helped to modify the internal atmosphere of coated fruits (Valverde et al., 2005) there by reducing the respiratory process (Serrano et al., 2005b). The high reduction of TA for uncoated fruits in this study could mean that they have a higher ripening rate than coated fruits.

Both 25% and 50% concentration recorded the highest pH of 6.04 after storage period. pH increase during storage but reduced towards the end of storage period (Table 2). The increase in pH in this study could be as a result of *A. vera* gel coating slowing down fruit ripening and senescence. The low pH of uncoated fruits in this study could be as a result of faster ripening which is supported by the report of (Wills et al. 1989) who stated that the low pH of uncoated fruits was because of the production of acids from metabolism of sugar at a faster rate as the fruit is ripening. The steady increased in pH of the coated fruits up to the last day of storage could be as a result of reduced respiration rate

Table 2
Main and interaction effects of *A. vera* gel (fresh and food grade), concentrations (0%, 15%, 25% and 50%) and storage durations (0, 3, 6, 9, 12 and 15 days) on titratable acidity (TA), pH, ascorbic acid (AA) and carotenoid content of papaya fruits at room temperature (28 ± 2 °C).

Factors	TA (%)	pH	Ascorbic acid (mg/100 g FW)	Carotenoid (mg/100 g FW)
Aloe vera (A)				
Fresh	0.63 a	5.90 a	49.36 a	3.36 a
Food	0.62 a	5.90 a	48.74 a	3.35 a
Concentration(C) (%)				
0	0.58 d	5.61 c	43.20 c	3.16 b
15	0.64 b	5.90 b	50.42 b	4.72 a
25	0.66 a	6.04 a	50.76 b	2.90 c
50	0.62 c	6.04 a	51.82 a	2.63 d
Storage duration (D) (Days)				
0	0.39 e	5.55 d	44.40 c	1.03 f
3	0.67 b	5.93 b	42 d.80	1.40 e
6	0.72 a	6.11 a	4 9.73 b	1.72 d
9	0.73 a	6 .10 a	56.17 a	4.86 b
12	0.65 c	5.88 c	56.53 a	4.73 c
15	0.58 d	5.84 c	44.67 c	6.39 a
A*C	ns	ns	ns	**
A*D	ns	ns	ns	ns
C*D	**	**	**	**
A*C*D	ns	ns	ns	**

Means within a factor and column followed by the same alphabet are not significant different at p = 0.05 by using LSD test. ** = highly significant at P = 0.01. ns = not significant.

Table 3
Main and interaction effects of *A. vera* gel (fresh and food grade), concentrations (0%, 15%, 25% and 50%) and storage durations (0, 3, 6, 9, 12 and 15 days) on total phenolic (TPC), total flavonoids contents (TFC) and DPPH radical scavenging activity of papaya fruits at room temperature (28 ± 2 °C).

Factors	TPC (mg/100 g FW	TFC (mg/100 g FW)	DPPH (% inhibition)
Aloe vera (A)			
Fresh	38.19 a	13.00 a	43.21 a
Food	37.93 a	12.88 a	42.92 a
Concentration(C) (%)			
0	34.16 c	12.53 bc	38.96 c
15	37.52 b	12.44 c	41.47 b
25	38.80 b	12.94 b	43.10 b
50	41.75 a	13.86 a	48.73 a
Storage duration(D) (Days)			
0	8.65 e	9.01 e	20.80 e
3	28.79 d	11.64 d	35.57 d
6	56.21 b	15.04 a	58.10 b
9	61.77 a	15.53 a b	65.21 a
12	42.61 c	12.64 a	44.80 c
15	30.33 d	9.00 e	33.92 d
A*C	ns	ns	ns
A*D	ns	ns	ns
C*D	**	**	**
A*C*D	ns	ns	ns

Means within a factor and column followed by the same alphabet are not significant different at P = 0.05 by using LSD test. ** = highly significant at P = 0.01. ns = not significant.

of coated fruits. This is supported by the statement of Mathooko, (2003) that a reduction in oxygen and increased in carbon dioxide could delay the rate of respiration in coated fruits.

