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EFFECT OF RAPID HOT WATER TREATMENT ON SOME POSTHARVEST QUALITY CHARACTERISTICS OF PHILIPPINE 'CARABAO' MANGO (*Mangifera indica* L.)

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ABSTRACT. *Mango is an important export fruit crop in the Philippines but highly perishable. Rapid hot water treatment (RHWT), as an alternative to hot water treatment (HWT), can be used to control common postharvest diseases particularly when processing large volumes of mangoes for export. The efficacy of RHWT (59-60ºC for 35 s + air-drying) on improving the quality of 'Carabao' mango was compared with the conventional HWT (52-55ºC for 10 min + 10 min hydrocooling + 30 min air-drying) and untreated fruit. Fruit were heat-treated within and past 24 h after harvest. The two heat treatments hastened color change in mango. The heat treatments resulted in better visual quality thus more fruit were marketable than the control. Higher percentage of marketable mangoes treated beyond 24 h was observed than within 24 h after harvest. Stem end rot (SER) was significantly reduced by both heat treatments. Anthracnose was also reduced but to a lesser extent. Anthracnose incidence was delayed up to two days while SER was delayed for four to six days by the heat treatments. SER was reduced by 33-50% and 20-25% at 14 d in HWT and RHWT, respectively. Weight loss in mango samples treated past 24 h did not vary while fruit subjected to RHWT within 24 h had lesser weight loss. This study showed that time of treatment did not reduce the greater efficacy of the traditional HWT. As to reduced time of treatment, RHWT can be recommended as an alternative postharvest practice in controlling postharvest diseases and prolonging the shelf life of 'Carabao' mangoes.*

KEY WORDS: *anthracnose, 'Carabao' mango, heat treatment, quality, stem end rot.*

INTRODUCTION

Anthracnose and stem end rot (SER) are the two most common postharvest diseases in mango production (Johnson & Coates 1993). Anthracnose is caused by *Colletotrichum gloeosporioides*. On the other hand, SER is a dark or black rot caused by *Dothiorella dominicana, Dothiorella mangiferae, Lasiodiplodia theobromae* as well as other fungi (including *Alternaria alternata*) which forms at the stem end as the mango fruit ripens after harvest (Johnson et al. 1992). In the Philippines, anthracnose caused by *Colletotrichum gloeosporioides* and SER caused by *Lasiodiplodia theobromae (Diplodia natalensis)* are also among the important diseases in mango (PCAARD-DOST 2013). Infected green fruit carry the fungi into storage where they remain invisible which then slowly shows black spots on the exocarp and stem end as fruit ripen (Haggag 2010).

Good quality mango fruit should be free of diseases that affect the shelf life and visual quality. This is usually achieved with chemicals, fungicides, and other postharvest treatments. However, the use of chemicals is discouraged through strict fruit specifications of mango importing countries due to health and environmental concerns (FAO 2012). Hot water treatment (HWT) is widely used in commercial scale in the USA and Central America (Jacobi et al. 2001) and in export market of 'Carabao' mango in the Philippines (Alvindia & Acda 2015). HWT is a health-, environment-, and economically-friendly technique that can effectively control anthracnose and SER. 'Carabao' mango subjected to HWT plus 10 min hydrocooling followed by 30 min drying prior to packing had very low disease incidence (3%) which delayed deterioration of fruit (Esguerra et al. 2006).

Despite the advantageous effects of HWT, other handlers and players in the supply chain are hesitant to adopt the technology due to long total treatment time that affects the processing time of mango for export (Esguerra et al. 2006). Faster packinghouse preparation of mangoes for export can be attained by modification of the current hot water treatment through reduction of treatment time. The rapid hot water treatment (RHWT) technology can help shorten the process while effectively and efficiently controlling important postharvest diseases like anthracnose and SER. The modified treatment could appeal more to exporters since a large volume of mangoes can be treated in a shorter time.

To compare the efficacy of the conventional HWT and RHWT on 'Carabao' mangoes treated within and past 24h after harvest, commercially mature mango fruit were subjected to heat treatments accordingly at controlled time-temperature durations.

