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Effect of Vapor Heat and Hot Water Treatments on Disease Incidence and Quality of Taiwan Native Strain Mango Fruits

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ABSTRACT

Taiwan native strain mango fruits (Tuu Shien) had three types of treatments: Hot water (HW) (52, 55, 58°C); Vapor heat treatment (VHT) (46.5°C for 40 min) and hot water + vapor heat treatment followed cold storage (1, 3, 6, 9, 12, 15, 20°C) to determine incidences disease control treatment and the changes in quality. The HW at 55°C for 3 min was decreased total spots of anthracnose disease for 6 days compared to control. Moreover, HW at 55°C for 3 min controlled anthracnose disease treatment for 6 days. The vapor heat maintained peel color index, firmness and total soluble solid content at 3°C of storage time. The disease incidences of the *Alternaria alternata and Colletotrichum gloeosporiodes* were decreased by application of HW and VHT followed by storage at 3°C for 3 weeks. *Dothiorella mangiferae* area increased during the same time but did not affect quality. The HW + VHT combined with continuous storage at 3°C for ambient room temperature produced the highest fruit quality. © 2010 Friends Science Publishers

Key Words: Hot water; Vapor heat; Mango disease incidence; Native strain mango fruits; Mango fruit quality

INTRODUCTION

Mango (*Mangifera indica* L.) is a delicious tropical fruit and an important export crop. So it is important for mango countries to find techniques to control pests and diseases satisfactorily. An attractive flavor is one of characteristics of mangoes. The varying flavor at different stages of harvest and after certain storage time is not only distinguishable by human senses, but also reflects physiological and quality changes. The postharvest life of mangoes usually doses not exceed 2-3 weeks and is limited by physiological deterioration of the fruit related to over-ripening and by disease development leading to decay. So, there is a need to monitor the disease severity during the shelf life of mangoes to prevent the spread of diseases.

Anthacnose, caused by *Colletotrichum gloeosporiodes* Penz. and Sacc., is the major post-harvest disease of mango (Dodd *et al*., 1997). *Alternaria alternata* and *Botryodiplodia* spp. the causal organisms of black spot disease and stem-end rot, cause high losses and compromise storage life of the fruits (Prusky *et al*., 1997; Kobiler *et al*., 2001). The post-harvest, stem-end rots are caused by a number of fungi, including *Lasiodiplodia theobromae* (Pat.) Griffon and Maubl., *Dothiorella dominicana*, *D. mangiferae*, *Phomopsis mangiferae*, *Pestalotiopsis mangiferae*, *Nattrassia mangiferae* and *Cytosphaera mangiferae* (Johnson *et al*., 1993; Korsten *et al.*, 1993). The major causal agent for this group of rots varies among different production areas. These diseases are normally more of a problem, when anthracnose levels are reduced by climatic factors or preharvest control (Estrada, 1994). Heat treatments such as hot water dip, vapor heat, hot dry air or combinations of these have been increasingly used as a quarantine treatment in several studies to retard post-harvest fungal damage to fruits and vegetables (Mansour *et al*., 2006), because it does use chemicals for the treatments.

Vapor heat is a method of heating fruit with air saturated with water vapor at temperatures of 40-50°C to kill insect eggs and larvae as a quarantine treatment before fresh market shipment (APHIS, 1985). Vapor heat was developed specifically for insect control, but hot air has been used for both fungal and insect control and to study the response of commodities to high temperature. Bard and Kaiser (1996) found that heat treatments in a selection of fruit have been used with several objectives: controlling of insect pest; disinfesting of fungal and bacterial rots; de-sensitizing fruit to chilling injury; reducing incidence of post-harvest physiological disorders; decreasing rate of ripening and prolonging shelf life.

The aim of this work was to study the impact of vapor heat and hot water treatments on the quality (color, firmness & total soluble solid) and % of changes in incidents of disease in Taiwan native strain mango fruits during cold storage.

MATERIALS AND METHODS

Plant material: 'Tuu Shien' mangoes (*Mangifera indica* L.) were obtained from orchards in Taiwan. Four hundred

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twenty-two mango fruits were selected to be as green as possible and transferred to ambient temperature before arrival at the laboratory for treatments. The mango fruits were selected by uniform size and maturity stage.

