The Effect of Coating with Hexanal Vapour on Quality Retention of Mango (*Mangifera indica* L.)

W.S.C. PERERA[1], I.G.N. HEWAJULIGE[2], S. WILSON WIJERATNAM[2] and R.H.M.K. RATNAYAKE[1]

[1]*Department of Horticulture and Landscape Gardening, Faculty of Agriculture and Plantation Management Wayamba University of Sri Lanka, Makandura, Gonawila (NWP), 60170, Sri Lanka*

[2]*Industrial Technology Institute (ITI), No.363, Bauddhaloka Mawatha, Colombo 07, 00700, Sri Lanka*

ABSTRACT

Postharvest diseases such as anthracnose and stem end rot are a major cause of yield loss in mango. Biologically active volatiles can delay the postharvest decay of fruits. Therefore, a study was conducted to find out the efficacy of Hexanal vapour treatment to improve the keeping quality of Tom JC mango fruits. The fruits were subjected to Hexanal vapour at concentrations of 0 (Control), 300, 600 and 900 µL L^{-1} for four hours followed by storage at ambient conditions or cool conditions. Fruit quality attributes were assessed after 7, 14, and 21 days after storage. Treatment with 600 µL L^{-1} Hexanal showed the ability to delay the ripening process in terms of lower total soluble solid contents and higher titratable acidity levels. In addition, it resulted marketable fruits with no disease incidence up to seven days in ambient storage and up to 14 days storage at 13.5 ± 2 °C.

KEYWORDS: Coating, Hexanal, *Mangifera indica*, Mango, Shelf life

INTRODUCTION

Postharvest decay caused by pathogens results in substantial quality loss of fruits and vegetables. Many infections occur during the growing season, with symptoms developing during postharvest storage (Eckert and Ogawa, 1985). Postharvest disease control has become more challenging due to fungicide resistance, availability of limited number of registered fungicides, and the consumers' desire for organically produced high quality products. Alternatives to chemical control of postharvest decay on different fruits include heat treatment (Paliath *et al*, 2007), ozone treatment (Kim *et al.*, 1999), high CO_2 treatment (De Vries-Paterson *et al.*, 1991), gamma irradiation and biocontrol agents (Paliath *et al.*, 2007).

Interest in the use of natural volatiles to prevent fungal growth has also increased markedly (Wang and Buta, 2003). Biologically active volatiles, such as (E)-2-hexenal, have been reported to reduce postharvest decay in fruits (Fallik *et al.*, 1998). Six-carbon aldehydes, with or without double bonds, are dominant compounds released by plant material through the lipoxygenase pathway after tissue disruption (Vick and Zimmermann, 1987). Most of these plant volatiles are generally recognized as safe (GRAS; Newberne *et al.*, 2000) compounds.

Hexanal is a naturally occurring volatile C6 aliphatic aldehyde. The molecular formula is $C_6H_{12}O$ and molecular weight is 100.15888 g mol^{-1} (Paliath *et al.*, 2007). It is a colourless liquid with a pungent odour. Hexanal is less dense than water and insoluble in water. It is highly soluble in ethanol or ethyl ether and soluble in acetone and benzene. Hexanal is produced naturally during lipid peroxidation, and has the characteristic green flavour produced during wounding processes in green plants (Palianth *et al.*, 2007). Hexanal coating inhibited spore germination of *Penicillium exapansum*, reduced lesion expansion and enhanced aroma biosynthesis in apples (Fan *et al.*, 2006).

Mango (Family Anacardeaceae) is a popular fresh fruit in local markets (Anon, 2006). In addition, foreign exchange could be earned by exporting both fresh and processed mango products. Annual mango production in 2013 was 134,369 mt while only 34 mt was exported as fresh fruits (Anon, 2014). Tom JC (TJC) mango, with an average fruit weight of 600 g, has a golden orange colour unblemished skin. The popularity is due to its desirable flavour, low fibre content, smooth flesh and small seed (*i.e.* more flesh; Anon, 2016).

Postharvest losses of mango in tropical countries range from 15% in the dry season to 70% in the rainy season, mostly because of poor storage conditions and anthracnose disease (Anon, 2016). Anthracnose is the most prevalent postharvest disease in humid tropical climates. Infection occurs in leaves, stems, young flowers and fruits. Sunken black spots appear on the surface of the fruit during ripening. Stem-end rot is also a common postharvest disease of mangoes, resulting in sporadic losses of up to 20% (Johnson *et al.*, 1995). In the light of increased consumer acceptance for organically grown produce, controlling these diseases without synthetic fungicides will be advantageous. This study was, therefore, conducted to find out the efficacy of coating with Hexanal for improving the keeping quality of mango fruits.

