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Effect of Pre-cooling Combined with Exogenous Oxalic Acid Application on Storage Quality of Mango (*Mangifera indica*)

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Abstract

This study was undertaken to determine low cost treatments that may be readily adoptable by local producers and exporters to extend the storage life of mango. The experiment was conducted for the var. 'Karuthacolomban'. The fruits were harvested 13 weeks after flowering. Just after harvesting, the half of the lots of selected fruits were subjected to pre-cooling by using hydro-pre-cooling (water temperature 15ºC) till the fruit temperature reaches to 13-15ºC and remaining was kept without pre-cooling. The pre-cooled and non pre-cooled fruits were dipped in 5% sodium bicarbonate solution for 10 min followed by 6 and 8 ppm oxalic acid solution for 10 min, air-dried and the treated fruits were stored at ambient (28-30ºC, 65-70% RH) and low temperature (13±2ºC, 55-60% RH) conditions. The fruits from each treatment were observed to evaluate the physiological weight loss, fruit firmness, total soluble solids, titratable acidity, pH and rate of respiration. The results revealed that fruits dipped in 5% sodium bicarbonate solution followed by 8 ppm oxalic acid application along with pre-cooling was the most effective for extension of storage life of fresh mango up to 12 and 24 days under ambient (28-30ºC, 65-70% RH) and low temperature storage (13±2ºC, 55-60% RH), respectively. Fruits stored under low temperature exhibited better retention of all physiological and biochemical characteristics than the same treatments during ambient storage.

Keywords

Pre-cooling
Oxalic acid
Sodium bicarbonate
Mango
Storage

INTRODUCTION

Mangoes (*Mangifera indica*) are produced in over 90 countries worldwide and Asia accounts for approximately 77% of global mango production. In 2005, world production of mango was estimated at 28.51 million metric tons (FAO, 2007). The world production of mango is over 15 million tons per annum. Though the demand of mango is high in the export market, there is a limited supply mainly due to lack of established technologies on postharvest handling operations. Various systems have been developed to take produce from the field to the consumer and the selection of particular method depends on several factors, including perishability and value of the crop. Mango fruit (*Mangifera indica*) suffer from having a brief shelf-life and postharvest deterioration problems as a result of postharvest disease, insect infestation and over ripening (Mitra et al., 1997).

Pre-cooling is a process of removing field heat from freshly harvested produce in a sufficient time to prevent spoilage and maintenance of pre-harvest freshness and flavor (Anon.1982). Usually most produce are pre-cooled before loading for transport to market or before short or long term storage. Prompt cooling after harvest is important for most fruit crop since a product

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may deteriorate as much in one hour at 32°C as 24 hr at 10°C (Guillo, 1960). Pre-cooling also reduces bruising damage from vibration during transits, and reduce the amount of refrigeration required during transport. Produce can be cooled either by means of cool air, cool water, and direct contact with ice or by evaporation of water from the produce (evaporative cooling, vacuum cooling) (Guillo, 1960, Zheng, et al., 1999). Several kinds of edible chemicals, acidulants and reducing agents are in use for the extension of postharvest life of fruits. Oxalic acid being an organic acid received much attention for food preservation (Zheng et al., 2007). Oxalic acid (OA) is not only a potential anti-browning agent, postharvest application to vegetables (Castaner et al., 1997), banana slices (Yoruk et al., 2002) and litchi fruits (Zheng et al., 2005), has also been proved as a natural antioxidant in the natural and artificial safeguarding of oxidized materials from deterioration (Kayashima and Katayama, 2002). The application of oxalic acid has already been shown to induce systematic resistance against diseases caused by bacteria, fungi or viruses (Mucharroman, 1991) to affect anti-oxidant systems in plants (Malencic et al., 2004). Furthermore, oxalic acid is considered to be a natural anti-oxidant for artificial preservation of oxidized materials (Kayashima and Katayama, 2002) and is under consideration to replace synthetic alternatives to minimize the risk of residues in bee products (Moosbeckhofer et al., 2003). In previous works, it is reported that oxalic acid treatment in combination with controlled atmosphere (6% CO_2 + 2% O_2) storage at 14±1°C, can extend the storage life and decrease the incidence of decay in mango fruits (Zheng et al., 2005).