Anthracnose diseases: The experiment was carried out to determine the best temperature for hot water dipping 52, 55, or 58°C for 1, 3, or 5 min to inhibit for anthracnose disease. Ten fruits each were placed treated with different combinations of hot water and time. After hot water treatments were finished, all mango fruits were removed to ambient room temperature (28°C) before they were put into jars (a jar with a volume of 60 L). Every jar was connected to an air pump to increase relative humidity.

A count of anthracnose spots on mango fruit was determined after mango peel began to show black spots. Anthracnose spots were measured for 6 days. When a spot had a diameter of 5 mm, they were counted and recorded. Additionally, the diseased anthracnose area was estimated by optic subjective two different times (3rd day & 6th day). The diseased anthracnose area was assessed by evaluating the percentage of fruit surface covered (McDonald & Miller, 1994): 1 = no decay; 2 (trace), ≤2% or less of aggregate surface area affected; 3 = (slight), ≥ 3 ≤ 10%; 4 = (moderate), ≥ 11 ≤ 20%; and 5 = (severe), ≥ 21%.

Storage temperature: Two hundred eleven mango fruit samples were taken from the original four hundred twenty two mangoes for vapor heat treatment to determine a suitable temperature for cold storage. The fruit was subjected to vapor heat treatment until fruit center temperature was 46.5°C for 40 min. After vapor heat, all mango fruits were cooled for 20 min by hydro-cool and removed to ambient room temperature (25°C) before putting into jars. The protocol for using these jars was the same as the hot water tests. Then, ten mango fruits each were placed at 1, 3, 6, 9, 12, 15 and 20°C for temperature storage treatments.

Subjective assessments of disease: The results of anthracnose disease and temperature storage tests indicated that hot water at 53°C for 3 min; vapor heat at 46.5°C for 40 min; and cold storage at 3°C retained the best quality of mango fruit. These results were used for the subjective assessments of diseases test. Mangoes were dipped in hot water at 55°C for 3 min then left at room temperature for 3 h to reduce fruit temperature. After, 3 h fruit was exposed to a VHT of 46.5°C and stored at 3°C for 3 weeks. During this period, there were three fungi examined, *C. gloeosporiodes*, *A. alternata* and *D. mangiferae*. For each fungus, percentage of disease area was determined by the same rate assessment as anthracnose disease area except all spots, regardless of size, were examined and counted.

Quality analysis: After storage at 1, 3, 6, 9, 12, 15, and 20°C for 1, 2, or 3 week(s), the mango fruits remained at room temperature for 24 h before determining fruit qualities. Ten mangoes per each temperature level were taken out and examined for color, firmness and total soluble solid (°Brix).

Color: Ripeness development was assessed by viewing the mango fruits skin. A color index was recorded according to the following rating scale (Shorter & Joyce, 1998): 1= 100% green; 2= 75% green; 3= 50% green and 50% yellow; 4= 75% yellow; 5= 100% yellow. The color index was proportionally converted from a percentage to a numerical value to facilitate comparison with total soluble solid.

Firmness: Firmness of fruits was measured using a Sun Rheo Meter (Sun Scientific Co, Japan) fitted with a 10 mm hemispherical probe driven downwards at 100 mm/min to a depth of 3 mm.

Total soluble solid (TSS): For TSS (°Brix), the samples were measured with a Digital Hand-held "Pocket" Refractometer PAL-1 and expressed as a percentage. Juice samples were prepared by throughly mixing mango slices (two slices for every mango fruit, from the widest part of the mango & cut from the surface to a depth of 1 cm).

Statistical analysis: Data analysis was carried out using SAS version 9.1.3 (SAS, 2004). The 95% probability level was taken to indicate significant differences. Means were compared by Turkey's HDS range tests after data were checked for normal distribution and variance homogeneity. In addition, F-value and coefficient of variation analysis for measured parameters were conducted.

