INTERNATIONAL JOURNAL OF AGRICULTURE & BIOLOGY
ISSN Print: 1560–8530; ISSN Online: 1814–9596
11–095/DZS/2011/13–5–645–651
http://www.fspublishers.org

Full Length Article

Performance of Hot Water Phytosanitary Treated Mangoes for Intended Export from Pakistan to Iran and China

ABDUL JABBAR, AMAN U. MALIK[1], MUNAZZA SAEED, OMER H. MALIK, MUHAMMAD AMIN, AHMAD S. KHAN, ISHTIAQ A. RAJWANA†, BASHARAT A. SALEEM‡, RABIA HAMEED AND M. SOHAIL MAZHAR
Postharvest Research and Training Centre (PRTC), Institute of Horticultural Sciences; University of Agriculture, Faisalabad (38040), Pakistan
†Department of Horticulture, University College of Agriculture, Bahauddin Zakariyya University, Multan (60000), Pakistan
‡Hill Fruit Research Station, Sunny Bank, Murree (47150), Pakistan
[1]Corresponding author's e-mail: malikaman1@gmail.com

ABSTRACT

A late maturing (End Aug to Mid Sept) Pakistani mango cv. Sufaid Chaunsa has high export potential, particularly in neighboring markets of Iran and China. However, market access is conditional with hot water (HW) phytosanitary treatment protocol for disinfestation of fruit fly as agreed with both countries (Iran: HW dip at 45°C for 75 min; China: HW dip at 48°C for 60 min). Objectives of present studies were to evaluate the effect of obligatory market access protocols on Sufaid Chaunsa mangoes; and to optimize storage temperature (10 & 12°C) under the prospective of shipping the treated mangoes to these countries. For this purpose, uniform mature mangoes were subjected to hot water treatment (HWT) at 45 and 48°C for 75 and 60 min, respectively. Some more fruit were also subjected to HWT of 48°C for 60 min with additional dip of hot carbendazim (40 g/100 L) at 52°C for 5 min. Non-treated fruit were considered as control. Treated fruit were divided into two equal lots and stored at 10 and 12°C (80-85% RH). During storage, fruit peel color and softness were recorded on 21, 27 and 32 days, while disease development, physico-chemical and organoleptic characteristics were assessed at ripe stage. Fruit subjected to HWT (48°C for 60 min) with additional treatment of hot carbendazim (40 g/100 L) at 52°C for 5 min were more firm and had higher levels of total sugars as compared to the fruit of other treatments. Higher fruit peel color development score (after 21, 27 & 32 days of storage) and higher total carotenoid levels (at ripe stage) were recorded in fruit stored at 12°C, irrespective of HW treatment effect. Higher titratable acidity was recorded in fruit subjected to HWT at 45°C for 75 min at 10°C storage. Among organolaptic characteristics, better pulp color score with better taste, texture and aroma was recorded in fruit stored at 10°C by the taste panel. HW treated fruit showed lesser anthracnose incidence as compared to fruit with no treatment. In conclusion, HW phytosanitary protocols for export of mango to Iran and China had no negative effect on fruit quality attributes of cv. Sufaid Chaunsa; and 10°C was found as the better shipping temperature. However, control of diseases especially stem end rot is critical and aroma volatile production warrants further research for successful sea shipments for export of this cultivar.

Key Words: Mango; Quarantine; Trade; Quality; Hot water treatment; Disease

INTRODUCTION

Mangoes fruit is admired globally for excellent taste, flavour and nutritive value; while cultivated mainly in tropical and subtropical countries. Apart from its dietary significance (amino acids, carbohydrates, fatty acids, minerals & organic acids), the fruit also contains antioxidant properties and phenolic compounds (Shivashankara *et al.,* 2004), which are believed to be associated with reduction in the incidence of cardiovascular diseases and cancer (Soong & Burlow, 2004). Pakistan being the fourth-leading exporter of mangoes in the world (Anonymous, 2006) enjoys prominent position in the international markets due to the unique taste and pleasant aroma of its mango fruit. Presently, ethnic population in Europe, Middle East and rest of the world are the prime consumers of Pakistani mango, yet the trade necessitates more affluent consumers with better paying capacity. Iran (oil rich country) and China (world's largest population & fastest growing economy) are the new emerging markets for Pakistani mangoes. However, the mango industry needs to conform to the prescribed quality standards throughout the supply chain and manage quarantine issues. Management of fruit fly by spraying insecticides can lead to health issues as synthetic chemicals have enduring adverse effects on human health (Lichtenberg & Zilberman, 1987) and environment (Weaver *et al.,* 1990). Worldwide research efforts are under way to develop non-chemical control strategies to manage these issues. Hot water treatments are economical mean for quarantine quality maintenance (43-49°C for 60-90 min), along with

To cite this paper: Jabbar, A., A.U. Malik, M. Saeed, O.H. Malik, M. Amin, A.S. Khan, I.A. Rajwana, B.A. Saleem, R. Hameed and M.S. Mazhar, 2011. Performance of hot water phytosanitary treated mangoes for intended export from Pakistan to Iran and China. *Int. J. Agric. Biol.,* 13: 645–651

dipping in hot fungicides (at 52-55˚C for 2-5 min) like carbendazim and Prochloraz, is also found as efficient means of manipulating mango postharvest diseases (Jeffries *et al.,* 1990; Crane & Campbell, 1991; Dang *et al*., 2008). However, tolerance to hot water treatment and its effects on shelflife and quality may vary with variety, maturity and treatment conditions (Iqbal, 2007; Dang *et al*., 2008).