MATERIALS AND METHODS

Commercially mature and uniform quality 'Carabao' mango fruit harvested at 110 days after flower induction (DAFI) were purchased from a farm in Mati, Davao Oriental in Southern Mindanao. The fruit were transported to the Postharvest Biology Laboratory of the University of the Philippines Mindanao, Mintal, Davao City. Fruit were sorted, weighed, labeled, and subjected to flotation test prior to treatment. The flotation test used 1% salt solution and 200 μL L^{-1} sodium hypochlorite. Mature mango fruit (sinkers) were treated within 24 hours (h) after harvest or past 24 h (i.e. 28 h) after harvest. Treatments for each group were hot water treatment (HWT), and rapid hot water treatment (RHWT). Untreated fruit served as control. There were 78 (26 per treatment) fruit treated within 24 h while 60 fruit treated past 24 h (20 per treatment).

Mangoes in HWT and RHWT groups were subjected to hot water immersion in the hot water set-up in the laboratory. Fruit in the HWT group were treated using conventional HWT process (fruit dipped in hot water at 52-55ºC for 10 min + 10 min hydrocooling and 30 min air-drying) used in Philippine packinghouses. Mangoes in RHWT groups were exposed to the modified treatment following the method of Esguerra et al. (2006), where fruit were exposed to hot water at 59-60ºC for 35-60 s without hydrocooling. The non-treated group served as control. Fruit were stored under ambient room conditions (27.35ºC, 82.17% RH).

Physical tests included the visual quality rating (VQR), peel color change, and percentage weight loss. The VQR of samples was monitored daily from the initial day to 14 days after treatment (DAT) using a scale of 1-5 (5 = excellent, no symptoms of deterioration; 4 = good, minor symptoms of deterioration that are not objectionable; 3 = fair, evident deterioration but not serious, limit of saleability; 2 = poor, serious deterioration, limit of useability; and 1 = extremely poor, unuseable (Ekman et al. 2019). Color change was checked using a peel color index (PCI) with a 1-6 scale (1= green; 2 = breaker, a trace of yellow at the stem-end;3 = turning, more green than yellow; 4 = more yellow than green; 5 = yellow with traces of green; and 6 = fully yellow (Esguerra and Lizada 1990) until all mangoes reached table ripe stage (TRS) at PCI 5 and 6. The fruit weight loss was obtained when fruit reached TRS. Weight loss was computed and expressed in percentages by obtaining the initial (green) and final (at TRS) weights of mango fruit.

Disease monitoring was done by checking the severity and incidences of anthracnose and stem end rot (SER) every two days. Disease severity was assessed using the slightly modified anthracnose and SER scale charts of Alvindia & Acda (2015). Anthracnose was assessed using the following scale: 1- no visible spots, 2- one depressed spot, dark in color with 1-5 mm in diameter on the epidermis of the fruit, 3- 2 to 3 depressed spots, dark in color with 1-5 mm in diameter, 4- 2 to 3 depressed spots, dark in color with more than 5 mm in diameter, 5- more than 3 depressed spots, dark in color with more than 5 mm in diameter, 6- spots merged. SER was evaluated using the following scale: 1- no discoloration of the stem end, 2- discoloration limited at the stem end, 3- 10% discoloration of the fruit surface area initiated by SER, 4- 11-30% discoloration of the fruit surface area initiated by SER, 5- 31-50% discoloration of the surface area initiated by SER, 6- more than 51% discoloration of the surface area initiated by SER. Disease incidence was monitored daily. Mango samples infected with anthracnose and SER were counted and the disease incidence was estimated. The number of saleable fruit (% marketability) was evaluated. End of marketability was recorded when fruit reached VQR 3, infected with anthracnose (Disease Severity of 3), infected with SER (Disease Severity of 3) or when distinct shriveling was achieved. These mangoes have very low price in the market due to poor visual quality. The percentage marketability of mangoes was assessed by counting the number of good quality mangoes with VQR of at least 3.

Data obtained in groups treated within and past 24 h were subjected to analysis of variance (ANOVA) and treatment means were compared using LSD at 5% level of significance.

RESULTS AND DISCUSSION

Peel color change

Mangoes subjected to heat treatments (HWT and RHWT), treated within and past 24 h after harvest, had the fastest rate of ripening (Figure 1). Heat-treated mango showed more yellow than green color as early as 5 days compared to the control at 6 days. All mangoes exposed to HWT both within and past 24 h after harvest evenly attained PCI 6 (full yellow) at 8 days. As color of mangoes continued to change in the succeeding days, no significant difference was found in all fruit as this showed uniform color change at PCI 5 or 6. Since mangoes treated past 24 h after harvest were already at their breaker stage or PCI 2, change of color was slightly more advance than the control.