MATERIALS AND METHODS

Location and Sample Collection

The research was conducted at Food Technology Section of the Industrial Technology Institute, Colombo 07, Sri Lanka from January to May 2016.

Fruits of mango variety TJC were harvested at optimum maturity 12 weeks after flowering (mature green stage with sign of light yellow) from commercial orchards of Ellawala Horticulture (Pvt.) Ltd., Dambulla (LCDZ) and Nelna Agri Development (Pvt.) Ltd., Ranwala, Meethirigala (LCWZ), Sri Lanka. Fruits with uniform size and shape, without deforms and apparent disease symptoms were selected.

Hexanal Vapour Treatment

The fruits were subjected to four Hexanal concentrations: 0 $\mu L\ L^{-1}$ (Control), 300 $\mu L\ L^{-1}$, 600 $\mu L\ L^{-1}$ and 900 $\mu L\ L^{-1}$ (Pers. Communication, Tamil Nadu Agriculture University, India), each for a duration of 4 h (Atthanayake, 2015).

Each treatment contained 15 individual fruits as replicates. The fruits were arranged in an air tight, stainless steel vapour chamber. Hexanal vapour was generated by evaporating the required amount of liquid Hexanal. The fruits which were exposed to Hexanal vapour for 4 h were then packed in corrugated cardboard boxes and stored under ambient temperature of 25±2 °C and RH of 75±2% in an air conditioned store room. The control, fruits were held in the vapour chamber under the same conditions minus the Hexanal vapour. The best Hexanal vapour concentration which resulted in the lowest disease incidence was then selected to treat fruits in the second step. The treated fruits were stored at 13.5±2 °C and 75±2% RH. The following parameters were recorded at 7, 8 and 12 days after treatment in fruits stored under ambient conditions and at 7, 14 and 21 days in fruits under cold storage. Five fruits per treatment were used at a time.

Fruit Colour

The skin and flesh colour of fruits were recorded using Munsell Colour Chart for plant tissues.

Fruit Firmness

Both skin and flesh firmness (kg^{-1}) of fruits were measured using fruit texture analyzer (LABSCO-D360, Friedberg/H- Germany) by compression to a depth of 10 mm.

Total Soluble Solids (TSS) Content

The flesh was placed on a muslin cloth and was squeezed to obtain juice. The TSS content (Brix value) was obtained using a handheld refractometer (Ranganna, 1986).

Titratable Acidity (TA) and pH

Ten grams sample of fruit pulp was mixed with 40 mL of distilled water to make a solution. A sample of 5 mL was titrated against 0.1 N NaOH in the presence of phenolphthalein indicator. Titratable acidity was calculated using the equation:

$$Titratable\ acidity = \frac{T \times V1 \times N \times E}{V2 \times W \times 1000} \times 100$$

where, E-Equivalent weight of acid; N-Normality of alkali; T- Volume of titre; V1-Volume made up; V2-Volume of sample taken for estimation; W-Weight or volume of sample taken (Ranganna, 1986).

Acidity of the prepared solutions was also measured using a portable pH meter (Cyber Scan series 600, EUTECH Instruments, Singapore).

Percentage Weight Loss

Initial fresh weight and weight of fruits after the storage period were recorded and the percentage loss of fresh weight was calculated:

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

Percentage Disease Incidence

Percentage Disease Incidence was recorded after different storage periods by visual estimation of the extent of symptoms on each fruit and expressed as a percentage of the total surface area.

Sensory Evaluation

A panel of ten trained taste panellists carried out the acceptance tests for fruits after seven days of storage. The panellists were asked to indicate their preferences using a Nine Point Hedonic scale for appearance, colour of flesh and skin, odour, texture, taste and overall acceptability.

Scale of Acceptance was: Dislike extremely (1), Dislike very much (2), Dislike moderately (3), Dislike slightly (4), Neither like nor dislike (5), Like slightly (6), Like moderately (7), Like very much (8), Like extremely (9).

Experimental Design and Statistical Analysis

The treatments were arranged in completely randomized design (CRD). There were four treatments with 15 individual fruits as replicates. The data were statistically analyzed using SPSS Statistical software (Version 21).