The highest ascorbic acid was recorded on papaya fruits coated with 50% concentration and the lowest was on uncoated papaya fruits after the end of storage. The ascorbic acid content increased during storage

Table 4
Effect of *A. vera* gel coating on the disease incidence of papaya fruits after 15 days storage at room temperature.

Aloe vera	Concentration (%)	Disease Incidence (%)
Control	0	100
Fresh	15	13.33
	25	0
	50	0
Food	15	20
	25	0
	50	0

and the highest was recorded on day 12 of storage. The decreased in ascorbic acid started on day 15 of storage period. Ascorbic acid is minor constituent of fruits and vegetables but very important in human consumption as it forms 90% of dietary vitamin C needed by human body (Hernández-Muñoz et al., 2006). This finding is in line with the findings of Bron and Jacomino, (2006) and Wills and Widjanarko, (1995) who reported that ascorbic acid increase with increased ripening stages then showed a decline there after. In the same report he noted that the ascorbic acid in papaya fruits increased until the fruit developed yellow colour. He also stated that ascorbic acid in papaya increased about 20%–30% during ripening regardless of the maturity stages. The same could be seen in this present study as ascorbic acid increased with increase storage period then decline towards the end of storage period. In this present experiment, coated fruits showed a slower initial increase in ascorbic acid compared to uncoated fruits but at the end of storage they maintained higher ascorbic acid content than uncoated fruits. Mahmud et al. (2008) reported an increase in ascorbic acid content of papaya fruits dipped in calcium at the beginning of storage, then a declining trend when they reached senescence which are in line with the findings of the present study. In this present study, *A. vera* coated fruits were able maintained higher ascorbic acid content at the end of storage period.

Even though there was no significant interaction between the fresh *A. vera* and food grade *A. vera*, there was a significant interaction at p = 0.001 between the three factors(*A. vera*, concentration and storage days). 15% concentration recorded the highest carotenoids content of 4.72 mg/100 g after storage period and the lowest was on 50% concentration. The carotenoid content increased as papaya peel ripened. Carotenoid are natural organic pigment and lipophilic compound that found in the chromopasts of flowering plant kingdom and are important parameters in that they impart attractive colors such as yellow, orange and red (da Silva et al., 2014). This is in line with the report by Carrillo-Lopez and Yahia, (2009) that the content of carotenoid increase from zero to high levels in a few days because of maturation and ripening. Uncoated fruits in this study have a rapid increase in carotenoid because the uncoated fruits ripening faster than coated fruits. The ripening was delayed in coated fruits because of *A. vera* coating which resulted to a lower increment of carotenoid content during storage, but at the end of 15 day storage, coated fruits were able to maintain higher carotenoid content than uncoated. The uncoated fruits were unable to retain the carotenoid content in this present study because carotenoid are highly unsaturated and can be subjected to isomerization and oxidation. Oxidation degradation which is the main cause of major losses of carotenoids is depended upon the availability of oxygen and is stimulated by light, enzymes, metals and co-oxidation by lipid hydro peroxide (Rodríguez-Amaya, 1999). This could be the reason why uncoated fruits in this study lose carotenoid content rapidly because they lack the protection that was provided by *A. vera* gel coating in controlling oxidation degradation. There are varying factors that may be responsible for the different in the results among which could the sample preparation and extraction, cultivar or variety, climate/geographic location during their growth, maturity at harvest and temperature during storage (Alvarez-Parrilla et al., 2010). Maintaining