Also some extension of shelf-life has been demonstrated using controlled atmospheric storage (Bender et al., 1972) however, CO_2 injury, increased ethanol production, and flavor problems due to anaerobic respiration have been reported. Therefore, development of such pre-treatment together with pre-cooling and low temperature storage would greatly benefit the producers and retailers to improve their income by improving the quality and the reduction of quantitative loss of produce. The objective of present study was to identify low cost treatments that may be readily adoptable by local producers to extend the shelf-life of mango.

Materials and Methods

Mango fruits were procured from a commercial orchard situated at Anuradhapura district in North Central part. The fruits were harvested 13 weeks after flowering and just after harvesting, the fruits were divided into two lots and one was subjected to pre-cooling by using hydro-pre-cooling (water temperature 15ºC) till the fruit temperature reaches to 13-15ºC. Then, the pre-cooled and without pre-cooled fruits were dipped in 5% sodium bicarbonate solution for 10 min followed by 6 and 8 ppm oxalic acid solution for 10 min, air-dried and then, the treated fruits were stored at ambient temperature (28-30°C) and low temperature storage (13±2ºC) for 12 and 24 days, respectively.

Measurement of physico-chemical parameters

The fruits from each treatment were observed to evaluate the physiological weight loss. Weight loss was measured by the difference between the initial and final weight of each replication. The loss in weight during storage was expressed as % of initial weight. Fruit firmness was measured by using a digital fruit firmness tester (TURONI, model 53205). Readings were taken in three positions of fruit area, averaged and recorded in Newton (N). Total soluble solids (TSS) content of the juice was measured using a hand refractometer (ATAGO, model: HR-5) by squeezing the juice with cotton wool on to the cleaned sensor and reading was reported as ºBrix. Measurements were taken from three pieces

of the ventral shoulder, middle and back of the fruit slice. pH of a known amount of fresh and homogenized fruit juice in a 100 ml beaker was recorded with a digital pH meter (Thermoorion, model 230A+) after standardizing the pH meter with buffer solutions of pH 4 and 7 (Ranganna, 1986). Titratable acidity (TA) was expressed as a percentage (%) of citric acid. To determine the titratable acidity, known weight of fruit sample was crushed and taken into 250 ml volumetric flask and the volume was made up. After filtration, 10 ml of filtrate was titrated against 0.1 N NaOH using phenolphthalein as indicator (Horwitz, 1980). Respiration rate was measured by the closed method described by Kader *et al*., (1989) where, gas tight glass box of 1 L volume were filled with approximately 1 kg of mangoes per box. The accumulation of CO_2 inside the box was measured after a period of 30 min. Sample of ml of head space gas were taken from each box with a calibrated syringe and CO_2 production monitored in gas analyzer (Varian cp- 3800, P.O. Box 8033, 43330 EA, MIDDELBURG, The Netherlands)

Statistical analysis

The treatment effect was assessed by Statistical Analysis System (SAS) and mean separation was done by using Least Significant Difference (LSD) at α= 0.05 in two factor factorial Completely Randomized Design (CRD).

Table 1 Effect of post-harvest treatment on physiological weight loss (%) and fruit firmness (N) of mango at ambient storage (28-30ºC)

Treatments	Physiological loss in weight (%)			Fruit firmness (N)		
	Days of storage			Days of storage		
	4	8	12	4	8	12
6ppm OA-PC	5.9	4.5	4.7	49.5	27.8	15.3
6ppm OA-WPC	5.9	4.0	4.8	37.3	14.8	9.7
8ppm OA-PC	5.7	4.1	5.2	36.0	21.1	14.1
8ppm OA-WPC	6.8	4.9	6.1	26.5	19.4	10.6
Control	7.2	6.3	7.9	27.3	10.4	4.4

CD0.05 T= 0.16, S= 0.12, T*S= 0.28

CD0.05 T= 0.17, S= 0.13, T*S= 0.29 OA- oxalic acid, PC- pre cooled, WPC- without pre cooled

Table 2 Effect of post-harvest treatment on physiological weight loss (%) and fruit firmness (N) of mango at low temperature (13±2ºC)