RESULTS AND DISCUSSION

Fruit Colour and Firmness

The colour of fruit skin plays a major role in marketability and the acceptability. If the fruit skin is free of deforms, aberrations, and uniform in colour, the acceptability and market value is increased. Colour change is a physical sign of ripening. The colour of both skin and flesh changed with time. The Hue value changed in skin from 5Y to 7.5YR while the flesh colour changed from 2.5Y to 5YR in all the treatments after seven days of ambient storage (Table 1). The Hue value of the skin colour changed from 5Y to 7.5YR in the 0 µL L^{-1} treatment while the Hue value of flesh colour changed from 2.5Y to 5YR in low temperature storage within seven days (Table 2). However, the change of Hue of 600 µL L^{-1} treatment was from 5Y to 2.5Y only within seven days in low temperature storage. The Hue values of skin and flesh colour of fruits were same in both treatments after 14 days of low temperature storage. (Table 2). Therefore, the temperature has also effect on fruit ripening. The colour should be measured using a digital chromometer as naked eye could not identify small colour changes.

When fruits were stored under ambient conditions for seven days, skin firmness decreased from 17.52 kg^{-1} (day 0) to 2.94 kg^{-1} in the control. However, there were no significant differences in skin firmness among the Hexanal treated fruits and the control on day seven (Table 1). Nonetheless, fruits treated with 600 µL L^{-1} Hexanal had a significantly higher flesh firmness (1.39 kg^{-1}). A harder flesh indicates that the ripening process has delayed in those fruits resulting in a relatively longer shelf life.

When fruits were stored under cool condition, fruits treated with 600 µL L^{-1} Hexanal showed a significantly higher skin firmness both on day seven (5.2 kg^{-1}) and day 14 (3.2 kg^{-1}) compared to non-treated fruits (4.0 and 2.4 kg^{-1}, correspondingly). Flesh firmness was, however, not significantly different from that of the control on both days (Table 2).

Internal Fruit Quality Attributes

Both the 300 µL L^{-1} and 600 µL L^{-1} Hexanal treatments resulted in significantly lower TSS contents compared to the control after seven days of storage under ambient conditions (Table 1).

Similarly, after seven days of low temperature storage at 13.5±2 °C and 75±2% RH , 600 µL L^{-1} Hexanal treated fruits showed a significantly lower TSS content (15.1%) compared to the control (17.8%) indicating a slower ripening of the treated fruits (Table 2).

Both TA and pH are related to the sugar content and ripening. Organic acids turn into sugars during the ripening process. Although there was no significant difference between treatments, 600 µL L^{-1} Hexanal showed the higher TA on day seven both in ambient storage (0.280; Table 1) and low temperature storage (0.274; Table 2). Moreover, the level of TA was significantly higher on day 14 when storage at 13.5±2 °C and 75±2% RH (0.226) compared to the control (0.16; Table 2). These results indicate that 600 µL L^{-1} Hexanal treatment has delayed the internal ripening process. It is reported that coating of fruits will disturb the air exchange of fruit and, thereby, decelerate the chemical changes associated with ripening (Palliath *et al.*, 2007).

Percentage Weight Loss

The lowest weight loss was recorded by 600 µL L^{-1} Hexanal treatment after seven days in ambient storage (5.5%) and 13.5±2 °C storage (2.4%) although the differences with the control were not significant (Table 1 and 2). Post-harvest weight loss is mainly associated with water loss. A coating could act as a barrier for loss of water (Palianth *et al.*, 2007).

Percentage Disease Incidence (PDI)

There were no disease symptoms recorded on fruits which were treated with 600 µL L^{-1} Hexanal, after seven days of ambient storage while the control showed 11% PDI (Table 1). When stored at 13.5±2 °C, the 600 µL L^{-1} treatment resulted in 5% PDI after 14 days whereas the control showed 5% after seven days and 7.5% PDI after 14 days (Table 2). Therefore, in comparison to other treatments, 600 µL L^{-1} displayed the best marketable fruits.

Sensory Attributes

There was no significant difference between median values among the treatments on the preferences on day seven (Tables 3 and 4). After considering all the factors, 600 µL L^{-1} concentration of Hexanal was chosen as the best treatment.