RESULTS AND DISCUSSION

The color index of 'Tuu Shien' mango fruits: Before treatment, the color of the skin of whole 'Tuu Shien' mango fruits were visually estimated and measured by peel color index given above (Table I). Color index between the three weeks was significantly different ($P<0.001$). The peel color index was not different between storage temperature and time (1°C & 3°C after 1, 2 & 3 weeks). After storage at 1°C to 6°C, the peel color index did not change up to 2 weeks, whereas after which, the peel color index changed from 1.8 to 2.1. After the third week of storage at 6°C, there was only a slight change.

Rapid change of the peel color index of 'Tuu Shien' mango fruit happened when the storage time was prolonged. The mango fruits treated with vapor heat strongly changed for peel color index on the first week for 20°C group and on the second week for 15°C group. Their color index reached 5 during storage temperature. At the end of 3 weeks storage time, the peel color of mango fruit changed rapidly and was inedible.

The peel color index fluctuated in the 3 weeks at 9°C storage temperature. However, there was no significant change between the peel color index of mango fruits at 12°C after 2 weeks. At 3°C and 9°C storage temperatures, the peel color index was 1.7, 1.7, 1.8 and 2.6, 3.2, 2.4 (1 week, 2 weeks & 3 weeks, respectively). At 3°C, the peel color index change was less than at 9°C. This demonstrated that 3°C storage temperature is most suitable for the shelf life of 'Tuu Shien' mango fruit. Peel color index was related to chilling injury and ripening of fruits. The flesh discoloration and abnormal ripening can occur in more severe cases of

chilling (Phakawatmongkol *et al*., 2004). McLauchlan and Well (1994) reported that duration of storage on 'Kensington Pride' mangoes can be at 10°C for 3 weeks or at 7°C for 2 weeks, but the skin color development can be affected. On the other hand, the fruit will deteriorate rapidly after removal from storage but storage temperature lower than 8°C can also be used for up to 21 days without deterioration in quality (Van Straten & Oosthuyse, 1994).

The firmness of 'Tuu Shien' mango after vapor heat treatment: The firmness of the fruit was reduced on mango fruits of the storage temperature (Table II). The firmness value was higher at 3°C during first week of the storage and significant differences between the storage temperatures. At the second week, there were no significant differences in the firmness value between the storage temperatures from 1°C to 9°C, while it decreased during third week except at 1°C. The firmness was the lowest (4.74 & 4.13 at 15°C & 20°C, respectively) during the third week. Similar analyses, for peel color index were obtained (Table I), which was correlated with the fruit firmness (Table II). Additionally, the firmness values were higher at 3°C storage temperature. They were 24.41, 20.24 and 20.00 N (1, 2, & 3 weeks, respectively). There were significant differences in the firmness between storage temperatures. So, the firmness was related to the storage temperatures.

Fruit firmness is one of the criteria of fruit quality determined by various researchers for different fruits. El-Salhy *et al*. (2006) reported that after four weeks of cold storage, fruit firmness ranged from 1.7 to 2.1 lb in the first season and from 1.8 to 2.1 lb in the second seasons of 'Awais' mango fruits after irradiation and hot water. Jha *et al*. (2010) indicated that the firmness was decreased after the 5th day of storage at ambient temperature (27±2°C) on mango hybrids.

The total soluble solid (TSS) of 'Tuu Shien' mango fruits: The TSS (°Brix) of mango fruits was highest at 1°C storage temperature (Table III). Storage temperatures caused significant changes between TSS during the first week of the storage time. However, there were no significant differences in the TSS of mango fruits between storage temperatures at 3, 6, 9 and 20°C. During the second week of the storage time, there were significant differences in TSS of mango fruits between storage temperatures. However, TSS of mango fruits was much greater at 3°C storage than other temperatures during the second week. The same was true for mango fruits at 1°C, 6°C and 9°C during the second week of the storage time. In addition, the TSS during the second week was slightly reduced compared to first week, although there were no significant differences in TSS between 15°C and 20°C groups. This showed that higher storage temperature and longer time are related to the quality (color, firmness & TSS). However, TSS in mango fruits during 3°C of storage temperature at the third week was lower than other temperature levels but storage temperature caused no statistically significant differences in TSS, except in decayed fruits, which were in traces. Changes in TSS were parallel to the changes in firmness of mango fruits, as reported during severe chilling injury (four weeks of cold storage) for 'Keitt' mango fruits (Lederman *et al*., 1997). Djioua *et al*. (2009) reported that the final TSS value was higher after 9 days of storage by hot water dipping for 50°C at 30 min.