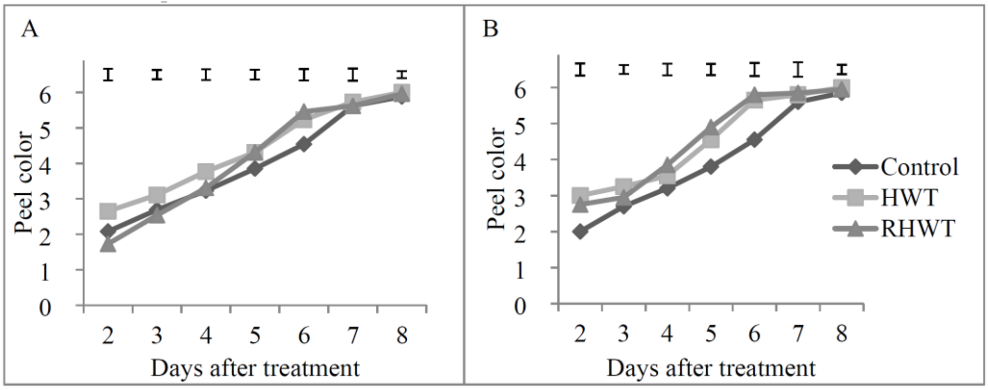

Figure 1. Peel color of 'Carabao' mango groups subjected to hot water treatment (HWT) and rapid hot water treatment (RHWT) within (A) and past (B) 24 h after harvest. Vertical lines indicate LSD values at P≤0.05.

Visual quality

The deterioration of visual quality of mango intensified as storage increased (Figure 2). The visual quality of mango subjected to the two heat treatments

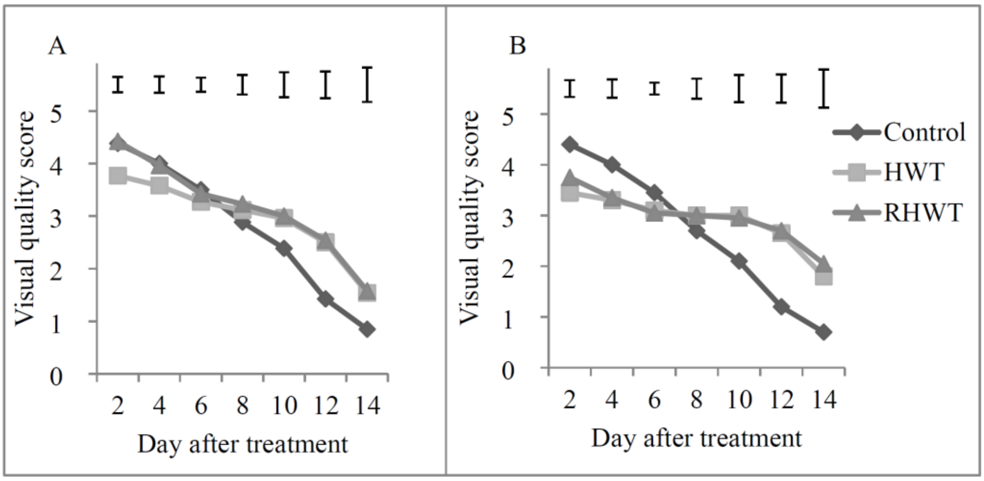

Figure 2. The visual quality of 'Carabao' mango groups subjected to hot water treatment (HWT) and rapid hot water treatment (RHWT) within (A) and past (B) 24 h after harvest. Vertical lines indicate LSD values at P≤0.05.

was comparable as mangoes achieved table ripe stage on day 8. In within 24 h treatments, control fruit had better quality at the earlier period of storage but as storage progressed up to 14 days, its quality significantly decreased compared to heat treatments.

Marketability (%)

The visual quality of mango greatly affects the percentage of marketability and consumers' preferences. Heat treatments resulted in greater number of visually acceptable fruit as storage progressed, thus saleability of mangoes was also higher (Figure 3). Marketability of fruit was up to 12 and 14 days for HWT and RHWT, respectively. Since HWT and RHWT reduced the severity and incidence of disease in mangoes, it extended marketability of mango. Slightly more marketable fruit remained in fruit treated past 24 h showing 50-65% for HWT and RHWT, respectively compared to 39% when treated within 24 h for both heat treatments.

