

EFFECT OF FRUIT HEAT TREATMENT IN THREE MANGO VARIETIES ON INCIDENCE OF POSTHARVEST FUNGAL DISEASE

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SUMMARY

Alternaria alternata, *Botryodiplodia theobromae* and *Botrytis cinerea* were isolated from rotted fruits of mango cultivars Keitt, Kent, and Tommy Atkins, and proved to be highly pathogenic to all these varieties. Preliminary tests showed that dipping fruits in hot water (HW) at 50°C for 5 min or holding in hot air (HA) for 4 h at 40°C did not damage the fruit. Combination of HA for 4 h followed by HW for 5 min (HA + HW) was the most effective treatment for retarding postharvest disease without peel blackening and fruit damage. These heat treatments, especially HA + HW increased the shelf life of inoculated and uninoculated fruits. The quality characteristics of non-inoculated fruits of the three varieties including total soluble solids, titratable acidity and vitamin C contents were not significantly affected by these heat treatments.

Key words: *Alternaria*, *Botryodiplodia*, *Botrytis*, heat treatment, mango.

INTRODUCTION

Mango (*Mangifera indica* L.) is a tropical fruit, in high demand and fetches a good price all over the world. Its susceptibility to postharvest diseases increases during storage as a result of physiological changes and senescence which favor pathogen development (Prusky and Keen, 1993; Prusky, 1996). *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.*, 1981, 1997; Kobiler *et al.*, 1998, 2001). Abdalla *et al.* (2003) found that the most prevalent fungi isolated from Egyptian mango fruits during storage were *Botryodiplodia theobromae*, *Colletotrichum gloeosporioides*, *A. alternata* and *Botrytis cinerea*. Heat treatments such as hot water dipping, vapor heat, hot dry air or combinations of these

have been increasingly used as a quarantine treatment in several studies to retard postharvest fungal damage to fruits and vegetables. Their particular attraction is that they do not involve chemicals (Couey, 1989; Fallik *et al.*, 1996; Lopez *et al.*, 1998; Rodov *et al.*, 2000; Tohamy *et al.*, 2004). The mango is a sub-tropical fruit and thus tolerates heat treatment well (Jacobi and Giles, 1997; Opara and Nguyen, 1999). Jacobi *et al.* (2000) noted that Kensington mangoes were more resistant to postharvest disease and of higher quality after treatment with hot air, hot water or both. The aim of this study was to retard the growth of the fungi prevalently causing postharvest diseases in three mango varieties in orchards and storage. Physical treatments like hot water or hot air or a combination of them were developed to provide disease control. The effect of these treatments on fruit quality was also studied.

MATERIALS AND METHODS

Isolation and identification of the causal organisms.

Fungi were isolated from 90 diseased mango fruits (30 from each variety) of the varieties Keitt, Kent and Tommy Atkins collected from different mango orchards, El-Nobarria region, El-Behira Governorate, Egypt. Pieces of diseased fruit were washed with tap water and surface sterilized with 1% sodium hypochlorite solution for two min, washed twice with sterilized distilled water, then dried using sterile filter paper. The pieces were separately transferred to sterilized Petri dishes containing plain agar (PA) medium and incubated at 25°C for 10 days. Petri dishes were observed daily and colonies of fungi were chosen. The isolated fungi were purified using single spore technique, and then kept in a refrigerator on potato dextrose agar (PDA) medium (Gams *et al.*, 1998). Pure colonies of fungal isolates were identified according to Ellis (1971), Domsch *et al.*, (1980) and Moubasher (1993) and confirmed at the Mycological Research Department, Plant Pathology Research Institute, Agricultural Research Center, Giza, Egypt.

Pathogenicity test and varietal resistance. The isolated

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fungi *B. theobromae*, *A. alternata* and *B. cinerea* were investigated for their pathogenicity on healthy mango fruits of cvs Keitt, Kent and Tommy Atkins varieties. Fruits were washed and surface-sterilized by dipping in the 1% sodium hypochlorite solution for two min then washed several times with sterilized distilled water and allowed to dry. Fruits (three replicates for each fungus, each replicate containing 10 fruits) were wounded at the petiole region with a sterilized needle to 1 mm depth and sprayed with a spore suspension of each of the three fungal isolates at a concentration of 7×10^5 spores ml^{-1} . The inoculated fruits were put in sterilized fiberboard carton and stored at 12°C and 90-95% RH for four weeks.