Table 1. Quality attributes of fruits after seven days of storage in ambient conditions at 25±2 °C and 75±2% relative humidity

Hexanal Treatment	Firmness (kg^{-1})		TSS (%)	TA (%)	pH	Percentage Wt. loss (%)	Colour change		Disease incidence (%)
	Skin	Flesh					Skin	Flesh	
Initial (Day 0)	17.52	9.076	6.60	0.312	3.620	-	5Y/8/8	2.5Y/8/8	-
0 μL L^{-1}	2.94^{a}	0.418^{a}	15.6^{a}	0.248^{a}	5.122^{a}	6.01^{a}	7.5YR/7/10	5YR/7/10	11
300 μL L^{-1}	3.22^{a}	0.346^{a}	13.4^{b}	0.240^{a}	5.064^{a}	8.47^{b}	7.5YR/7/10	5YR/7/10	2.5
600 μL L^{-1}	3.24^{a}	1.390^{b}	13.0^{b}	0.280^{a}	5.174^{a}	5.55^{a}	7.5YR/7/10	5YR/7/10	0
900 μL L^{-1}	3.20^{a}	0.392^{a}	15.0^{a}	0.240^{a}	5.186^{a}	5.87^{a}	7.5YR/7/10	5YR/7/10	2.5

The means in a column with same superscript letters are not significantly different at 0.05 level; TSS- Total soluble solids, TA- Total acidity, Wt loss- Weight loss

Table 2. Quality attributes of mango fruits after seven and 14 days when stored at 13.5±2 °C and 75±2% relative humidity

Hexanal Treatment	Storage period (Days)	Firmness (kg^{-1})		TSS (%)	TA (%)	pH	Percentage Wt. loss	Colour change		Disease Incidence (%)
		Skin	Flesh					Skin	Flesh	
Initial (Day 0)	0	14.446	4.874	9.40	0.37	3.67	-	5Y/8/12	2.5Y/8/10	-
0 μL L^{-1}	7	4.045^{a}	1.002^{a}	17.8^{a}	0.22^{a}	4.14^{a}	2.92^{a}	7.5YR/7/10	5YR/7/10	5%
	14	2.360^{a}	0.793^{a}	16.8^{a}	0.16^{a}	4.55^{a}	4.98^{a}	7.5YR/8/10	7.5YR/7/8	7.5%
600 μL L^{-1}	7	5.210^{b}	0.918^{a}	15.1^{b}	0.27^{a}	4.05^{a}	2.41^{a}	2.5Y/8/10	2.5Y/8/10	0
	14	3.170^{b}	0.703^{a}	16.2^{a}	0.22^{b}	4.29^{a}	5.43^{a}	7.5YR/7/8	7.5YR/8/6	5%

The means in a column with same superscript letters are not significantly different at 0.05 level; TSS- Total soluble solids, TA- Total acidity, Wt loss- Weight loss

Table 3. Sensory attributes of fruits after seven days of storage in ambient conditions at 25±2 °C and 75±2% relative humidity

Hexanal treatment (μL L^{-1})	Storage period	Appearance	Colour		Odour	Texture	Taste	Overall Acceptance
			Skin	Flesh				
0	5	4	5	6.5	7	7	6.5	5
300	5.5	4.5	6	5.5	6.5	5	5.5	5.5
600	5.5	5	6.5	6.5	6.5	6	6	5.5
900	4.5	4.5	5	5.5	5.5	5	5	4.5

Median values are not significantly different at 0.05 level Scale of Acceptance ; Dislike extremely (1), Dislike very much (2), Dislike moderately (3), Dislike slightly (4), Neither like nor dislike (5), Like slightly (6), Like moderately (7), Like very much (8), Like extremely (9)

Table 4. Sensory attributes of fruits after 7 and 14 days of storage in cold conditions at 13.5±2 °C and 75±2% relative humidity

Hexanal Treatment (μL L^{-1})	Appearance	Colour		Odour	Texture	Taste	Overall Acceptance
		Skin	Flesh				
0	7.0	7.0	7.0	7.5	7.0	7.0	7.0
600	7.5	7.0	7.5	7.5	7.0	7.0	7.0

Median values are not significantly different at 0.05 level. Scale of Acceptance ; Dislike extremely (1), Dislike very much (2), Dislike moderately (3), Dislike slightly (4), Neither like nor dislike (5), Like slightly (6), Like moderately (7), Like very much (8), Like extremely (9).

CONCLUSIONS

Treating TJC mangoes with 600 μL L^{-1} Hexanal delayed ripening, minimized the disease incidence of anthracnose and stem end rot, and improved the marketability of fruits. The lower (300 μL L^{-1}) or higher (900 μL L^{-1}) concentrations were ineffective.

When treated with 600 μL L^{-1} Hexanal vapour, fruits could be stored at ambient temperature for seven days and at 13.5±2 °C storage for 14 days with marketable quality. The temperature was also observed to have an effect on quality retention of fruits. Further research is recommended to affirm the results and to optimize the Hexanal concentration.

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