Treatments	Physiological loss in weight (%)						Fruit firmness (N)					
	Days of storage						Days of storage					
	4	8	2	16	20	24	4	8	12	16	20	24
6ppm OA-PC	0.3	1.3	1.3	3.3	3.4	3.6	54.4	36.2	23.5	23.2	22.6	13.9
6ppm OA-WPC	0.9	2.0	2.8	3.9	3.9	4.0	43.3	33.5	29.0	26.5	22.9	9.9
8ppm OA-PC	0.3	2.0	2.2	3.0	3.0	3.0	46.5	32.3	22.4	21.5	18.3	8.7
8ppm OA-WPC	2.9	2.0	2.1	2.3	4.6	7.0	35.3	31.4	28.8	19.4	18.4	13.6
Control	2.5	2.9	3.0	3.9	6.9	8.8	31.5	20.4	18.3	14.2	7.6	2.4

CD0.05 T= 0.11, S= 0.11, T*S= 0.26

CD0.05 T= 0.70, S= 0.77, T*S= 1.72 OA- oxalic acid, PC- pre cooled, WPC- without pre cooled

Table 3 Effect of post-harvest treatment on titratable acidity (%) and pH of mango at ambient storage (28-30ºC)

Treatments	Titratable acidity (%)			pH		
	Days of storage			Days of storage		
	4	8	12	4	8	12
6ppm OA-PC	2.1	1.3	0.1	3.2	4.1	4.4
6ppm OA-WPC	2.1	1.2	0.1	3.2	4.5	5.1
8ppm OA-PC	2.0	1.1	0.2	3.2	3.4	4.8
8ppm OA-WPC	2.0	1.2	0.3	3.4	4.7	5.1
Control	1.2	0.9	0.1	3.4	4.0	5.4

CD0.05 T= 0.09, S= 0.07, T*S= 0.15

CD0.05 T= 0.08, S= 0.06, T*S= 0.13 OA- oxalic acid, PC- pre cooled, WPC- without pre cooled

Table 4 Effect of post-harvest treatment on titratable acidity (%) and pH of mango at low temperature (13±2ºC)

Treatments	Titratable acidity (%)						pH					
	Days of storage						Days of storage					
	4	8	12	16	20	24	4	8	12	16	20	24
6ppm OA-PC	2.9	2.7	2.5	2.3	2.1	1.1	3.2	3.2	3.3	3.3	3.4	3.5
6ppm OA-WPC	2.4	2.3	2.2	2.0	1.8	1.0	3.3	3.4	3.4	3.5	3.5	3.8
8ppm OA-PC	2.2	2.0	1.8	1.7	1.7	1.0	3.4	3.5	3.5	3.6	3.6	3.6
8ppm OA-WPC	2.0	1.9	1.7	1.4	1.3	1.0	3.5	3.6	3.6	3.7	3.8	3.8
Control	1.9	1.6	1.5	1.0	0.8	0.4	3.6	3.7	3.9	4.0	4.5	4.7

CD0.05 T= 0.02, S= 0.02, T*S= 0.05

CD0.05 T= 0.02, S= 0.25, T*S= 0.06 OA- oxalic acid, PC- pre cooled, WPC- without pre cooled

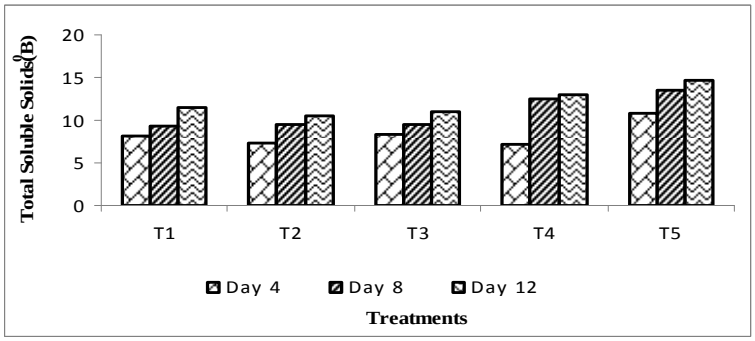

Fig. 1. Effect of post-harvest treatment on total soluble solids content (°B) of mango at ambient storage (28-30°C), T_1: 6 ppm oxalic acid + Pre-cooling; T_2: 6 ppm oxalic acid (without pre-cool); T_3: 8 ppm oxalic acid + Pre-cooling; T_4: 8 ppm oxalic acid (without pre-cool); T_5: Control