For the assessment of fruit rots, an empirical scale was employed (0 = healthy fruit; 1 = decayed tissue less than 10%; 2 = from 10% to less than 25% decayed tissue; 3 = from 25% to less than 50% decayed tissue; 4 = from 50% to less than 75% decayed tissue; 5 = decayed tissue more than 75%) and the disease incidence (DI) was determined according to Forsberg (1970) as follows: $\text{DI} = \sum (n \times v) / 5N \times 100$ where: n = the number of affected fruits for each rate; v = rate of disease incidence of the affected fruits; N = total number of fruits; 5 = maximum rate for disease infection.

Preliminary experiment. This experiment was carried out to determine the best temperatures for dipping in hot water or exposure to hot air, without causing fruit blackening (Frith and Chalker, 1983). Fruits, collected from orchards in El-Nobarria region, El-Behira Governorate, Egypt, were healthy, commercially mature based on internal pulp color, similar in weights, uniform in size and appearance. They were washed, drained and randomized for heat treatment. The fruits were immersed in hot water at 45, 50 or 55°C for 5, 10 or 15 min or exposed to hot air at 40, 45 or 50°C for 4, 5 or 6 h. For each treatment 5 fruits per replicate and 3 replicates were used. Peel blackening was recorded for both treatments after four weeks of storage at 12°C and at 90-95% RH as follows: 1- no blackening; 2- negligible blackening (less than 10% damage); 3- slight blackening (from 10% to less than 25% damage); 4- moderate blackening (from 25% to 50% damage); 5- severe injury (over 50% damage).

Heat treatments. Healthy fruits of each variety tested were divided into two lots; one uninoculated (natural infection) and the other artificially inoculated. For artificial inoculation, the surface-sterilized fruits were inoculated with *B. theobromae*, *A. alternata* or *B. cinerea* as described in the pathogenicity test. Twenty-four hours after inoculation each lot was divided into four parts and each part was subjected to one of the following treatments: 1- Hot water (HW): The fruits were dipped in hot water at 50°C for 5 min, cooled at room tempera-

ture, and allowed to dry; 2- Hot air (HA): The fruits were exposed to hot air at 40°C for 4 h, then submerged in plastic containers filled with running tap water (22-23°C) to decrease the fruit temperature below 30°C. The treated fruits were placed outside to dry at room temperature; 3- Hot water + hot air (HW + HA): The fruits were treated with hot water at 50°C for 5 min and then exposed to hot air at 40°C for 4 h; 4- Hot air + Hot water (HA + HW): The fruits were treated with hot air at 40°C for 4 h and then hot water at 50°C for 5 min.

Untreated fruits for each treatment served as controls. Each treatment was replicated three times, each replicate containing ten fruits. All treatments of the uninoculated and artificially inoculated fruits as well as untreated fruits were packed in sterilized fiberboard cartons and stored at 12°C and 90-95% RH. After 4 weeks, DI was calculated for all treatments and the Efficacy (E) of each heat treatment was calculated as follows:

$$E = \frac{\text{DI control} - \text{DI treated}}{\text{DI control}} \times 100$$

Shelf life. After storage at 12°C for 2 or 4 weeks, the uninoculated (natural infection) and artificially inoculated mango fruits, heat treated as above, were kept at $20 \pm 2^\circ\text{C}$. Shelf life was determined as the period (in days) through which the fruits remained healthy at $20 \pm 2^\circ\text{C}$. Development of fruit rot during the shelf life period was determined as DI.

Quality. Surface sterilized healthy uninoculated fruits of each cultivar uniform in size and color were treated with HW, HA, HW + HA and HA + HW as mentioned above and stored at 12°C for 4 weeks. Each treatment was replicated three times, each replicate containing five fruits. At the end of storage period, total soluble salts (TSS) were determined using a hand refractometer, titratable acidity (TA) was determined according to AOAC (1990) and vitamin C by the method of Jemey and Kovacs (1968).

Statistical analysis. The data were statistically analyzed using the completely randomized design in factorial arrangement method as outlined by Steel and Torrie (1980).