Another aspect is short shelf life of mango, which limits its distant market opportunities. Cold storage or shipping at low temperature is an option for extending its consumption period, regulating market supplies and transporting to distant markets (McLauchlan & Wells, 1994). However, physiological changes after harvest and during prolonged storage result in increased incidence of disease development (Eckert *et al*., 1996), yet if properly handled and stored/shipped at optimum temperature, extension in shelflife is possible. Studies show that storage temperatures below 12°C may cause chilling injury in some cultivars, which drastically reduce fruit quality and increase spoilage (Medlicott, 2003; Nair & Singh, 2009).

Pakistan has already signed HWT phytosanitary protocols with Iran (HWT 45°C for 75min) and China (HWT 48°C for 60min) (Anonymous, 2005) paving the way for export of mangoes to these new lucrative markets. Additionally, being a neighboring country, Pakistan has a geographical advantage to export mango by road or sea to Iran and China. Overtime, there has been increased interest of industry in exporting a late season (End August to Mid September) mango cv. Sufaid Chaunsa, characterized by large fruit size (500 g), which makes it preferred choice in import markets. However, it is imperative to provide confidence to industry by evaluating the effect of HW phytosanitary treatment protocol, since many of the mangoes have limited shelf life (Anwar & Malik, 2007; Dang *et al*., 2008; Anonymous, 2009). Furthermore, in order to realize the potential of this cultivar for offshore shipments, the optimum storage conditions also need to be determined. Previously, there have been no studies on this cultivar in this regard.

The objectives of this study were to evaluate the effect of HW phytosanitary treatment as per protocol signed with Iran and China, on shelflife and fruit quality of mango cv. Sufaid Chaunsa, as well as to evaluate the performance of fruit at two different storage temperatures (i.e., 10°C & 12°C) at different storage durations.

MATERIALS AND METHODS

Fruit sampling and treatment application: The study followed two factor factorial arrangements under Completely Randomized Design (CRD) along with three replicates (experimental unit of 21 fruit). At anticipated physiological maturity, uniform sized mango fruit of cv. Sufaid Chaunsa were harvested along with 4-6 cm long pedicels intact, from a commercial orchard located in district Multan (latitude: 30°12`N; longitude: 71°26`E; altitude: 710 feet above mean sea level), Pakistan. After desapping (1.0% lime solution, 2-3 min), the fruit were packed in cardboard boxes and transported to Postharvest Research Centre, Ayub Agricultural Research Institute (AARI), Faisalabad for HW phytosanitary treatment and storage. The treatments included Control, Iran protocol (HWT 45°C for 75 min), China protocol (HWT 48°C for 60 min) and China protocol + HWT 52°C with Carbendazim @ 40 g/100 L for 5 min. Each treatment contained sixty fruit (20 fruit in each replicate). After HW phytosanitary treatment, fruit were air dried and re-packed in cardboard boxes and divided into two lots to store at 10°C and 12°C (80-85% RH). During storage, fruit firmness and peel color development data was recorded at 21, 27, 32 days interval. After 32 days, fruit were moved out from both storage temperatures and kept at room temperature (25°C±2) for ripening. At ripe stage (after 4 days of shelf), the data was recorded regarding fruit firmness, peel color, physico-chemical and organoleptic characteristics, along with diseases and disorder development.

Data Collection

Fruit softness and peel color development ratings: A rating scale of 1-5 was used for estimation of peel color (1= 100% green, 2= 1-25% yellow, 3= 26-50% yellow, 4= 51-75% yellow & 5= 75-100% yellow) and fruit softness (1= hard, 2= sprung, 3= slightly soft, 4= eating soft & 5= over ripe) (Miller & McDonald, 1991).

Assessment of postharvest diseases and disorders: Postharvest diseases like anthracnose (1- No fruit lesions; 2- 1 to 3 fruit lesion; 3- 4 to 6 fruit lesions; 4- 7 to 15 fruit lesions & 5- >30% fruit surface covered with lesions) and stem end rot [1- None; 3- Traces (after careful observation); 5- Slight; 7- Moderates and 9- Severe] were recorded as described by Akhtar and Alam (2002). Internal discoloration was recorded as scale; 1-25% affected area; 2-50% affected area; 3-75% affected area and 4-100% affected area.