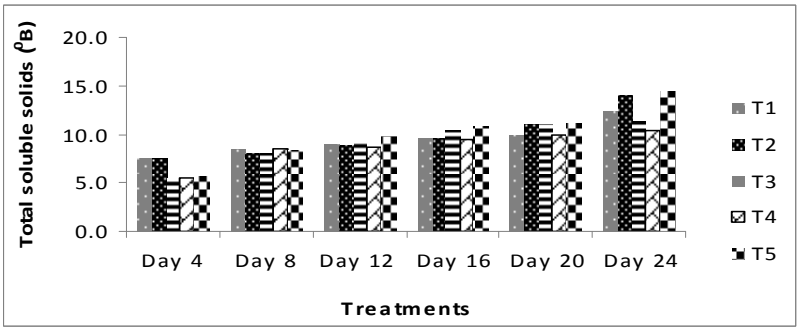

Fig. 2. Effect of post-harvest treatment on total soluble solids content (B°) of mango at low temperature (13±2°C), T_1: 6 ppm oxalic acid + Pre-cooling; T_2: 6 ppm oxalic acid (without pre-cool); T_3: 8 ppm oxalic acid + Pre-cooling; T_4: 8 ppm oxalic acid (without pre-cool); T_5: Control

Table 5 Changes of respiration rate (ml CO_2 Kg^{-1} hr^{-1}) of mango at ambient storage (28-30°C).

Treatments	Storage intervals in days			
	Day 2	Day 4	Day 6	Day 8
6ppm OA-PC	4.1_{c}	4.3_{ab}	4.4_{abc}	3.1_{ef}
6ppm OA-WPC	4.1_{c}	4.2_{ab}	4.0_{d}	3.2_{e}
8ppm OA-PC	4.1_{c}	4.2_{ab}	4.2_{ab}	4.1_{c}
8ppm OA-WPC	4.2_{a}	4.3_{ab}	4.3_{ab}	4.2_{ab}
Control	4.2_{ab}	4.5_{abc}	4.6_{ab}	4.0_{d}

Means within same raw and same column with different superscripts are significantly different ($p<0.05$) , n=3

Table 6 Changes of respiration rate (ml CO_2 Kg^{-1} hr^{-1}) of mango at low temperature (13±2°C).

Treatments	Storage intervals in days					
	Day 4	Day 8	Day12	Day 16	Day 20	Day 24
6ppm OA-PC	2.1_{c}	2.1_{c}	3.3_{ab}	4.4_{abc}	3.1_{ef}	3.1_{ef}
6ppm OA-WPC	2.1_{c}	2.1_{c}	3.2_{ab}	4.0_{d}	3.2_{e}	3.2_{e}
8ppm OA-PC	2.1_{c}	2.1_{c}	3.2_{ab}	4.2_{ab}	4.1_{c}	3.7_{ab}
8ppm OA-WPC	2.2_{a}	2.2_{c}	3.3_{ab}	4.3_{ab}	4.2_{ab}	3.6_{ab}
Control	2.2_{ab}	3.2_{c}	3.5_{abc}	4.6_{a}	3.2_{ab}	3.0_{ef}

Means within same raw and same column with different superscripts are significantly different ($p<0.05$) , n=3

Results and Discussion

During storage an increase in PLW was observed in all treatments (Table 1 and 2) under low temperature as well as ambient storage with pre-cooling. The most effective treatment was 8 ppm OA with pre-cooling having minimum changes in physiological weight loss during ambient and low temperature storage. However, the fruits stored under low temperature conditions showed slower changes. This may entirely due to the fact that loss of moisture from pre-cooled commodities is slower if higher relative humidity is maintained in the surroundings. Such conditions can easily be achieved by lowering the temperature as the storage environment tends to be more saturated simply by reduction in temperature (Lurie, 1990). The increase of weight loss because reduced metabolic activity produces a decrease in respiration rate, which in turn, results in lower rates of weight loss (Alves et al., 2004) and moisture evaporation through the skin. The rate at which water is lost depends on the water pressure gradient between the fruit tissue and the surrounding atmosphere and the storage temperature (Hernandez-Munoz, et al., 2008; Wijewardane, 2013; Rahaman and Bishop, 2013). Kalra and Thandon (1983) who found that lower fruit temperature and storage temperature slowed down the rate of increase in physiological weight loss reported a similar observation.