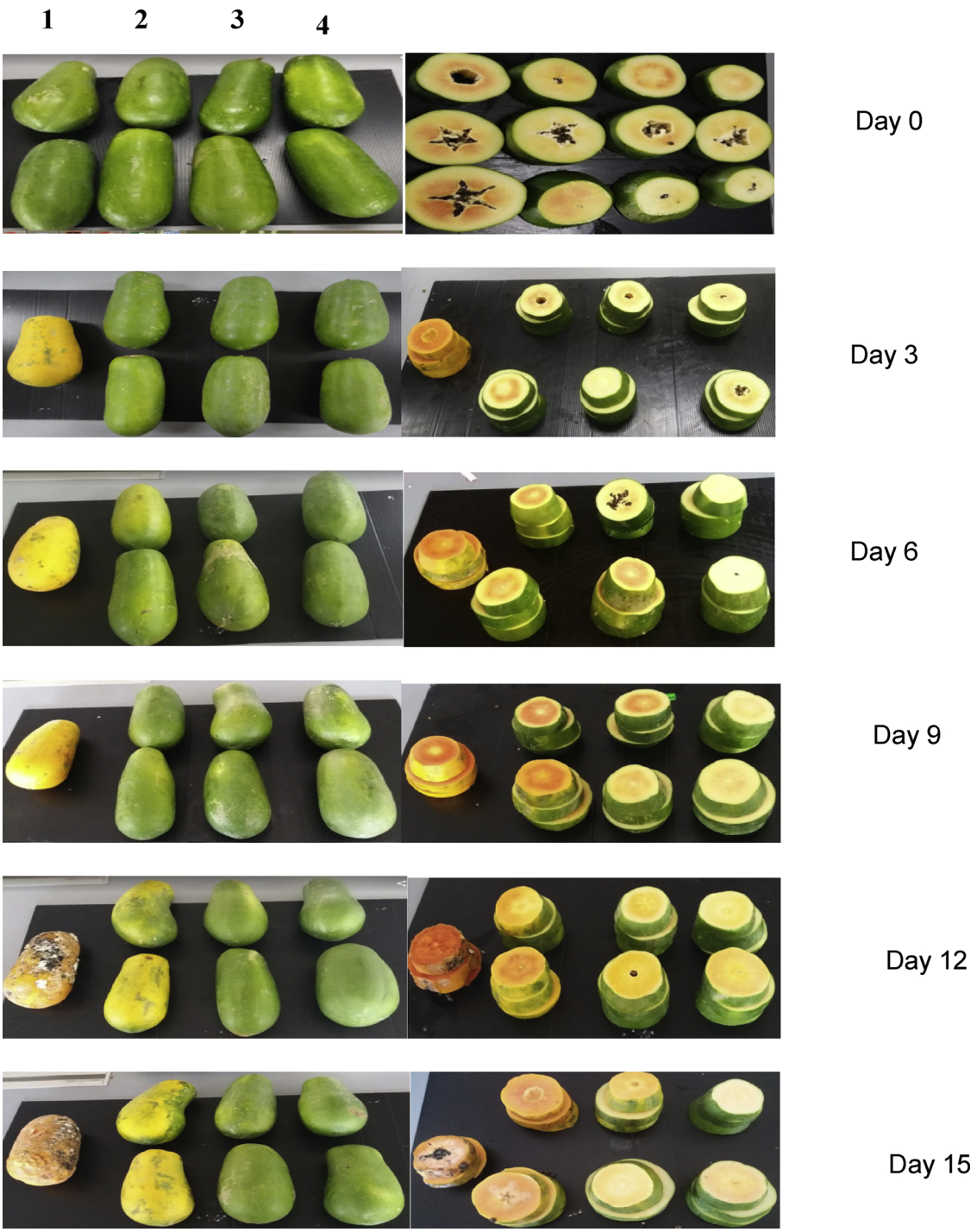

Fig. 1. Effect of fresh *A. vera* gel coating on the storage life of papaya fruits after 15 days of storage at room temperature (28 ± 2 °C). With papaya fruits on the left, 1 in the first column represents control. On the first (upper) horizontal row 2 = 15%, 3 = 25% and 4 = 50% for food grade *A. vera*. On the second (lower) horizontal row 2 = 15%, 3 = 25% and 4 = 50% for fresh *A. vera*. The arrangements are the same for the papaya slices on the right.

carotenoid content in papaya fruits is very important, as carotenoid are dietary bioactive compounds that provide protection against a number of degenerative conditions such as cardiovascular diseases, cancer, immunity and muscular degeneration among others (Sharoni et al., 2012; Meyers et al., 2014).