Bio-chemical characteristics and organoleptic evaluation: Total soluble solids (TSS) were determined using digital stage refractometer (Atago, RX 5000, Japan). A drop of juice and placed on clean prism of refractometer and the lid was closed. Reading was taken directly from the scale at room temperature. Total titratable acidity and sugars (total sugars, reducing & non-reducing sugars) were determined as stated by Hortwitz (1960) and Malik and Singh (2006). Vitamin C contents were determined by 2, 6-Dichlorophenol Indophenol's titration method as stated by Malik and Singh (2005). Total carotenoids were estimated following the method of Lalel *et al.* (2003) and were expressed as mg/g of β-carotene equivalent from a standard curve of b-carotene. Organoleptic characteristics (pulp color, taste, flavor, texture and aroma) evaluation of the fruit was done by a panel of ten judges, using the 9 point Hedonic scale, 9 being 'like extremely' and 1 as 'dislike extremely' (Jacobi & Wong, 1991).

Data analysis: The experimental data were subjected to analysis of variance (ANOVA) under two factor factorial arrangements (treatments vs storage temperature) using Genstat Release 8.2 (Lawes Agricultural trust, Rothmsted Experimental Station, UK) running separate analysis at 21, 27 and 32 days of storage and at ripening (4 days after shelf). Least significant difference (Fisher's protected LSD) was calculated following significant F test ($P \leq 0.05$). The validity of ANOVA was confirmed by checking all the assumptions of analysis.

RESULTS AND DISCUSSION

Fruit firmness: Fruit firmness is a basic criterion to examine the fruit ripening stage during prolonged storage of mango fruit at low temperature. Data were recorded after 21, 27 and 32 days of mango storage and at ripe stage. Effect of HW on fruit firmness compared with control was significant at ripe stage, while after 21, 27 and 32 days of storage the effect was statistically non-significant. At ripe stage, fruit subjected to HWT (48°C for 60 min) followed by hot carbendazim dip (52°C for 5 min) were significantly more firm (3.77 softness score) as compared to control (4.12) (Table I).

Effect of storage temperatures (10 & 12°C) on fruit firmness during storage was highly significant after 27 and 32 days of storage, while at ripe stage the effect was statistically non-significant. Overall, the fruit stored at 10°C expressed better firmness (Table I). The interaction effect of HWT and storage temperature (10 & 12°C) on fruit firmness was statistically non-significant after 21, 27 and 32 days of storage, while at ripe stage the interaction effect was significant. Higher fruit firmness (3.53) was observed in fruit with HWT at 48°C for 60 min stored at 10°C, at ripe stage followed by fruit with HWT at 48°C for 60 min plus hot carbendazim dip (52°C for 5min), compared to control.

Fruit subjected to HWT at 48°C for 60 min alone and/or in addition with hot carbendazim dip (52°C for 5 min) remained more firm compared to other treatments. Previously, an increase in ripening with HWT and decrease in flesh firmness was reported (Yahia & Pedro-Campos, 2000; Jacobi *et al.,* 2001), but Swart *et al.* (2002) found that hot water treatments incorporating fungicides extended shelf life of mango fruit during overseas shipments, by protecting mango against postharvest pathogen infection. Our results coincide with the findings of Swart *et al.* (2002), since HW treatment (48°C for 60 min) followed by hot water fungicide dip (52°C with Carbendazim- 5 min) retained better fruit firmness and hence showed potential for extended shelf life. Better fruit firmness at lower storage temperature could be explained on the basis that lower storage temperature retards ripening related changes (Kader, 2008) and thus fruit at 10°C had better firmness compared to those at 12°C, as earlier suggested by Pathak (2007) for another related mango cultivar.

Fruit peel color: Effect of different HWT on fruit peel color development was statistically non significant, while storage temperature (10 & 12°C) showed significant effects on fruit peel color development after 21, 27 and 32 days of storage (Table II). The data showed that fruit peel color development score was significantly higher in fruit stored at 12°C as compared to those stored at 10°C after 21, 27 and 32 days of storage (Table II). The interaction effect of HWT and storage temperature on fruit peel color development showed significant results only after 21 and 27 day of storage, while after 32 days and at ripe stage, it was statistically non significant. Fruit stored at 10°C after HWT at 48°C for 60 min followed by hot carbendazim dip at 52°C for 5 min; showed minimum fruit peel color development after 21 (1.08) and 27 days (1.25) of storage as compared fruit stored at 12°C as well as control. However, the fruit of same treatment exhibited maximum fruit peel color development when stored at 12°C after 21 (2.43) and 27 days (3.27) (Table II), indicating the critical role of storage temperature.