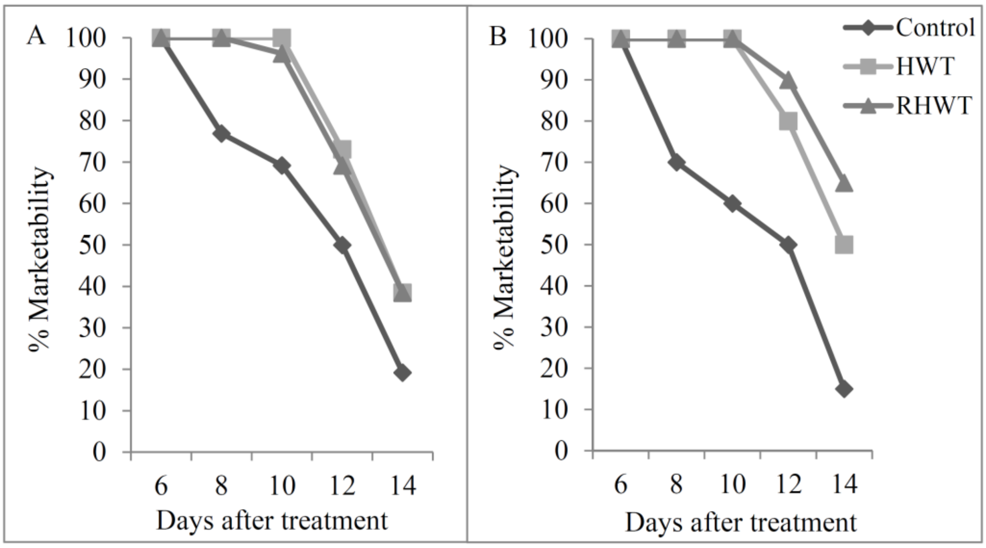

Figure 3. The percentage of marketability of 'Carabao' mango groups subjected to hot water treatment (HWT) and rapid hot water treatment (RHWT) within (A) and past (B) 24 h after harvest.

Disease Severity and Incidence (%)

Anthracnose occurred as early at 5 days in heat-treated fruit within and past 24 h after harvest as fruit attained the table ripe stage (TRS) (Figure 4) where sugar was increasingly available for the organism causing the disease. Heat treatments delayed the occurrence of anthracnose for only one to two days. The severity of anthracnose increased during storage in all treatments but was significantly reduced in all heat-treated samples at 10 days after treatment (DAT). Though exhibiting increasing trend in severity and incidence in both HWT and RHWT, increases were lesser than those observed in control treatments. This showed the efficacy of the heat treatments in controlling postharvest microbial growth resulting in less fruit damage.