3.1.3. Total phenolic content/flavonoid content/DPPH scavenging activity

There was no significant different ($p < 0.05$), on papaya fruits coated with fresh *A. vera* and food grade *A. vera* for phenolic content, flavonoid content and DPPH scavenging activity after storage period. The highest phenolic content (41.75 mg/100 g) was recorded for 50% fresh *A. vera* coated papaya fruits on the day 9 of storage (Table 3). Even though the uncoated papaya fruit had a rapid increased in the phenolic content, they were unable to maintain it towards the end of storage. In contrast the coated papaya fruits were able to maintain phenolic content better than uncoated fruits and this could be as result of *A. vera* gel coating slowing down metabolism in coated fruits. The phenolic content of papaya fruits increase with increased storage period then declined towards the end of storage. The highest phenolic content was registered on the day 9 of storage period and the lowest was on the

first day of storage (Table 3). The present study is in line with reports by the following authors that phenolic content increased during fruit growth and then decreases as fruits ripening and during storage period (Chidtragool et al., 2011). Pablo et al. (2013) also reported an increase in phenolic content up to a maximum on gabiroba fruit under different storage temperature. It was reported by Addai et al. (2013) that the phenolic content of 50% methanolic papaya pulp extracts ranged from 11.20 to 60.40 mg GA/100 g. The higher amount of phenolic content in coated fruits in this study at the end of storage period means that *A. vera* gel coating was able to maintain the phenolic content of papaya fruit during storage.

The highest flavonoid content (13.86 mg/100 g) was observed on 50% concentration after 15 days storage. Flavonoid content of papaya fruits increased during the first days of storage then declined towards the end of storage period. The highest flavonoid content was recorded on day. The findings in this study are supported by the findings of Addai et al. (2013) in which the ripening stages 1, and 5 having TFC quercetin equivalent of 38.12 and 22.53 (mg QE/100 g) respectively during an experiment in which the antioxidant activities of papaya fruits under different ripening stages were determined during normal ripening. Flavonoids (TFC) have a powerful pharmacological activities which make them important in human health. They have a lot of health benefits like antioxidative activity, free radical scavenging capacity, coronary heart disease prevention, anticancer among other things (Hertog et al., 1993).

The DPPH activity of papaya fruits increased in the beginning of storage but declined at the end of storage period. The highest DPPH was on day 9 of storage and 50% concentration recorded the highest DPPH activity at the end of storage period (Table 3). The freshly DPPH solution had a purple colour and the purple colour disappears when it was mixed with extracts. This is because the antioxidant in the extracts scavenge free radicals through the conversion of DPPH to a stable DPPH-H form after accepting electron or hydrogen radical (Bakar et al., 2015). The DPPH assay is a simple and rapid method used to evaluate the ability of antioxidant to scavenge free radicals. The colour of solution differed between concentrations and became lighter in colour as concentration of papaya extracts increased in the solution indicating higher antioxidant of extracts as concentration increased. The colour of the samples turned from purple to yellow colour after 30 min except for control. The colour changed is as a result of antioxidant in the samples and it acts as preliminary detection of the presence of antioxidant activity. Addai et al. (2013), reported that the scavenging activity on DPPH is related to ripening stage and that the activity increased as a result of increasing ripening stages. Sancho et al. (2010) also reported that the antioxidant capacity assessed by oxygen radical absorbing capacity increased as fruit matured. In addition Sancho et al. (2010) reported that DPPH activity of ripe papaya to be 6.5 ± 7.12 (mg /ml) and unripe 4.3 ± 0.01 (mg/ml). This could be seen in the present study were the DPPH for both coated and uncoated fruits increased during the first days of storage period then decreased towards the end of storage period (Table 4).