During normal ripening process, mango skin color changes from green to yellow; this involves a loss of chlorophyll and biosynthesis of other pigments (e.g., carotenoids). It appears that storage at low temperature slows down the fruit ripening process and thus peel color development is also lower in fruit stored at 10°C than those held at 12°C. In this regard, Govender *et al.* (2005) found that low temperature stored mango fruit (subjected to biocontrol-Prochloraz with HW combination) at 10°C with 91% RH and then ripened at 20°C (75% RH) for 7 days, retained fruit color and firmness effectively. Fruit subjected to HW treatment of 48°C-60 min plus hot carbendazim dip at 52°C for 5 min, exhibited delayed peel color development when stored at 10°C. Previous studies report that fruit peel color development is usually enhanced by HWT at higher temperature (Jacobi & Wong, 1991), but in this experiment, effect of storage temperature on fruit color is also evident. According to Lizada *et al.* (1986), the application of HWT to fruit did not alter the pattern of postharvest skin color changes irrespective of the degree of fruit maturity. On the other hand, Anwar and Malik (2006) reported that HW treated Sindhri mangoes had more peel color development indicating the impact of HW quarantine treatment on mango fruit ripening process without any negative effect on shelf life. Likewise, low temperature storage is known to increase shelf life (Kader, 2008). In context of storage temperature, Ueda (2001) observed no change in respiration rate of mango fruit stored at 10°C for up to 10days. Our results are in line with these studies, since minimum fruit peel color development at 10°C and higher firmness (as discussed before); indicate a retardation of ripening process at lower temperature with shelflife extension potential.

Total titratable acidity: HW treatments and storage temperature (10°C & 12°C) showed statistically significant effect on total titrable acidity of mango fruit (Table III). Higher percentage of total titrable acidity (0.47%) was recorded in fruit having HWT of 45°C for 75 min (Iran

Table I: Effect of hot water phytosanitary treatments and storage temperatures on fruit softness after different intervals of storage in mango cv. Sufaid Chaunsa

Treatment (TRT)	Storage period											
	21 days			27 days			32 days			Ripe stage		
	10°C	12°C	TRT Mean	10°C	12°C	TRT Mean	10°C	12°C	TRT Mean	10°C	12°C	TRT Mean
Control (No HWT)	1.03	1.22	1.12	1.07	1.58	1.33	1.09	1.75	1.42	4.23a	4.00a	4.12A
HW 45°C-75 min	1.10	1.07	1.08	1.10	1.13	1.12	1.13	1.23	1.18	4.13a	4.00a	4.07A
HW 48°C-60 min	1.00	1.00	1.00	1.00	1.13	1.07	1.00	1.13	1.07	3.53b	4.00a	3.82B
HW 48°C-60 min+Carbendazim dip, 52°C-5 min	1.00	1.10	1.05	1.00	1.40	1.20	1.00	1.58	1.29	3.63b	4.00a	3.77B
Mean (Storage temp.)	1.03	1.09		1.04B	1.31A		1.06B	1.42A		3.88	4.00	

Mean not sharing any letter are significantly different (P≤0.05); Small letters used for interaction effects, while capital letters for HWT and storage temperature effects

Table II: Effect of hot water phytosanitary treatments and storage temperatures on fruit peel color after different intervals of storage in mango cv. Sufaid Chaunsa

Treatment (TRT)	Storage period											
	21 days			27 days			32 days			Ripe stage		
	10°C	12°C	TRT Mean	10°C	12°C	TRT Mean	10°C	12°C	TRT Mean	10°C	12°C	TRT Mean
Control (No HWT)	1.25c	1.90ab	1.57	1.78de	2.53abc	2.16	2.15	2.82	2.48	4.27	4.37	4.32
HW 45°C-75 min	1.63bcd	1.67bc	1.65	1.97cde	2.47bcd	2.22	2.30	2.53	2.42	4.20	4.33	4.27
HW 48°C-60 min	1.27cd	1.87b	1.57	1.70e	2.83ab	2.27	2.20	3.07	2.63	4.07	4.17	4.12
HW 48°C-60 min+Carbendazim dip, 52°C-5 min	1.08d	2.43a	1.76	1.25e	3.27a	2.26	1.70	3.33	2.52	4.07	4.48	4.26
Mean (Storage temp.)	1.31B	1.97A		1.67B	2.77A		2.09B	2.94A		4.15	4.34	

Mean not sharing any letter are significantly different (P≤0.05); Small letters used for interaction effects, while capital letters for storage temperature effects

Table III: Effect of hot water phytosanitary treatments and storage temperatures on TSS, total titrable acidity, vitamin C and total carotenoids, at ripe stage, in mango cv. Sufaid Chaunsa

Treatment (TRT)	TSS (°Brix)			Total titrable acidity (%)			Vitamin C (mg/100ml)			Total Carotenoids (µg/g)		
	10°C	12°C	TRT Mean	10°C	12°C	TRT Mean	10°C	12°C	TRT Mean	10°C	12°C	TRT Mean
Control (No HWT)	22.64	21.41	22.03	0.44	0.37	0.41B	41.3	41.3	41.3	70.3	80.1	75.2
HW 45°C-75 min	21.58	21.07	21.33	0.51	0.43	0.47A	45.3	44.0	44. 7	78.6	80.0	79.3
HW 48°C-60 min	22.49	20.45	21.47	0.43	0.42	0.42B	40.0	41.3	40.7	65.5	97.1	81.3
HW 48°C-60 min + Carbendazim dip, 52°C-5 min	21.50	22.90	22.20	0.47	0.40	0.44AB	42.7	40.0	41.3	75.7	89.9	82.8
Mean (Storage temp.)	22.05	21.46		0.46A	0.41B		42.3	41.7		72.5B	86.8A	