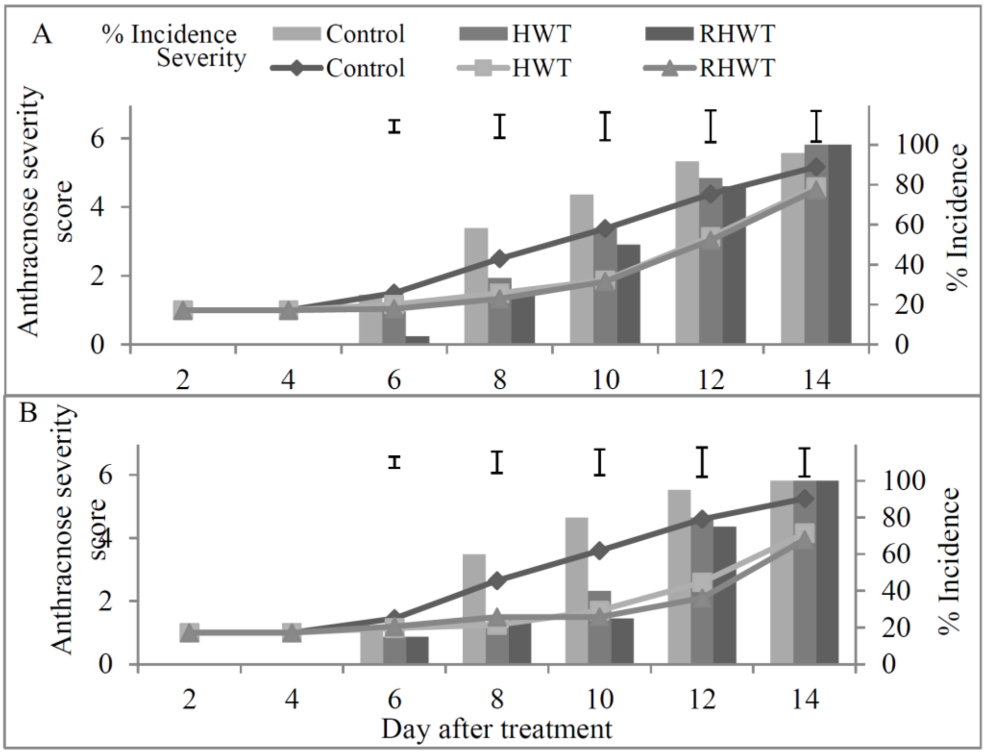

Figure 4. Anthracnose disease severity and incidence (%) in 'Carabao' mango groups subjected to hot water treatment (HWT) and rapid hot water treatment (RHWT) within (A) and past (B) 24 h after harvest. Vertical lines indicate LSD values at $P \leq 0.05$.

On the other hand, stem end rot (SER) increased during storage. The incidence also occurred at 5 DAT in control fruit both in fruit treated within and past 24 h (Figure 5). SER was higher in control than in heat-treated fruit both within and past 24 h after harvest. Heat treatments, HWT and RHWT, inhibited the infection in fruit for four to six days. Moreover, SER incidence was reduced by 33-50% in HWT fruit while 20-25% in the RHWT fruit at 14 DAT. Although incidence was delayed by more than one day, progression of SER was observed to affect marketability and quality of fruit. HWT showed better effect on fruit since SER was greatly delayed by this treatment.

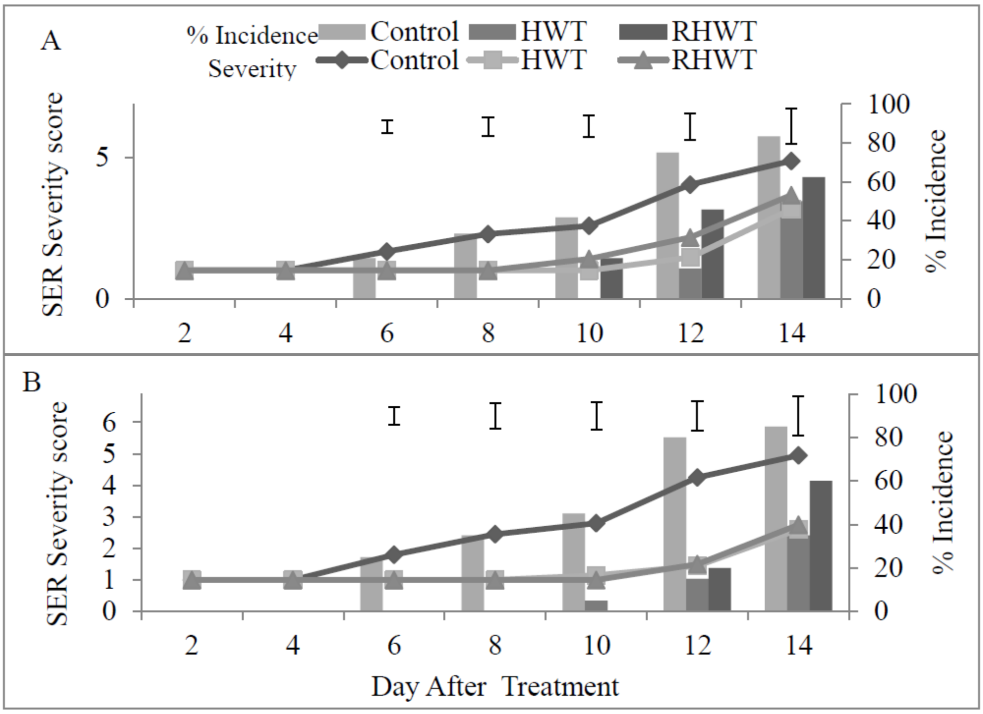

Figure 5. Stem end rot (SER) disease severity and incidence (%) in 'Carabao' mango groups subjected to hot water treatment (HWT) and rapid hot water treatment (RHWT) within (A) and past (B) 24 h after harvest. Vertical lines indicate LSD values at $P \leq 0.05$.