RESULTS

Fungi isolated from rotten fruit. Three species belonging to three genera were isolated from rotted fruits of the three varieties (Table 1). *B. theobromae* Patouillard (*Lasiodiplodia theobromae* Pat.) was the commonest fungus on cvs Kent and Tommy Atkins (52.6% and

48.1% frequency), followed by *A. alternata* (Fr.) Keissler (40.9% and 47.3%) and *B. cinerea* Persoon (6.5% and 4.6%), respectively. On cv Keitt *A. alternata* was the most frequent (53.0%), followed by *B. theobromae* (36.6%) and *B. cinerea* (10.4%).

Table 1. Frequency (%) of the fungi causing fruit rot on three mango varieties.

Fungi	Mango variety		
	Keitt	Kent	Tommy Atkins
<i>Alternaria alternata</i>	53.0	40.9	47.3
<i>Botryodiplodia theobromae</i>	36.6	52.6	48.1
<i>Botrytis cinerea</i>	10.4	6.5	4.6

Pathogenicity of isolated fungi. Table 2 shows that *B. theobromae* gave the highest disease incidence on cvs Keitt, Kent, and Tommy Atkins with 81.0, 79.0 and 76.0% respectively followed by *A. alternata* (60.0, 62.0 and 70.0%) while *B. cinerea* had the lowest incidence on the three varieties, 25.0, 24.0 and 18.5%, respectively.

Table 2. Pathogenicity of fungi isolated from rotted mango fruits on the healthy fruits of the three mango varieties. Fruits were inoculated, stored at 12°C for 4 weeks, and then examined for DI determination.

Mango variety	DI		
	<i>A. alternata</i>	<i>B. theobromae</i>	<i>B. cinerea</i>
Keitt	60.0 b	81.0 a	25.0 a
Kent	62.0 b	79.0 ab	24.5 a
Tommy Atkins	70.0 a	76.0 b	18.5 b

The same letters within a column are not significantly different ($P \leq 0.05$). DI = disease incidence calculated as in Materials and Methods.

Effect of heat treatment on peel blackening. Table 3 shows that no blackening occurred on fruits dipped in hot water at 45 and 50°C for 5 min, while the other treatments caused different degrees of blackening which increased with raised water temperature and/or dipping time to 10 and 15 min. The highest degree of blackening was observed at 55°C for 15 min, with slight blackening for Keitt and Kent and moderate blackening for Tommy Atkins. Table 4 shows that exposure to hot air at 40 and 45°C for 4 h did not cause blackening in any variety. Increasing exposure time to 5 or 6 h at these temperatures caused slight and moderate blackening. Severe damage was occurred at 50°C and increased gradually as exposure time increased.

Effect and efficacy of heat treatments on disease incidence on fruits inoculated with *A. alternata*, *B. theobromae* and *B. cinerea*. Table 5 shows that the lowest DI caused by each of the three isolates to the three man-

Table 3. Effect of dipping in hot water on peel blackening of three mango fruit varieties, rated from 1 to 5 (see Materials and Methods).

Temperature °C	Dipping time (min)	Mango variety		
		Keitt	Kent	Tommy Atkins
45	5	1	1	1
	10	1	1	2
	15	1	2	2
50	5	1	1	1
	10	2	2	2
	15	2	2	3
55	5	2	2	2
	10	3	3	3
	15	3	3	4

go varieties, and the highest E of disease treatments were obtained using a combination of HA exposure at 40°C for 4 h followed by dipping in HW at 50°C for 5 min (HA + HW). This treatment significantly decreased DI with each of the three pathogens. It decreased rotting of the inoculated and natural (uninoculated) fruits of cv Keitt from 58.0, 70.0, 32.0 and 30.0 in case of control (untreated) fruits to 1.0, 3.5, 1.0 and 1.3 (E of treatment; 98.3, 95.2, 96.9 and 96.7, respectively). Similar significant results were also obtained with the other two varieties where the E of HA + HW treatment of fruits infected by each of the three pathogens compared with the natural (uninoculated) fruits were 98.6, 93.0, 92.9 and 100% for cv Kent and 98.5, 92.9, 97.1 and 96.4% for cv Tommy Atkin, respectively. The other combined heat treatment (HW + HA) also gave high E, but less than (HA + HW), followed by HW and finally HA treatments for all inoculated and natural (uninoculated) fruits of the three varieties ($P \leq 0.05$).

Table 4. Effect of hot air exposure on peel blackening of three mango fruit varieties, rated from 1 to 5 (see Materials and Methods).