Fruit firmness and TA decreased, while pH (FAO, 2007; Guillo, 1960), TSS (Fig.1 and 2) increased in mango fruit during storage. However, oxalic acid treatment not only resulted in significantly higher fruit firmness after storage of 12 days and 24 days at ambient as well as low temperature storage, respectively. The reduction in firmness due to enzymatically mediated degradative changes in cell walls during ripening and degradation of those constituents decreased under low temperature conditions due to suppressed ripening. The enzymes are pectin esterase and polygalcturonase may be synthesized, activated or a combination of both, at or near the onset of ripening processes (Kays et al., 1991). Xiaolin et al. (2007) reported that the effect of oxalic acid on delaying mango fruit ripening was accompanied by a considerable inhibition of ethylene production during prolong storage.

Increase in TSS was observed in all treatments in ambient as well as low temperature storage (Fig.1 and 2) but the application of high concentration (8 ppm) of oxalic acid together with pre-cooling effectively reduced the rate of increase. Also under low temperature conditions the increase of TSS was slower than the ambient conditions. The similar results were given by Zheng et al. (2005); Mango (cv. Shengxin) fruits dipped in 5 mmol oxalic acid/ liter for 10 minutes and stored at controlled atmospheres (6% CO_2, 2% O_2 and 14±1°C) were more firm and had lower total soluble solid contents, disease index and decay incidence compared with control. It was suggested that the effects of exogenous oxalic acid on the enhancement of antioxidant capacity helps to retardation of the ripening process and decrease in decay incidence during storage, and that oxalic acid treatment is an alternative method for prolonging the storage life of mango fruits. Thus, pre-storage application of oxalic acid delayed the mango fruit ripening process during cold storage (Zheng et al., 2007).

TA was decreased in all treatments and consequently pH increased during storage (Table 3 and 4). The decrease in TA during storage was due to the reduction in the organic acids consumption or their conversion to sugars during respiratory metabolism (Alves et al., 2004; Siddiqui and Dhua, 2010). In addition, increased activity of citric acid during ripening or reduction in acidity may be due to their conversion into sugars and further utilization in the metabolic process of the fruit respiration (Abbasi et al., 2009). Softening of flesh, decreased acidity, increased carotenoid pigments are among the recognized

parameters of maturity and ripening in mango (Lakshminaarayana, 1980). Thus pre-storage application of oxalic acid delayed the mango fruit ripening process during cold storage.

In the present study, after 2 to 4 days and 4 to 8 days of storage at ambient and low temperature respectively, mango had similar respiration rate (RR) independent of the control (Table 5 and 6). Maximum level of rate of respiration was found in control among all the treatments under ambient condition at the end of storage. Data illustrated in Table 5 and 6 related that there was significant increase thereafter; decrease in respiration rate was recorded in mango. In general, all treatments showed lower rate of CO_2 production than control (4.6 ml CO_2/ Kg/ hr) at ambient conditions and the production of CO_2 were increased up to 6^{th} day and thereafter decreased significantly. The same was happened in fruits under low temperature that the increase can be seen up to 16^{th} day there after decreased. The decrease in rate of respiration at the end of storage may be due to higher degradation of stored constituent at prolonging storage mainly organic acids. CO_2 production rates were altered according to fruit maturity and storage duration. Mangoes are tropical fruits and therefore sensitive to chilling when stored below a critical minimum temperature (Chaplin et al., 1991; Lizada, 1991). If stored at low temperatures for prolonged time, storage could have an effect on ripening. It has been reported that cvs. Langra and Dasheri can safely be stored at 7-8°C for up to 25 days (Mann and Singh, 1976). However, recommended temperatures are in the range of 10-15°C and lead to storage life of 2 to 3 weeks.

Conclusion

The results of this experiment indicate that dipped in 5% sodium bicarbonate solution followed by 8 ppm oxalic acid application along with pre-cooling was the most effective for extension of storage life of fresh mango up to 12 and 24 days under ambient (28-30ºC) and low temperature storage (13 ± 2ºC), respectively. Fruits stored under low temperature exhibited better in retention of all physiological and biochemical characteristics tested.

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