Mean not sharing any letter are significantly different (P≤0.05); Small letters used for interaction effects, while capital letters for HWT and storage temperature effects

Table IV: Effect of hot water phytosanitary treatments and storage temperatures on sugars (reducing, non-reducing and total) at ripe stage, in mango cv. Sufaid Chaunsa

Treatment (TRT)	Reducing sugars (%)			Non-reducing sugars (%)			Total sugars (%)		
	10°C	12°C	TRT Mean	10°C	12°C	TRT Mean	10°C	12°C	TRT Mean
Control (No HWT)	3.94	3.19	3.57	13.88	11.22	12.55	18.56ab	15.00c	16.78
HW 45°C-75 min	3.95	3.82	3.88	12.66	12.45	12.55	17.27abc	16.92abc	17.10
HW 48°C-60 min	3.50	3.49	3.49	12.27	13.62	12.94	16.42abc	17.82abc	17.12
HW 48°C-60 min+Carbendazim dip, 52°C-5 min	3.48	3.49	3.49	11.49	14.77	13.13	15.57bc	19.04a	17.31
Mean (Storage temp.)	3.72	3.49		12.58	13.01		16.96	17.20	

Mean not sharing any letter are significantly different (P≤0.05); Small letters used for interaction effects

protocol) as compared to control. Percentage of total titrable acidity in other HW treatments was statistically at par with each other.

As far as the effect of storage temperature is concerned, higher total titrable acidity percentage (0.46%) was recorded in fruit stored at 10°C as compared to those stored at 12°C (0.41%) (Table III). The result of total titrable acidity (%) for the interaction effect of different HWT's and two different storage temperatures was statistically non-significant. Previously, HW did not show significant effect on total titrable acidity, pH and total sugars (Ram *et al.*, 1983), Likewise, Anwar and Malik (2006) also revealed that ripening process in cv Sindhri is slightly affected by HWT, which does not exhibit any significant effect on shelf life of mango fruit. During ripening, the acidity is reduced, while sugar contents increased since

Table V: Organoleptic characteristics of mango cv. Sufaid Chaunsa fruit as affected by hot water phytosanitary treatments and storage temperatures

Treatment (TRT)	Pulp color			Taste			Flavor			Texture			Aroma		
	10°C	12°C	TRT Mean	10°C	12°C	TRT Mean	10°C	12°C	TRT Mean	10°C	12°C	TRT Mean	10°C	12°C	TRT Mean
Control (No HWT)	6.25	4.81	5.53	5.94	4.67	5.31	6.00	4.89	5.44	5.92	5.03	5.47	6.00	5.17	5.58
HW 45°C-75 min	5.78	6.06	5.92	5.78	5.78	5.78	5.92	7.33	6.62	5.86	5.64	5.75	5.77	5.50	5.63
HW 48°C-60 min	6.28	6.00	6.14	6.33	5.81	6.07	6.06	5.64	5.85	6.08	5.61	5.85	5.87	5.47	5.67
HW 48°C-60 min+ Carbendazim dip, 52°C-5 min	6.19	4.81	5.50	5.89	4.67	5.28	5.67	5.00	5.33	5.56	5.08	5.32	5.70	5.00	5.35
Mean (Storage temp.)	6.12A	5.42B		5.99A	5.23B		5.91	5.72		5.85A	5.34B		5.83A	5.28B	

Mean not sharing any letter are significantly different ($P \leq 0.05$); Capital letters used for storage temperature effects

Table VI: Effect of hot water phytosanitary treatments and storage temperature on diseases and internal discoloration of mango cv. Sufaid Chaunsa

Treatment (TRT)	Anthracnose			Stem end-rot			Internal discoloration		
	10°C	12°C	TRT Mean	10°C	12°C	TRT Mean	10°C	12°C	TRT Mean
Control (No HWT)	2.06	1.77	1.92A	3.33	2.69	3.01	0.00b	0.43a	0.22A
HW 45°C-75 min	1.08	1.17	1.13B	1.08	2.92	2.00	0.00b	0.00b	0.00B
HW 48°C-60 min	1.15	1.08	1.11B	1.00	2.17	1.58	0.00b	0.00b	0.00B
HW 48°C-60 min + Carbendazim dip, 52°C-5 min	1.563	1.25	1.41B	2.67	1.50	2.08	0.00b	0.00b	0.00B
Mean (Storage temp.)	1.464	1.32		2.02	2.32		0.00 B	0.11A	

Mean not sharing any letter are significantly different ($P \leq 0.05$); Small letters used for interaction effects, while capital letters for HWT and storage temperature effects

organic acids are converted into sugars. As the low temperature storage slows down the ripening process (Kader, 2008), that is why the fruit stored at 10°C had higher percentage of total titrable acidity than fruit stored at 12°C.