Table I: Effect of storage temperature and duration on the color index of 'Tuu Shien' mango fruits after vapor heat treatment and then re-warming at 25°C for 1 day following storage in 2009 summer

Storage temperature (°C)	Peel color index[z]		
	1 week[y]	2 weeks	3 weeks
1	1.8 c[x] ± 0.8	1.9 c ± 0.6	2.0 c ± 0.0
3	1.7 c ± 0.7	1.7 c ± 0.5	1.8 c ± 0.8
6	1.6 c ± 0.5	2.4 c ± 0.5	2.1 bc ± 0.6
9	2.6 b ± 1.1	3.2 b ± 1.0	2.4 b ± 0.5
12	3.1 b ± 0.6	4.8 a ± 0.4	5.0 a ± 0.0
15	4.9 a ± 0.3	5.0 a ± 0.0	5.0 a ± 0.0
20	5.0 a ± 0.0	5.0 a ± 0.0	5.0 a ± 0.0
Mean	2.96	3.43	3.33
F-value	***	***	***
CV (%)	19.68	15.31	12.76

[z]Color index was recorded according to the rating scale: 1 = 100% green; 2 = 75% green; 3 = 50% green and 50% yellow; 4 = 75% yellow; 5 = 100 % yellow

[y]Storage time

[x]Values in columns followed by the same letter are not significantly different according to the Tukey test of transformed data

F-value for main effect or interaction significant at P<0.001 (***)

Table II: Effect of storage temperature and duration on the firmness of 'Tuu Shien' mango fruits after vapor heat treatment and then re-warming at 25°C for 1 day following storage in 2009 summer

Storage temperature (°C)	Firmness (N)		
	1 week[y]	2 weeks	3 weeks
1	21.37 ab[x] ± 4.15	21.21 a ± 4.13	17.51 ab ± 2.56
3	24.41 a ± 3.01	22.64 a ± 4.52	20.00 a ± 2.14
6	23.26 ab ± 3.24	20.24 a ± 3.32	19.04 ab ± 2.67
9	23.48 ab ± 3.24	19.77 a ± 3.08	15.08 b ± 2.52
12	19.55 b ± 3.03	14.30 b ± 3.19	8.08 c ± 5.24
15	15.30 c ± 3.20	9.41 c ± 3.34	4.74 c ± 2.29
20	13.70 c ± 3.42	6.80 c ± 2.72	4.13 c ± 1.15
Mean	20.15	16.33	12.65
F-value	***	***	***
CV (%)	15.26	20.58	23.20

[y]Storage time

[x]Values in columns followed by the same letter are not significantly different according to the Tukey test of transformed data

F-value for main effect or interaction significant at P<0.001 (***)

Anthracnose disease of 'Tuu Shien' mango fruits: After 6 days of observation, there were no significant differences in total spots of anthracnose disease on Taiwan native strain mango fruits between temperature and time (Table IV). A highest total spots of anthracnose disease were observed in the control and the 58°C for 5 min treatment. A total of 1.90 spots per each fruit at 52°C for 1 min were the lowest of all other temperatures. This caused the coefficient variance analysis to result in a high number of total spots per each mango fruit. After 3 days of observation, anthracnose

incidence showed no significant differences in anthracnose incidence between temperatures and times. The anthracnose incidence was low at 52°C for 3 and 5 min treatment, while it was highest in the control, but at 5.30% anthracnose incidence, this area was slight (McDonald & Miller, 1994).