Temperature °C	Exposure time (h)	Mango variety		
		Keitt	Kent	Tommy Atkins
40	4	1	1	1
	5	2	2	2
	6	3	3	3
45	4	1	1	1
	5	2	2	2
	6	3	3	3
50	4	2	2	2
	5	3	3	4
	6	4	4	4

Table 5. Effect of heat treatment on mango fruits inoculated by *A. alternata*, *B. theobromae* or *B. cinerea*, and dipped in hot water (HW), exposed to hot air (HA), hot water + hot air (HW + HA) or hot air + hot water (HA + HW) and stored at 12°C for 4 weeks.

Mango variety	Treatment			Artificially inoculated fruits						Natural (uninoculated) fruits	
	Heat	Temp °C	Time	<i>A. alternata</i>		<i>B. theobromae</i>		<i>B. cinerea</i>		DI	E
				DI	E	DI	E	DI	E		
Keitt	HW	50	5 min	3.7 fg	93.6 d	14.0 ef	80.0 e	10.0 e	68.7 ef	4.4 b	85.3 f
	HA	40	4 h	5.0 ef	91.4 e	16.1 d	77.0 f	11.5 d	64.0 g	6.0 b	80.0 h
	HW+HA	50+40	5 min + 4 h	2.4 gh	95.9 b	9.5 g	86.4 c	7.0 h	78.1 d	3.7 b	87.7 e
	HA+HW	40+50	4 h +5 min	1.0 h	98.3 a	3.5 i	95.2 a	1.0 k	96.9 a	1.3 b	96.7 d
	Control				58.0 c		70.0 b		32.0 b		30.0 a
Kent	HW	50	5 min	4.5 ef	92.9 d	15.0 de	78.9 e	9.0 f	67.8 f	3.8 b	84.8 f
	HA	40	4 h	6.0 de	90.5 f	18.0 c	74.6 g	10.0 e	64.3 g	5.4 b	78.6 h
	HW+HA	50+40	5 min + 4 h	3.0 fg	95.2 bc	10.5 g	85.2 c	8.0 g	71.4 e	1.2 b	95.0 d
	HA+HW	40+50	4 h +5 min	0.9 h	98.6 a	5.0 h	93.0 b	2.0 j	92.9 b	0.0 b	100.0 a
	Control				63.0 b		71.0 b		28.0 c		25.0 a
Tommy Atkins	HW	50	5 min	4.5 ef	93.1 d	13.3 f	82.2 d	2.6 j	92.6 b	4.3 b	84.4 f
	HA	40	4 h	7.5 d	88.5 g	15.0 de	80.0 e	3.8 i	89.1 c	5.2 b	81.4 g
	HW+HA	50+40	5 min + 4 h	3.3 fg	94.9 c	9.5 g	86.8 c	7.0 h	80.0 d	1.3 b	95.4 d
	HA+HW	40+50	4 h +5 min	1.0 h	98.5 a	5.3 h	92.9 b	1.0 k	97.1 a	1.0 b	96.4 c
	Control				65.0 a		75.0 a		35.0 a		28.0 a

The same letters within a column are not significantly different ($P \leq 0.05$)

DI = Disease incidence calculated as in Materials and Methods

E = Efficacy calculated as in Materials and Methods

Table 6. Effect of heat treatments on shelf life of mango fruits uninoculated or after inoculation with *A. alternata*, *B. theobromae* and *B. cinerea*. Shelf life was determined as the period (in days) through which the fruits remain healthy at 20°C after storage at 12°C for 2 or 4 weeks.

Mango variety	Treatment			Artificially inoculated fruits						Natural (uninoculated) fruits	
	Heat	Temp °C	Time	<i>A. alternata</i>		<i>B. theobromae</i>		<i>B. cinerea</i>		2 weeks	4 weeks
				2 weeks	4 weeks	2 weeks	4 weeks	2 weeks	4 weeks		
Keitt	HW	50	5 min	6	4	8	6	9	5	7	5
	HA	40	4 h	4	2	7	4	7	4	5	3
	HW+HA	50+40	5 min+4 h	5	3	9	6	8	3	6	4
	HA+HW	40+50	4 h+5 min	5	4	9	8	10	7	8	5
	Control			2	0	3	0	4	1	2	0
Kent	HW	50	5 min	7	5	4	5	8	6	8	6
	HA	40	4 h	5	3	3	3	5	3	5	5
	HW+HA	50+40	5 min+4 h	6	4	6	5	6	4	6	4
	HA+HW	40+50	4 h+5 min	8	6	8	7	8	5	9	7
	Control			4	0	2	0	3	0	2	0
Tommy Atkins	HW	50	5 min	6	4	5	4	7	5	8	5
	HA	40	4 h	5	3	4	3	4	4	5	4
	HW+HA	50+40	5 min+4 h	4	3	9	6	5	3	7	6
	HA+HW	40+50	4 h+5 min	8	5	10	7	6	5	10	8
	Control			3	0	1	0	3	0	1	0