3.1.4. Diseases incidence and severity

Disease incidence and severity was used as measured to indicate the microbial infection of papaya fruits during storage (Table 5.4). Uncoated fruits began to show signs of disease infection after day 3 of storage but *A. vera* coated fruits were able to suppress disease development up to last day of storage for 25 and 50% coated fruits and just slight infection sign on 15% coated fruits (Fig. 1). This could because of the anti-microbial potentially of *A. vera* in suppressing the growth of fungi and delaying ripening. There was 100% disease incidence for control fruits from day 12 to day 15 of storage. There was 0% disease incidence for 25% and 50% fresh *A. vera* and food grade *A. vera* coated fruits. The coated fruits were over ripe and rendered uneatable by the 12 day of storage. In an experiment conducted by Brishti et al. (2014), 100% diseases index was observed by control fruits but AG (*A. vera* gel) and PLEAG (papaya leaf extract plus *A. vera* gel) recorded 27% and 13% after 12 days of storage at (25–29 °C) and 82–84% relative humidity. Similar finding were also reported by Marpudi et al. (2011) who stated that control fruits decay within 10 days of storage at 30 ± 3 °C.

4. Conclusion

Postharvest loss is a major factors limiting the distribution of fruits and vegetables. In order to overcome this problem, strategies must be put in place to minimise this losses. With the disapproved use of fungicides because of the health hazards to humans, *A. vera* gel can be used as a substitute to control disease pathogens on papaya fruits and at the same time delay ripening. *A. vera* coating is a convenient and safe measure to use as it is biodegradable in nature. It is easily available in bulky quantity, easy to extract and sterilized and can solve the challenges faced by postharvest losses. *A. vera* gel coating maintained the quality and the nutritional content of papaya fruits after harvest in this present study by acting as a physical barrier to water loss and respiration thus reducing weight loss. There was no significant different between the fresh *A. vera* and food grade *A. vera* gel. Therefore *A. vera* gel can be used as coating to maintain the eating quality of papaya fruits until they reach consumers especially in the local market where less care is given to the quality of the fruit.

Acknowledgement

We thank the Government of the Republic of The Gambia for the fellowships provided to Therese K. Mendy. This project was funded by Putra Graduate Initiative (IPS) of Universiti Putra Malaysia.