Sugars: Effect of HWT and storage temperatures on total sugars was statistically non-significant (Table IV). While the interaction effect of storage temperatures with different HW treatments on total sugars of mango fruit after storage was significant. Maximum total sugars (19.04%) were recorded in fruit subjected to HWT at 48°C for 60 min plus hot carbendazim dip at 52°C for 5 min and then stored at 12°C compared to control (15.00%), stored at the same temperature. The total sugars in fruit subjected to Iran (HWT at 45°C for 75 min) and China (HWT at 48°C for 60 min) protocol and then stored at 10°C and 12°C were statistically at par among each other (Table IV).

It is obvious that irrespective of country (Iran or China); phytosaniatry treatments did not affect sugar contents in Sufaid Chaunsa cultivar. However, an additional higher temperature exposure for disease control (HWT at 48°C for 60 min plus hot carbendazim dip at 52°C for 5 min) affected the internal metabolic process leading to higher sugar conversion, when fruit were stored at higher temperature (12°C compared to 10°C). Higher hot water temperature plus higher storage temperature resulted in increased ripening process. During ripening process, sugar production is due to hydrolysis of starch granules in the chloroplast, which continues until ripening. A previous study on cv Sindhri did show that HWQT resulted in low sugar production compared to control, possibly by hindrance the normal metabolic process of starch hydrolysis (Anwar & Malik, 2007) however, this was not found in Sufaid Chaunsa, which may be due to varietal difference.

Effect of HWT and storage temperature on reducing and non-reducing sugars was statistically not significant.

Vitamin C and TSS: Results for the effect of HWT and storage temperatures on TSS and vitamin C were statistically non-significant (Table III).

Total carotenoids: Effect of HWT on total carotenoids was statistically non-significant; however, storage temperature had significantly effect in this regard (Table III). Maximum total carotenoids (86.8 μg/g) were estimated in fruit stored at 12°C as compared to the fruit stored at 10°C (72.5 μg/g). At higher storage temperature (12°C), the process of ripening seems to be at comparatively higher rate compared to lower storage temperature (10°C), so that resulted in higher total carotenoids biosynthesis in fruit. Previous report also mention that low temperature retains green coloration for longer period and affects total carotenoid contents during storage (Medlicott *et al.,* 1986), while Yahia and Pedro-Campos (2000) studied that total carotenoid contents were higher in fruit at 20°C than stored at 10°C. Likewise, Thomas and Oke (1983) reported that after ripening fruit had poor flavor and carotenoids development, when fruit stored at 10°C for 30 days. This phenomenon may be due to varietal effect and HW treatments difference. Results for the effect of HWT and storage temperatures interaction on total carotenoids were statistically non-significant (Table III).

Organoleptic characteristics: Results for the effect of HWT, and its interaction with storage temperature on organoleptic characteristics were non-significant (Table V). However, the effect of storage temperature on pulp color, taste, texture and aroma of ripened mango fruit after storage was significant. Better pulp color (6.12), taste (5.99), texture (5.85) and aroma (5.83) were observed in fruit, which were stored at 10°C as compared to 12°C (Table V).

Storage of fruit at lower temperature maintains postharvest quality and increases the shelf life (Kader, 2008). Organoleptic evaluation revealed that lowering the temperature from 12 to 10°C significantly improved fruit quality of cv. Sufaid Chaunsa, which shows its good potential for long distance export under refrigerated conditions.

In contrary to these results of better texture at 10°C at ripe stage, Thomas and Oke (1983) reported that Alphonso mangoes developed chilling injury (CI) as pitting after storage at 10°C for 30 days. After ripening, fruit had poor flavour and carotenoids development. This difference may be due the varietal potential for low temperature endurance during extended storage.

Diseases and disorders: HWT showed significant effect in controlling anthracnose incidence in mango during storage (Table VI). Significantly higher anthracnose incidence (1.92) were recorded in control fruit (with no HWT), while anthracnose incidence in fruit subjected to Iran (HWT at 45°C for 75 min) and China (HWT at 48°C for 60 min) protocol and then stored at 10°C and12°C were statistically at par among each other (Table VI). The interaction effects (HWT x storage temperature) regarding anthracnose were statistically non-significant. The result shows that besides being used as quarantine treatments, hot water treatments also have positive effect in reducing anthracnose, a critical postharvest disease.

Results for the effect of HWT and storage temperatures on the incidence of stem end-rot of mango fruit were non-significant. All the treatments had score of 1.58 to 3.01, with highest being in fruit of control treatment (Table VI). Previous reports also showed that HWQT gives inconsistent control of stem end rot in cv. 'Kensington Pride', which can cause severe losses in mango (Coates *et al.,* 1993). This is because the heat treatments are non-residual and do not provide residual control in storage as does a fungicide/heat treatment combination. In this experiment, even an additional hot water treatment with fungicide did not significantly reduce the stem end rot incidence, which warrants search for alternate fungicide and disease control strategies for long distance shipment of mango cv Sufaid Chunsa. The strategies may involve inoculum reduction (tree hygiene, using more effective fungicide-new chemistry, at pre & postharvest stages) and exploring controlled atmosphere, which also show potential for long distance shipments.