Table 7. Effect of heat treatment and storage on quality characteristics (total soluble salts, TSS; titratable acidity, TA; vitamin C) of healthy uninoculated mango fruits treated with hot water (HW), exposure to hot air (HA), hot water + hot air (HW+HA) or hot air + hot water (HA+HW) and stored at 12°C for 4 weeks.

Mango variety	Treatment			TSS%	TA%	TSS/TA	Vitamin C, mg/100g fruit
	Heat	Temp. °C	Exposure time				
Keitt	HW	50	5 min	13.9 bc	0.334 b	41.6 gh	35.0 ab
	HA	40	4 h	13.4 c	0.330 b	40.6 h	37.4 a
	HW+HA	50+40	5 min + 4 h	13.8 bc	0.328 bc	42.0 gh	33.9 ab
	HA+HW	40+50	4 h +5 min	14.0 ab	0.321 bcd	43.6 fg	33.6 ab
	Control			14.5 a	0.356 a	40.7 h	33.0 ab
Kent	HW	50	5 min	16.2 b	0.335 b	48.4 bc	35.3 ab
	HA	40	4 h	16.0 b	0.334 b	47.9 bcd	37.6 ab
	HW+HA	50+40	5 min + 4 h	16.2 b	0.331 b	48.9 b	33.6 ab
	HA+HW	40+50	4 h +5 min	16.4 b	0.322 bcd	50.9 a	32.8 ab
	Control			16.9 a	0.360 a	46.9 bcd	31.9 abc
Tommy Atkins	HW	50	5 min	14.0 abc	0.335 b	41.8 gh	32.2 abc
	HA	40	4 h	13.8 bc	0.299 e	46.2 de	33.0 ab
	HW+HA	50+40	5 min + 4 h	13.7 c	0.309 de	44.3 ef	31.7 abc
	HA+HW	40+50	4 h +5 min	14.5 a	0.311 cde	46.6 cd	30.0 bc
	Control			14.3 ab	0.295 e	48.5 bc	25.7 ab

The same letters within a column are not significantly different ($P \leq 0.05$).

Effect of heat treatments on shelf life of inoculated and natural (uninoculated) fruits. The shelf life at 20°C of fruits inoculated mango with *A. alternata*, *B. theobromae* and *B. cinerea* compared with the natural (uninoculated) fruits after 2 and 4 weeks of storage at 12°C is shown in Table 6. It was generally noticed that HA + HW treatment was the most favorable for increasing shelf life. In fact shelf life was higher after two weeks than four weeks of storage. The highest shelf life of fruits treated by HA+HW after two weeks of storage was 10 days for cv Keitt inoculated with *B. cinerea*, "Tommy Atkins" inoculated with *B. theobromae* and that uninoculated. On the other hand, after four weeks of storage the longest shelf life of 8 days was obtained for cv. Keitt inoculated with *B. theobromae* and also treated by HA + HW. For uninoculated fruits treated with HA + HW and stored for four weeks, the highest shelf lives were 8, 7 and 5 days for cvs Tommy Atkins, Kent and Keitt, respectively.

Effect of heat treatments and storage on quality characteristics of healthy uninoculated fruits. TSS, TA, TSS/TA and vitamin C contents in healthy fruits of the three varieties treated with HW, HA, HW + HA and HA + HW and stored for 4 weeks at 12°C are recorded in Table 7. There were no significant differences ($P \leq 0.05$) in TSS, TA and TSS/TA among fruits of the three varieties treated with the different heat treatments as compared with untreated fruits. An exception was cv Kent, where TSS was higher and TSS/TA lower in the control than in heat-treated fruits. On the other hand, vitamin C content in all heat-treated fruits of the three varieties did not significantly differ from that in untreated fruits. Vitamin C content was slightly higher in fruits singly treated with HW or HA than those treated with HW + HA or HA+HW.