References

Ali, A., Muhammad, M.T.M., Sijam, K., Siddiqui, Y., 2011a. Effect of chitosan coatings on the physicochemical characteristics of Eksotika II papaya (*Carica papaya L.*) fruit during cold storage. Food Chem. 124 (2), 620–626.
Abu Bakar, M.F., Mohamed, M., Rahmat, A., Fry, J., 2009. Phytochemicals and antioxidant activity of different parts of bambangan *Mangifera* pajang and tarap *Artocarpus odoratissimus*. Food Chem. 113, 479–483.
Addai, Z.R., Abdullah, A., Mutalib, S.A., 2013. Influence of ripening stages on antioxidant properties of papaya fruit (*Carica papaya L.*). AIP Conf. Proc. 1571, 696–701.
Ali, A., Muhammad, M.T.M., Sijam, K., Siddiqui, Y., 2011b. Effect of chitosan coatings on the physicochemical characteristics of Eksotika II papaya (*Carica papaya L.*) fruit during cold storage. Food Chem. 124 (2), 620–626.
Alvarez-Parrilla, L.A., Rosa, dela, Amarowicz, R., Shahidi, F., 2010. Antioxidant activity of fresh and processed Jalapeño and Serrano peppers. J. Agric. Food Chem. 59, 163–173.
Bakar, M.F.A., Karim, F.A., Perisamy, E., 2015. Comparison of phytochemicals and antioxidant properties of different fruit parts of selected artocarpus species from sabah, Malaysia. Sains Malaysia 44 (3), 355–363.
Benítez, M.S., Hersh, M.H., Vilgalys, R., Clark, J.S., 2013. Pathogen regulation of plant diversity via effective specialization. Trends Ecol. Evol. 28 (12), 705–711.
Bill, M., Sivakumar, D., Korsten, L., Thompson, A.K., 2014. The efficacy of combined application of edible coatings and thyme oil in inducing resistance components in avocado (*Persea Americana Mills*) against anthracnose during post-harvest storage. Crop Prot. 64, 159–167.
Brishti, F.H., Misir, J., Sarker, A., 2014. Effect of biopreservatives on storage life of papaya (*Carica papaya L.*). Int. J. Food Stud. 2, 126–136.
Bron, I.U., Jacomino, A.P., 2006. Ripening and quality of "Golden" papaya fruit harvested at different maturity stages. Braz. J. Plant Physiol. 18 (3), 389–396.
Brummell, D.A., Harpster, M.H., 2001. Cell wall metabolism in fruit softening and quality and its manipulation in transgenic plants. Plant Mol. Biol. 47, 311–340.
Carrillo-Lopez, A., Yahia, E.M., 2009. Qualitative and quantitative changes in carotenoids and phenolic compounds in tomato fruit during ripening. Acta Horticult. 877, 1303–1308.
Chidtragool, S., Ketsa, S., Bowen, J., Ferguson, I.B., van Doorn, W.G., 2011. Chilling injury in mango fruit peel: cultivar differences are related to the activity of phenylalanine ammonia lyase. Postharvest Biol. Technol. 62, 59–63.
da Silva, M.R., Galli, V., dos Anjos e Silva, S.D., Rombaldi, C.V., 2014. Carotenoid biosynthetic and catabolic pathways: Gene expression and carotenoid content in grains of maize landraces. Nutrition 6, 546–563.
Embuscado, M.E., Huber, K.C., 2009. Edible Films and Coatings for Food Applications 7. Springer, pp. 211–244.
Gomez, M.L., Lajolo, F.M., Cordenunsi, B.R., 2002. Evolution of soluble sugars during ripening of papaya fruits and its relation to sweet teste. J. Food Sci. 67, 442–447.
Gonzalez-Aguilar, G.A., Villa-Rodriguez, Ja., Ayala-Zavala, J.F., Yahia, E.M., 2010. Improvement of the antioxidant status of tropical fruits as a secondary response to