The anthracnose incidence in mango fruits, as evaluated after 6 days, increased slightly at room temperature. There was significant difference of anthracnose incidence between temperature and time. After 6 days, the anthracnose incidences were severe in the control, at 52°C for 1 min, and 58°C for 1, 3 and 5 min, respectively. The maturity of mango fruits caused an increase in anthracnose disease incidence. However, mango fruits treated at 55°C for 3 min were the least affected by anthracnose disease throughout the observation time. In spite of total spots of anthracnose disease per each fruit being in the medium range, anthracnose incidence was slight. Thus water temperature should be between 50 and 55°C and dipping time must be for least 5 min, but different dipping conditions have also been recommended to control the disease effectively (Dodd *et al*., 1991). Factors that may account for different disparities include varying tolerances of the cultivars to the treatment and differing sensitivities of the *C. gloeosporioides* strains from different countries. The postharvest dips of fruit are considered as moderately effective against mango anthracnose (Arauz, 2000). On the other hand, Nelson (2008) reported that using hot water dip of mango fruits for 15 min at 49-55°C depending on variety. However, there were some varieties including of 'Carabao', Carrie', 'Florigon', 'Tommy Atkins' and 'Saigon' that were resistant to anthracnose (Peterson, 1986).

Disease incidences on 'Tuu Shien' mango fruits: The disease control treatment used in this study was a modified protocol from that used in the previous study. A hot water treatment of 55°C for 3 min and vapor heat treatment exposure of 46.5°C for 40 min were used to determine disease in total (%) and the quality of mango fruits after re-warming for one day at room temperature. There were no significant differences between the total of the diseased areas during the 3 weeks (30.50%, 34.07% & 39.83%) thought it increased regularly (Table V). The disease seriousness areas of *A. alternata* were the same statistical during the 3 weeks. However, the *C. gloeosporiodes* disease area of 13.33% at first week of this heat study was considerably higher than anthracnose area of 6.50% at 55°C for 3 min (Table IV). On the other hand, there was significant difference between disease areas of *D. mangiferae*. During the second to third week, the disease area of *D. mangiferae* increased from 5.50% to 12.17%. As the storage time of mango fruits were prolonged, the disease area of *D. mangiferae* increased.

Postharvest diseases that cause considerable losses for the mango industry were anthracnose caused by *C. gloeosporiodes* and some funguses (Govender *et al*., 2005). During the past few years, the use of heat treatments applied by hot water, vapor heat or heated air, increased in order to control insect pests, prevent fungal rots and increase resistance to chilling injury (Lurie, 1998). Disease occurring area increased on mango fruits, because of the extended storage. However, there was a difference in range of the disease area on each fruit. So CV of the diseases areas to *C. gloeosporiodes* and *D. mangiferae* were high (Table V).

The increased levels of disease observed in hot water or vapor heat treated 'Tuu Shien' mango may be accounted for by injury to the surface cells during treatment, thus making the fruit more susceptible to fungal attack. Internal injury can be associated with unfavorable internal gas composition. Jones (1939) found that high humidity created a film of water around the fruit, which interfered with the usual exchange of gases. Jacobi and Wong (1992) reported

Table III: Effect of storage temperature and duration on the total soluble solid (TSS) of 'Tuu Shien' mango fruits after vapor heat treatment and then re-warming at 25°C for 1 day following storage in 2009 summer

Storage temperature (°C)	Total soluble solids (°Brix)		
	1 week[y]	2 weeks	3 weeks
1	17.30 a[x] ± 1.29	16.03 a-c ± 1.61	15.33 ± 2.21
3	15.78 ab ± 2.28	16.74 a ± 1.76	14.90 ± 1.18
6	16.18 ab ± 1.81	16.48 ab ± 1.64	15.62 ± 1.45
9	15.31 ab ± 1.26	14.88 a-c ± 0.85	15.70 ± 2.73
12	14.80 b ± 1.55	14.05 bc ± 2.12	13.29 ± 1.76
15	14.77 b ± 2.31	13.56 c ± 1.70	-[w]
20	14.88 ab ± 2.04	13.71 c ± 2.84	-[w]
Mean	15.57	15.06	14.97
F-value	*	***	ns
CV (%)	11.48	12.40	13.17

-[w]: After 3 weeks, fruits were decay, no TSS column for 15°C and 20°C of storage temperature

[y]Storage time

[x]Values in columns followed by the same letter are not significantly different according to the Tukey test of transformed data