Internal discoloration: HWT exhibited significant effect on internal discoloration (browning) of mango fruit pulp color during storage (Table VI). Internal discoloration incidence score was recorded only in control fruit (with no HWT) stored at 12°C, while no incidence was observed in other treatments at both storage temperatures (10 & 12°C). This clearly shows that storage temperature has significant effect on ripening process and internal discoloration of fruit during prolonged period of storage. The interaction effect of storage temperatures with HWT on internal discoloration of mango fruit after storage was also significant. Maximum internal discoloration incidence score (0.44) was observed in fruit of control treatment (with no HWT) stored at 12°C (Table VI). Overall, the results showed that fruit without any HWT stored at 12°C for longer period of time (32 days) may develop internal discoloration. Postharvest storage temperature affects the development of internal browning in mango fruit pulp. Incidence and severity of internal browning increased as the postharvest storage period of fruit stored at 13 and 18±1°C was extended (Acosta *et al.,* 2000).

CONCLUSION

The results indicate that HWQT (Iran:45°C-75 min; China: 48°C-60 min) for export of mango cv Sufaid Chaunsa, to Iran and China, has no negative effect on quality attributes, rather helps to reduce anthracnose incidence and internal discoloration during storage. Furthermore, cv Sufaid Chaunsa showed better performance at storage temperature of 10°C compared to 12°C, with regard to physico-chemical and organoleptic fruit quality at ripening. However, for successful export of Sufaid Chaunsa mangoes to Iran and China, using reefer containers, it will be critical to control postharvest disease development especially stem end rot through pre and postharvest strategies, which needs further research.

Acknowledgement: We thank Pakistan Horticulture Development and Export Company (PHDEC) for providing financial assistance to conduct this study, and staff at Postharvest Research Center, Ayub Agricultural Research Institute (AARI), Faisalabad, Pakistan, for their cooperation and provision of cold storage facility.

REFERENCES

Acosta, R.M., A.D. Neito, N.G. Mena, O.D. Teliz, H.H. Vaquera and A.R. Neito, 2000. Effect of postharvest temperature on the development of internal darkening in mango fruits (*Mangifera indica* L.) cv Haden and their quality. *Acta Hort.,* 509: 401–412

Akhtar, K.P. and S.S. Alam, 2002. Assessment keys for some important diseases of mango. *Pakistan J. Bot.,* 5: 246–250

Anonymous, 2006. *Federal Bureau of Statistics*, Government of Pakistan, Karachi, Pakistan

Anonymous, 2005. *Mango Export to Iran from Next Month*; *The Dawn, 27th June 2005*. http://www.dawn.com/2005/06/27/naT22.htm

Anonymous, 2009. *PHDEB News: Mango Exports*: http://www.phdeb.org.pk/index.php?id=d3d9446802a44259755d38e6d163e 820&newsid=2006. Website visited: 22nd April 2009

Anwar, R. and A.U. Malik, 2007. Hot water treatment affects ripening quality and storage life of mango (*Mangifera indica* L.). *Pakistan J. Agric. Sci.,* 44: 304–311

Anwar, R. and A.U. Malik, 2006. Effect of hot water treatment and storage duration on shelf life and quality of Pakistani mango (*Mangifera indica* L.) cv Sindhri. *27th Int. Horticul. Congress and Exhibition (IHC), Korea*, p: 258. Abstract book

Coates, L.M., G.I. Johnson and A.W. Cooke, 1993. Postharvest disease control in mangoes using high humidity hot air fungicide treatment. *Ann. Appl. Biol.,* 123: 441–448

Crane, J.H. and W.C. Campbell, 1991. *The Mango*. Florida Cooperative Extension Service, Inst. Food and Agricultural Sciences, University of Florida

Dang, K.T.H., Z. Singh and E.E. Swinny, 2008. Impact of postharvest disease control methods and cold storage on volatiles, color development and fruit quality in ripe 'Kensington Pride' mangoes. *Agric. Food Chem.,* 56: 10667–10674

Eckert, J.W., M. Ratnayake, J.R. Sievert and R.R. Strange, 1996. Curing citrus fruit to control postharvest diseases. *In: Proc. VIII Congress Int. Soc. Citriculture*, Vol. 48. Sun City, South Africa

Govender, L., L. Korsten and D. Sivakumar, 2005. Semi-commercial evaluation of Bacillus Licheniformis to control mango postharvest disease in South Africa. *Postharvest Biol. Tech.,* 38: 57–65

Hortwitz, W., 1960. *Official and Tentative Methods of Analysis*, Vol. 9, pp: 320–341. Association of the Official Agriculture Chemist. Washington, D.C

Iqbal, M., 2007. *Postharvest Handling of Mangoes*. www.pakissan.com. Accessed 15 April, 2007

Jacobi, K.K. and L.S. Wong, 1991. The injuries and changes in ripening behaviour caused to Kensington mango by hot water treatment. *Acta Hort.,* 291: 372–378