Weight Loss (%)

Heat-treated fruit showed clear increase in weight loss due to rapid rate of ripening. At TRS, weight loss in mango samples treated past 24 h did not vary while fruit subjected to RHWT within 24 h had the least weight loss (Table 1). Mangoes subjected to HWT both within and past 24 h harvest showed higher percentage of weight loss than in control and RHWT. The percentage of weight loss in fruit subjected to HWT was higher (8.59%) than fruit in RHWT (8.11%). The weight loss in fruit treated past 24 h seemed to be lower compared to fruit treated within 24 h.

Table 1. Weight loss at table ripe stage of ‘Carabao’ mango fruit subjected to hot water treatment (HWT) and rapid hot water treatment (RHWT) within and past 24 h.

Treatment	Within 24 h (%)[z]	Past 24 h (%)[z]
Control	8.22[a]	8.07[a]
HWT	8.59[a]	8.30[a]
RHWT	8.11[b]	7.82[a]

[z] Means within a column with common letters are not significantly different at $P \leq 0.05$ using ANOVA.

Discussion

Heat treatments, both hot water treatment (HWT) and rapid hot water treatment (RHWT), hastened ripening of mango fruit since high temperatures increase production of ethylene (Brecht & Yahia 2009). The heat stress caused ripening as shown by rapid color change. The color change from green to yellow was initiated by the transformation of chloroplast to chromoplast (Parikh et al. 1990). Heat-treated fruit were observed to have an increase in color intensity of pulp and peel, which was also similar to the reports of Medlicott et al. (1986) and Esguerra & Lizada (1990). Due to long heat treatment duration, mangoes in HWT had faster color change at 2 to 4 days compared to the control and RHWT.

Lesser incidences of infection contributed to better quality of heat-treated mangoes within and past 24 h after harvest. Although fruit exposed to heat treatment showed better visual quality than the control, lenticel spots or black needle spots were observed on HWT mangoes. Lenticel spots were associated with excess duration in water baths (Chin et al. 2010). Exposure of plants to higher temperatures produce stress response that caused increase in respiration rates, decreased mRNA synthesis and increase in damage to proteins and membranes of plant (Paull & Chen 2000). However, lenticel spotting did not greatly affect the quality of fruit as exposure to heat decreased the incidence of decay that contributed to better quality of heat-treated fruit.

Both HWT and RHWT successfully controlled the increase in disease due to the inhibition of spores responsible for stem end rot (SER) and anthracnose proliferation in the surface of mango. The use of HWT and RHWT reduced the severity of SER in mango samples. The hot water studies of Esguerra et al. (2006) also had the lowest incidence scores of SER in HWT, hot water spray (HWS) and RHWT subjected to mangoes. The application of hot water dipping (55ºC for 5 min) on decay development in mango fruit was reported to induce threefold increase of resorcinol compounds found in fruit which restrained the growth of pathogens (Kobiler et al. 1998). The short duration and high temperature treatment exposure to fruit is believed to disinfect and induce resistance of fruit to pathogens (Pavoncello et al. 2001). Le et al. (2010) also reported the reduction of anthracnose for 6 days in Taiwan native strain mango fruit subjected to hot water at 55ºC for 3 minutes.

Mango fruit are susceptible to pathogen as ripening progress. Ripening in fruit allows the activity of fungus to obtain their energy sources from the fruit's sugar and other nutrients. The fungus *Lasiodiplodia theobromae* is naturally residing on the stem end surface of mangoes and only appears as fruit ripen (Nelson 2008). According to Masqood et al. (2014), among several carbon sources, glucose and sucrose were found superior for growth of SER fungus *L. theobromae*. This explains the occurrence of SER organism when fruit have increasing total soluble solids during ripening.

The growth of *Colletotrichum gloeosporioides* can also be affected by the temperature and relative humidity conditions during storage. Maqsood et al. (2014) reported that temperature ranges from 28 to 30ºC were favorable for the growth and spore production of different isolates of *C. gloeosporioides* grown on a solid medium. The ambient conditions in the laboratory reached almost 28ºC, a favorable condition on the pathogen's growth. However, heat treatments were able to control the growth of pathogens in mango. According to Quimio & Quimio (1974), 53-55ºC dip for 10 minutes can successfully kill spores and mycelia of *C. gloeosporioides*. In the case of RHWT, higher temperature could have readily killed spores and mycelia of the same fungus even for a shorter duration of heat exposure.