F-value for main effect or interaction significant at 0.01<P<0.05 (*), P<0.001 (***), and P>0.05

Table IV: Effect of hot water treatment for spot total (spot) and anthracnose disease percent of 'Tuu Shien' mango fruits in 2009 summer

Treatments		Spot/fruit	Anthracnose incidence (%)	
			3-DAT[y]	6-DAT
Control		**6.64 ± 3.61**	**5.30 ± 5.56**	**33.20 ab[x] ± 22.24**
52°C	1 min	1.90 ± 3.57	3.50 ± 4.74	38.20 a ± 20.98
	3 min	6.23 ± 4.26	1.00 ± 3.16	19.00 ab ± 21.83
	5 min	2.07 ± 4.12	1.00 ± 3.16	11.00 ab ± 20.79
55°C	1 min	4.74 ± 4.88	3.00 ± 6.75	22.00 ab ± 24.10
	3 min	3.30 ± 4.40	2.50 ± 4.25	6.50 b ± 14.15
	5 min	3.94 ± 5.09	1.70 ± 3.65	14.80 ab ± 20.75
58°C	1 min	2.24 ± 3.76	2.50 ± 4.25	15.00 ab ± 24.15
	3 min	3.75 ± 4.69	2.50 ± 4.25	12.00 ab ± 20.44
	5 min	7.43 ± 4.05	3.50 ± 4.74	29.00 ab ± 23.31
Mean		4.22	2.65	20.05
F-value		ns	ns	*
CV (%)		101.2	172.50	107.14

[x]Values in columns followed by the same letter are not significantly different according to the Tukey test of transformed data

F-value for main effect or interaction significant at P>0.05 (ns), or P<0.001 (***)

DAT[y]: Day after treatment

that combination of heat and anaerobic conditions may be to increase internal injury in 'Kensington' mango following hot water treatment compared to vapor heat treatment. Thus, increased relative humidity was used to decrease internal injury in 'Tuu Shien' mango fruits.

The efficacy of heat treatment was higher when HW dipping in 55°C for 3 min was combined with exposure in vapor heat at 46.5°C for 40 min, or vice versa, than HW treatment alone on 'Tuu Shien' mango fruits. Similar results were obtained after treating 'Kensington' mango with HW at 53°C for 5 min lowered disease incidence, while severity of fruit injury was lower in HW+VHT fruits than in VHT fruits alone (Jacobi & Giles, 1997). Similarly, heat protocols have been developed for treating a wide range of mango varieties (Mohamed *et al*., 1994), Kensington from Australia (Jacobi *et al*., 1996) and Buoi from New Zealand (Nguyen *et al*., 1998).

The quality of 'Tuu Shien' mango fruits: There were significant differences in peel color index during the 3 weeks. But the peel color index on the mango fruits were not significantly changed during the first 2 weeks. The values of the peel color index of the fruit stored at 3°C using hot water 55°C for 3 min and vapor heat treatments at 46.5°C for 40 min were higher than the ones only treated with VHT. There were significant differences in firmness values during the 3 weeks though the firmness values of the mango fruits were not significantly changed during the second and the third week. The firmness values of mango fruits were the greatest at the first week.

Total soluble solid (°Brix) was not significantly different between the 3 weeks. The TSS contents of the fruit stored at 3°C using hot water 55°C for 3 min and vapor heat treatments at 46.5°C for 40 min did not differ with the ones only treated with VHT. The observation mean of TSS was 15.64 °Brix. This showed that hot water and vapor heat in this test had no effect on TSS of 'Tuu Shien' mango fruits during the 3 weeks. High quality 'Tuu Shien' mangoes were maintained when the HW and VHT protocol were applied and fruit was stored at ambient room temperature 25°C for 3 weeks. HW and VHT accelerated ripening and treated fruit rated higher in peel color index than those only treated with VHT. The 10/22°C (10°C for 5 days, followed by 22°C for 5 days-to simulate cool storage, then ambient or no cool storage when fruit are transported to and handled in market) storage regimen caused a slowing of the normal fruit ripening processes (Jacobi & Giles, 1997).