some postharvest treatments. Trends Food Sci. Technol. 21 (10), 475–482.
Guillén, F., Díaz-Mula, H.M., Zapata, P.J., Valero, D., Serrano, M., Castillo, S., Martínez-Romero, D., 2013. Aloe arborescens and Aloe vera gels as coatings in delaying postharvest ripening in peach and plum fruit. Postharvest Biol. Technol. 83, 54–57.
Hagenmaier, R.D., 2004. Fruit coatings containing ammonia instead of morpholine. Proc. Florida State Horticult. Soc. 117, 396–402.
Hassanpour, H., 2015. Effect of *Aloe vera* gel coating on antioxidant capacity, antioxidant enzyme activities and decay in raspberry fruit. Food Sci. Technol. 60 (1), 495–501.
Hernández-Muñoz, P., Almenar, E., Ocio, M.J., Gavara, R., 2006. Effect of calcium dips and chitosan coatings on postharvest life of strawberries (*Fragaria* × *ananassa*. Postharvest Biol. Technol. 39, 247–253.
Hertog, M.G.L., Hollman, P.C.H., Van de Putte, B., 1993. Content of potentially antic-arcinogenic flavonoids of tea infusions, wines and fruit juices. J. Agric. Food Chem. 41, 1242–1246.
Jhalegar, M.J., Sharma, R.R., Singh, D., 2014. Antifungal efficacy of botanicals against major postharvest pathogens of Kinnow mandarin and their use to maintain post-harvest quality. Fruits 69, 223–237.
Kader, A.A., 2005. Increasing food availability by reducing postharvest losses of fresh produce. Acta Hortic. 682, 2169–2175.
Khan, A., Rahman, M.M., Tania, M., Fatima, N., Xu, A., Chen, H., 2013. Antioxidative potential of *Duranta repens* (LINN.) fruits against H_2O_2 induced cell death in vitro. Afr. J. Tradit. Complement. Altern. Med. 10 (3), 436–441.
Lazan, H., Ali, Z.M., Selamat, M.K., 1995. ß-galactosidase, polygalacturonase and pecti-nesterase in differential softening and cell wall modification during papaya fruit ri-pening. Physiol. Plants 95, 106–112.
Mahmud, T.M.M., Al Eryani-Raqeeb, A., Syed Omar, S.R., Mohamed Zaki, A.R., Abdul-Rahman, A.E., 2008. Effects of different concentrations and applications of calcium on storage life and physicochemical characteristics of papaya (*Carica Papaya L.*). Am. J. Agric. Biol. Sci. 3 (3), 526–533.
Manrique, G.D., Lajolo, F.M., 2004. Cell-wall polysaccharide modifications during post-harvest ripening of papaya fruit (*Carica papaya*). Postharvest Biol. Technol. 33, 11–26.
Marpudi, S.L., Abirami, L.S.S., Pushkala, R., Srividya, N., 2011. Enhancement of storage life and quality maintenance of papaya fruits using Aloe vera based antimicrobial coating. Int. J. Biotechnol. 10 (1), 83–89.
Martínez-Romero, D., Alburquerque, N., Valverde, J.M., Guillén, F., Castillo, S., Valero, D., Serrano, M., 2006. Postharvest sweet cherry quality and safety maintenance by Aloe vera treatment: a new edible coating. Postharvest Biol. Technol. 39 (1), 93–100.
Martínez-Romero, D., Castillo, S., Guillén, F., Díaz-Mula, H.M., Zapata, P.J., Valero, D., Serrano, M., 2013. Aloe vera gel coating maintains quality and safety of ready-to-eat pomegranate arils. Postharvest Biol. Technol. 86, 107–112.
Mathooko, F.M., 2003. A comparative study of the response of tomato fruit to low tem-perature storage and modified atmosphere packaging. Afr. J. Food Agric. Nutr. Dev. 2, 34–41.
Meyers, K.J., Mares, J.A., Igo, R.P.Jr., Truitt, B., Liu, Z., Millen, A.E., 2014. Genetic evidence for role of carotenoids in age-related macular degeneration in the car-otenoids in age-related eye disease study (CAREDS). Invest. Ophthalmol. Vis. Sci. 55, 587–599.
Misir, J., Brishti, H., Fatema, H., Hoque, M.M., 2014. Aloe vera gel as a novel edible coating for fresh fruits: a review. Am. J. Food Sci. Technol. 2 (3), 93–97.