Weight loss is generally due to transpiration as ripening increases, which can result in economic and product quality loss. Higher weight loss in HWT was due to faster ripening of mango resulting in the softening of tissues by breakdown of cell membranes. Moreover, lenticel spots were observed in heat-treated mangoes. Likewise, Quimio & Quimio (1974) also observed the lenticel spots as undesirable effect of HWT associated with excess duration in water baths and or excess detergent (Chin et al. 2010). Lenticels in mango fruit have been shown to be responsible for gaseous exchange and transpiration (Rymbai et al. 2012). Thus, the appearance of lenticel spots caused by longer heat treatment might also account for higher transpiration leading to higher weight loss.

On the other hand, RHW-treated fruit were observed to show lower weight loss compared to control and HWT. Alonso et al. (1997) reported that heat pretreatments allowed demethylation of pectin to form anionic carboxyl groups wherein calcium can then form salt bridge links. These salt bridge links or cation cross-bridges restricted fruit from enzymes that cause softening or cell wall-degrading enzymes produced by fungal pathogens (Sams et al. 1993). Initial heat treatment was reported to completely inactivate the enzymes for pectin degradation, however prolonged heat treatment may degrade the pectin via nonenzymatic way resulting in loss of pectin functionality (Diaz et al. 2007).

CONCLUSION

The effect of heat treatment on Philippine 'Carabao' mango was studied by subjecting commercially mature mango fruit to either hot water treatment (HWT) at 52-55ºC for 10 min and rapid hot water treatment (RHWT) at 59-60ºC for 35-60 s. The visual quality of mangoes treated within 24 h and past 24 h after harvest significantly showed better quality scores compared to control. At 10 days, when all mangoes achieved table ripe stage, HWT and RHWT showed better quality of fruit than the untreated fruit. HW-treated fruit exhibited fastest rate of ripening compared to control and RHW-treated fruit. The slowest rate of ripening and color development was observed in control. HW-treated fruit had the highest % weight loss at table ripe stage. Incidence of anthracnose was delayed up to two days in heat-treated fruit within and past 24 h after harvest while the onset of stem end rot (SER) was markedly delayed for four to six days in both treatments. The incidence of SER was reduced by 33-50% and 20-25%, respectively, in HWT and RHWT, in within and past 24 h of treatment after harvest. Both heat treatments, HWT and RHWT, reduced the severity of diseases until 14 days and helped prolong marketability and shelf life of fruit. Subjecting fruit to HWT and RHWT past 24 h after harvest was still able to prolong the shelf life of mango fruit. Since the use of HWT is said to be a bottleneck in mango production in Philippine packinghouses (especially in peak seasons) for export markets, RHWT can be recommended as an alternative postharvest treatment in controlling postharvest diseases and prolonging the shelf life of 'Carabao' mangoes.

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REFERENCES

Alonso, L., Canet, W., Rodriguez, T. (1997): Thermal and calcium pretreatment affects texture, pectinesterase and pectic substances of frozen sweet cherries. Journal of Food Science 62: 511-515.

Alvindia, D. G., Acda, M. A. (2015): Revisiting the efficacy of hot water treatment in managing anthracnose and stem-end rot diseases of mango cv.'Carabao'. Crop Protection 67: 96–101.

Brecht, J.K, Yahia, E.M. (2009): Postharvest Physiology. In: R.E. Litz, editor. The Mango: Botany, Production and Uses. 2nd Edition. CAB International, Wallingford, Oxon., UK. 484–528.

Chin, D., Brown, H., Condé, B., Neal, M., Hamilton, D., Hoult, M., Moore, C., Thistleton, B., Ulyatt, U., Zhang, L. (2010): Field guide to pests, beneficials, diseases and disorders mangoes. Northern Territory Government, Department of Resources, Darwin, Australia, 170p.

Diaz, J.V., Anthon, G.E., Barrett, D.M. (2007): Nonenzymatic degradation of citrus pectin and pectate during prolonged heating: effects of pH, temperature, and degree of methyl esterification. Journal of Agricultural and Food Chemistry 55(13): 5131-5136.

Ekman J.H., Goldwater A., Bayogan, E.V., Secretaria L.B., Lacap, A.T., Lubaton, C.C., Monterde, V.G., Benitez, M.M., Valida, A.D., Sudaria, E.E., Salabao, A.S., Rivera, F.C., Sudaria, M.M., Hinayon, E.P., Joyce, D.C., Anh, S.T., Mott, K., Perkins, M., Bhandari, B. (2019): Improved postharvest management of fruit and vegetables in the Southern Philippines and Australia. Final report part 1 ACIAR HORT 2012/098. Australian Centre for International Agricultural Research. 71p.