Fruit firmness is one of the most widely used indicators of fruit quality. The results suggested that HW and VHT maintained firmness during 1 week of storage at 3°C. Additionally, the firmness values of mangoes were decreased slightly at the third week of the storage. In a study, firmness of the mango fruits remained almost constant over the period of growth and it decreased after attaining maturity (Jha *et al*., 2006). According to Shalom *et al*. (1996), inhibition of solublization of the carbonate-soluble pectin fraction is one of the main factors contributing to firmness retention due to heat treatment. Measuring quality changes are of paramount importance for shelf life of mango fruits. In this study, there were no changes of TSS for using hot water and vapor heat on 'Tuu Shien' mangoes during the 3 weeks. Kim *et al*. (2009) showed that application of hot water at 46.1°C for 70, 90 and 110 min had no effect on soluble content of 'Tommy Atkin' mangoes. Djioua *et al*. (2009) indicated that hot water at 50°C for 30 min induced a slight decrease until 6 d, but after 9 d of storage the final TSS value was higher than at the beginning of the experiment on fresh-cut 'Keitt' mangoes.

Table V: Effect of hot water and vapor heat treatment on incidences of storage temperature at 3°C of 'Tuu Shien' mango fruits for re-warming at 25°C for 1 day following storage

Time	Total of disease area (%)	Disease seriousness area (%)		
		A[y]	C	D
1 week	30.50 ± 18.21	16.83 ± 13.10	13.33 ± 13.15	0.33 b[x] ± 1.27
2 weeks	34.07 ± 18.88	15.90 ± 11.06	12.67 ± 11.75	5.50 b ± 9.04
3 weeks	39.83 ± 24.41	14.00 ± 11.10	13.67 ± 15.14	12.17 a ± 14.72
Mean	34.80	15.58	13.22	6.00
F-value	ns	ns	ns	***
CV (%)	56.75	77.87	102.00	157.38

A[y].: Alternaria alternate; C: Colletotrichum gloeosporiodes; D: Dothiorella mangiferae

[x]Values in columns followed by the same letter are not significantly different according to the Tukey test of transformed data

F-value for main effect or interaction significant at P>0.05 (ns), or P<0.001 (***)

Table VI: Effect of hot water and vapor heat treatment on quality of storage temperature at 3°C on 'Tuu Shien' mango fruits for re-warming at 25°C for 1 day following storage

Time	Peel color index[z]	Firmness (N)	TSS (°Brix)
1 week	2.5 b[x] ± 1.2	19.41 a ± 3.00	15.86 ± 1.52
2 weeks	2.6 b ± 1.2	14.81 b ± 3.51	15.80 ± 1.71
3 weeks	3.6 a ± 0.9	15.43 b ± 3.57	15.28 ± 1.78
Mean	2.9	16.55	16.65
F-value	***	***	ns
CV (%)	34.22	21.33	10.55

[z]Color index was recorded according to the rating scale: 1 = 100% green; 2 = 75% green; 3 = 50% green and 50% yellow; 4 = 75% yellow; 5 = 100 % yellow

[x]Values in columns followed by the same letter are not significantly different according to the Tukey test of transformed data

F-value for main effect or interaction significant at P<0.001 (***)

CONCLUSION

The vapor heat treatment with 'Tuu Shien' mango fruit center temperature at 46.5°C for 40 min and storage temperature at 3°C for 3 weeks was demonstrated to maintain the appearance and peel color index of fruits. Firmness and TSS were maintained at 3, 6 and 9°C during 1 week of storage compared to the other storage temperature levels. The hot water dipping at 55°C for 3 min reduced anthracnose disease. Conditioning treatments, particularly of

hot water at 55°C for 3 min and vapor heat at 46.5°C for 40 min followed by 3°C of storage temperature, were found to decrease incidence of *A. alternate and C. gloeosporiodes*. However, the disease area of *D. mangiferae* in mangoes increased with longer storage time. Hot water at 55°C for 3 min and vapor heat at 46.5°C for 40 min kept up the fruit quality during 3 weeks. Additionally, the combination of hot water and vapor heat inhibited fungal rots, controlled disease and maintained of fruit quality.

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