Jacobi, K.K., E.A. Macrae and S.E. Hetherington, 2001. Effect of fruit maturity on the response of 'Kensington' mango fruit heat treatment. *Australian J. Exp. Agric.,* 41: 793–803

Jeffries, P., J.C. Dodd, M.J. Jeger and R.A. Plumbley, 1990. The biology and control of Colletotrichum species on tropical fruit crops. *Plant Pathol.,* 39: 343–366

Kader, A.A., 2008. *Mangoes Recommendations for Maintaining Postharvest Quality*. In: Fruit Ripening and Ethylene Management. 50-51. University of California Postharvest Technology Research and Information Center Publication Series #9. http://postharvest.ucdavis.edu/Produce/ProduceFacts/Fruit/mango.shtml

Lalel, H.J.D., Z. Singh and S.C. Tan, 2003. Distribution of aroma volatile compounds in different parts of mango fruit. *J. Hortic. Sci. Biotechnol.,* 78: 131–138

Lichtenberg, E. and D. Zilberman, 1987. Regulating environment and human health risk from agricultural residuals. *Appl. Agric. Res.,* 2: 56–64

Lizada, M.C.C., J.U. Agravante and E.O. Brown, 1986. Factors affecting postharvest disease control in 'Carabao' mango subjected to hot water treatment. *Philippine J. Crop Sci.,* 11: 153–161

Malik, A.U. and Z. Singh, 2005. Pre-storage application of polyamines improves shelf-life and fruit quality of mango. *J. Hortic. Sci. Biotech.,* 80: 363–369

Malik, A.U. and Z. Singh, 2006. Improved fruit retention, yield and fruit quality in mango with exogenous application of polyamines. *Sci. Hortic.,* 110: 167–174

Mclauchlan, R.L. and I.A. Wells, 1994. Storage and ripening temperatures for Kensington mangoes. *In*: *'ACIAR Proceedings No. 58, Development of Postharvest Handling and Technology for Tropical Tree Fruit*s. Canberra, Australia

Medlicott, A.P., S.B. Reynolds and A.K. Thompson, 1986. Effect of temperature on the ripening of mango fruit (*Mangifera indica* L. var. Tommy Atkins). *J. Sci. Food Agric.,* 37: 469–474

Medlicott, A.P., 2003. *Product Specifications and Postharvest Handling for Fruits, Vegetables and Root Crops Exported from the Caribbean*. Agribusiness online information service. www.agribusinessonline.com

Miller, W.R. and R.E. McDonald, 1991. Quality changes during storage and ripening of 'Tommy Atkins' mangoes treated with heated forced air. *Hort. Sci.,* 26: 395–397

Nair, S. and Z. Singh, 2009. Chilling injury during storage affects respiration rate and fruit quality in Kensington Pride mango fruit. *Acta Hort.,* 820: 737–744

Pathak, R.K., 2007. *Protocol for Postharvest Management of Mango.* Institute for Subtropical Horticulture, Lucknow. www.idfresearch.org. (Website visited: 01 June, 2007)

Ram, H.B., R.V. Singh, S.K. Singh and M.C. Joshi, 1983. *A Note on the Effect of Ethrel and Hot Water Treatment on the Ripening and Respiratory Activities of Mango Variety Dashehari*. Research notes. Govt. Fruit Preservation Institute, Lucknow, India

Shivashankara, K.S., S. Isobe, M.I. Al-Haq, M. Takenaka and T. Shiina, 2004. Fruit antioxident activity, ascorbic acid, total phenol, quercetin and carotene of Irwin mango fruits stored at low temperatura aftar high electric field pre-treatmant. *J. Agric. Food Chem.,* 52: 1281–1286

Soong, Y.Y. and P.J. Burlow, 2004. Antioxident activity and phenolic content of selected sedes. *Food Chem.,* 88: 411–417

Swart, S.H., J.J. Serfontein and J. Kalinnowski, 2002. Chemical control of postharvest diseases of mango-the effect of prochloraz, thiobendazole and fludioxonil on soft brown rot, stem-end rot and anthracnose. *S.A. Mango Growers' Assoc. Yearbook*, 22: 55–62

Thomas, P. and M.S. Oke, 1983. Improvement in quality and storage of Alphonso mangoes by cold adaption. *Sci. Hortic.,* 19: 257–262

Ueda, M., 2001. Effect of temperature and time on some properties during storage of mango fruit (*Mangifera indica* L. 'Irwin') cultured in plastic house. Nippon syokuhin kagaku kougaku kaishi. *Japanese Soc. Food Sci. Technol.,* 48: 349–355

Weaver, J.E., H.W. Hogmire, J.L. Brooks and J.C. Sencindiver, 1990. Assessment of pesticide residues in surface and soil water from a commercial apple orchard. *Appl. Agric. Res.,* 5: 37–43

Yahia, M.Y. and J. Pedro-Campos, 2000. The effect of hot water treatment used for insect control on the ripening and quality of mango fruit. *Acta Hort.,* 509: 495–514

(Received 07 February 2011; Accepted 05 July 2011)