Esguerra, E.B., Chavez, S.M., Traya, R.V. (2006): A modified and rapid heat treatment for the control of postharvest diseases of mango (*Mangifera indica* Linn. cv. Carabao) fruits. Philippine Agricultural Scientist 89 (2): 125-133.

Esguerra, E.B., Lizada, M.C.C. (1990): The postharvest behavior and quality of 'Carabao' mangoes subjected to vapor heat treatment. ASEAN Food Journal 5: 6-12.

FAO (2012): Good practice in the design management and operation of a fresh produce packing-house. RAP publication, Food and Agriculture Organization of the United Nations, Regional Office for Asia and the Pacific, Bangkok, 45p.

Haggag, W.M. (2010): Mango diseases in Egypt. Agriculture and Biology Journal of North America 1(3): 285-289.

Jacobi, K.K., MacRae, E.A., Hetherington, S.E. (2001): Postharvest heat disinfestation treatments of mango fruit. Scientia Horticulturae 89: 171–193.

Johnson, G.I., Mead, A.J., Cooke, A.W., Dean, J.R. (1992): Mango stem end rot pathogens - fruit infection by endophytic colonisation of the inflorescence and pedicel. Annals of Applied Biology 120: 225–234.

Johnson, G.I., Coates, L.M. (1993): Postharvest diseases of mango. Postharvest News and Information 4(1): 27N-34N.

Kobiler, I., Reved, R., Artez, L., Prusky, D. (1998): Antifungal compounds regulating quiescent diseases in mango. In Disease Resistance in Fruit. ACIAR Proceedings Series 80, Chiang Mai, Thailand. pp. 109-114.

Le, T.N., Shiesh, C.C., Lin, H.L. (2010): Effect of vapor heat and hot water treatments on disease incidence and quality of Taiwan native strain mango fruits. International Journal of Agriculture and Biology 12: 673–678.

Maqsood, A., Rehman, A., Ahmad, I., Nafees, M., Ashraf, I., Qureshi, R., Jamil, M., Rafay, M., Hussain, T. (2014): Physiological attributes of fungi associated with stem end rot of mango (*Mangifera indica* L.) cultivars in postharvest fruit losses. Pakistan Journal of Botany 46 (5): 1915-1919.

Medlicott, A.P., Bhogol, M., Reynolds, S.B. (1986): Changes in peel pigmentation during ripening of mango fruit (*Mangifera indica* var. Tommy Atkins). Annals of Applied Biology 109: 651-656.

Nelson, S.C. (2008): Mango Anthracnose (*Colletotrichum gloeosporioides*). Cooperative Extension Service, College of Tropical Agriculture and Human Resources, University of Hawaii at Manoa. Plant Desease 2008: PD-48.

Parikh, H.R., Nair, G.M., Modi, V.V. (1990): Some structural changes during ripening of mangoes (*Mangifera indica* var. Alphonso) by abscisic acid treatment. Annals of Botany 65: 121-127.

Paull, R.E., Chen, N.J. (2000): Heat treatment and fruit ripening. Postharvest Biology and Technology 2: 21-37.

Pavoncello, D., Lurie, S., Droby, S., Porat, R. (2001): A hot water treatment induces resistance to *Penicillium digitatum* and promotes the accumulation of heat shock and pathogenesis-related proteins in grapefruit flavedo. Physiologia Plantarum 111: 17-22.

Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development (PCAARD-DOST) (2013): Mango Production Manual. Los Baños, Laguna: PCAARD-DOST, 127p. (PCAARD Book Series No. 1667-C/2013: Reprint).

Quimio, A.J., Quimio, T.H. (1974): Pathogenicity of mango anthracnose. Philippine Agriculturist 58: 333-329.

Rymbai, H., Srivastav, M., Sharma, R.R., Singh, S.K. (2012): Lenticels on mango fruit: origin, development, discoloration and prevention of their discoloration. Scientia Horticulturae 135: 164-170.

Sams, C.E., Conway, W.S., Abbott, J.A., Lewis, R.I., Ben-Shalom, N. (1993): Firmness and decay of apples following postharvest pressure infiltration of calcium and hear treatment. Journal of the American Society of Horticultural Science 18: 623-627.