Musa, khalidhamid, Abdullah, A., Musa, K.H., Maskat, M.Y., Ghani, M.A., 2012. Antioxidant properties of three banana cultivars (*Musa acuminata* “Berangan”, “Mas” and “Raja”) extracts. Sains Malaysiana 41 (3), 319–324.
Pablo, E., Feres, A., Cardoso, L., Fante, C., Rosell, C.M., Valério, E., Vilas, D.B., 2013. Effect of postharvest temperature on the shelf life of gabiroba fruit (Campomanesia pubescens). Food Sci. Technol. 33 (4), 632–637.
Palou, L., Valencia-chamorro, S.A., Pérez-Gago, M.B., 2015. Antifungal Edible Coatings for Fresh Citrus Fruit: A Review. pp. 962–986.
Paull, R.E., Nishijima, W., Reyes, M., Cavaletto, C., 1997. Postharvest handling and losses during marketing of papaya (*Carica Papaya L.*). Postharvest Biol. Technol. 11, 165–179.
Prusky, D., 2011. Reduction of the incidence of postharvest quality losses, and future prospects. Int. Soc. Plant Pathol. 3 (4), 463–474.
Rahman, M.A., Mahmud, T.M.M., Kadir, J., Rahman, R.A., Begum, M.M., 2008. Major post-harvest fungal diseases of papaya cv.’ Sekaki’ in Selangor, Malaysia. J. Trop. Agric. Sci. 31 (1), 27–34.
Rodríguez-Amaya, D.B., 1999. Changes in carotenoids during processing and storage of foods. Archivos Latinoamericanos de Nutrición 49 (1), 38–47.
Saks, Y., Barkai-Golan, R., 1995. *Aloe vera* gel activity against plant pathogenic fungi. Postharvest Biol. Technol. 6 (1-2), 159–165.
Sancho, L.E.G., Yahia, E.M., Martínez-téllez, M.A., González-aguilar, G.A., 2010. Effect of maturity stage of papaya maradol on physiological and biochemical parameters. Am. J. Agric. Biol. Sci. 5 (2), 194–203.
Serrano, M., Martınez-Romero, D., Castillo, S., Guillen, F., Valero, D., 2005b. The use of antiflingal compounds improves the beneficial effect of MAP in sweet cherry storage. Innov. Food Sci. Emerg. Technol. 6, 115–123.
Seymour, G., Taylor, J., Tucker, G., 1993. Biochemistry of Fruit Ripening. Chapman and Hall Publishers, London, pp. 454.
Sharoni, Y., Linnewiel-Hermoni, K., Khanin, M., Salman, H., Veprik, A., Danilenko, M., Levy, J., 2012. Carotenoids and apocarotenoids in cellular signaling related to cancer: a review. Mol. Nutr. Food Res. 56, 259–269.
Sogvar, O.B., Koushesh Saba, M., Emamifar, A., 2016. Aloe vera and ascorbic acid coatings maintain postharvest quality and reduce microbial load of strawberry fruit. Postharvest Biol. Technol. 114, 29–35.
Soto-Zamora, G., Yahia, E.M., Brecht, J.K., Gardea, A., 2005. Effects of postharvest hot air treatment on the quality of “Rhapsody” tomato fruit. J. Food Quality 28 (5-6), 492–504.
UN Comtrade, 2012. http://comtrade.un.org/.
Valencia-Chamorro, S.A., Palou, L., Delŕio, M.A., Pérez-Gago, M.B., 2011. Antimicrobial edible films and coatings for fresh and minimally processed fruits and vegetables: a review. Crit. Rev. Food Sci. Nutr. 51 (9), 872–900.
Valverde, J.M., Valero, D., Martines romeo, D., 2005. Novel edible coating based on *Aloe vera* gel to maintain pistachio quality. J. Agric. Food Chem. 53 (3), 7807–7813.
Vieira, C., Thomas, O.P., Culioli, G., Genta-Jouve, G., Houlbreque, F., De Clerck, Gaubert J. Olivier, Payri, Claude E., 2016. Allelopathic interactions between the brown algal genus Lobophora (Dictyotales, Phaeophyceae) and scleractinian corals. Sci. Rep. 6, 18637.
Wall, M., 2006. Ascorbic acid, vitamin a, and mineral composition of banana (*Musa* sp.) and papaya (*Carica papaya*) cultivars grown in Hawaii. J. Food Compos. Anal. 19, 434–445.
Wills, R.B.H., Widjanarko, S.B., 1995. Changes in physiology, composition and sensory characteristics of Australian papaya during ripening. Aust. J. Exp. Agric. 35, 1173–1176.
Zaman, W., Biswas, S.K., Helal, M., Ibrahim, M., Hassan, P.J.A., 2006. Physico–chemical composition of four papaya varieties grown at Rajshahi. Biol. Sci. 14, 83–86.