DISCUSSION

Disease control treatment will be essential for export mangoes, especially with longer transit times. Storage diseases have the potential to destroy entire consignments if fruits are not treated prior to transport. *A. alternata*, *B. theobromae* and *B. cinerea*, isolated from rotten Keitt, Kent and Tommy Atkins fruits in high frequencies, are the main fungi causing rot of mango fruits. *A. alternata* was isolated in high frequency from cv Keitt, while *B. theobromae* was isolated in high frequency from cvs Kent and Tommy Atkins. The pathogenicity of these isolates was also high. Kobiler *et al.* (1998, 2001) mentioned that *A. alternata* causes black spots and side rots while *Botryodioploidia* spp. (*Lasiodioploidia*) cause stem-end rot of Keitt and Tommy Atkins. An increasing number of overseas markets are no longer permitting chemical dip treatments for fruit entering their countries.

Therefore, physical treatments like hot water are being developed. In our study it was found that dipping in HW at 50°C for 5 min or exposure to HA at 40°C for 4 h did not cause any peel blacking of the three varieties tested, but any further increase in temperature, dipping time or exposure caused peel blacking.

Similarly, Jacobi and Wong (1992), Jacobi *et al.* (1996) and Jacobi and Giles (1997) recommended 53°C for hot water dipping for 5 min as a successful treatment. Also, vapor heat treatment (VHT) at 47°C for 15-20 min was found to be suitable for disease control of Kensington mango (Jacobi and Giles, 1997). Grove *et al.* (1997) noted that immersing any of eight mango cultivars (Tommy Atkins, Irwin, Zill, Neldica, Kent, Keitt, Heidi and Sensation) at 46.1°C for 90 min and refrigerated after 24 h were not damaged, while water temperatures of 48.1°C and higher affected the fruits. Results of Nguyen *et al.* (1998) indicated that HW treatment of Buoi mango at 52°C for 10 min induced higher shrivel incidence while at 52°C for 5 min had potential for reducing postharvest diseases with minimal fruit mass loss and shriveling compared with untreated fruits. Efficacy of heat treatment was higher when HA exposure at 40°C for 4 h was combined with dipping in HW at 50°C for 5 min or vice versa, than HW or HA treatment alone. Also, disease infection was significantly lowered by these treatments compared to control fruits, especially in combination treatments (HA + HW or HW + HA). Jacobi and Giles (1997) found that, 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 fruit alone. Jacobi *et al.* (2000) also found that hot air conditioning at 40°C prior to HW treatment of Kensington mango fruits gave increased resistance to postharvest diseases. Similarly heat protocols have been successfully developed for treating a wide range of mango varieties, including Carabao from the Philippines (Merino *et al.*, 1985), Nang Klangwan from Thailand (Unahawatti *et al.*, 1986), Harumanis from Malaysia (Mohamed *et al.*, 1994) Kensington from Australia (Jacobi *et al.*, 1996) and Buoi from New Zealand (Nguyen *et al.*, 1998). Heat treatment as applied in this work increases the shelf life of fruits artificially inoculated or uninoculated and stored at 12°C for 2 or 4 weeks. Treatment with HA + HW or HW + HA was more effective in increasing shelf life than HW or HA treatment alone. Jacobi and Giles (1997) preferred 22°C as the storage temperature during the entire transit period after VHT to maximize the quality of fruits.

Another response to heat treatment found by Jacobi and Wong (1994) and Jacobi *et al.* (1995, 1996) was that untreated fruit tend to be firmer than heated fruit even at the ripe eating stage. Changes in cell wall composition of ripening mango have been related to the action of cell wall hydrolases. Jacobi and Giles (1997) suggested that

the decrease in Kensington mango fruit firmness following heat treatment might be attributed to an increase in activity of these hydrolases caused by increased temperature. Jacobi *et al.* (2000) showed that conditioning at 40°C prior to HW treatment of 45°C for 30 min or 47°C for 15 min accelerated fruit ripening, increased weight loss, reduced fruit firmness, increased Brix and lowered titratable acidity compared to untreated fruits and fruits receiving other heat treatments.

Further research is urgently required to improve suitable non-chemical protocols for mangoes and other fruits, to minimize the postharvest diseases in line with international quarantine requirements and to ensure that fruit quality remains competitive.

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