Journal of Animal & Plant Sciences, 31(5): 2021, Page: 1329-1337
ISSN (print): 1018-7081; ISSN (online): 2309-8694
https://doi.org/10.36899/JAPS.2021.5.0334

IMPACT OF VAPOUR HEAT QUARANTINE TREATMENTS ON 'SAMAR BAHISHT CHAUNSA' AND 'SUFAID CHAUNSA' MANGO FRUITS DURING SIMULATED AIR SHIPMENT TO JAPAN

M. S. Shah[1], A. U. Malik[1*], A. S. Khan[1], M. U. Hasan[1], R. Anwar[1], A. Amjad[2], M. Amin[3], S. Ali[4], M. A. Bakhsh[5] and M. Latif[6]

[1]Postharvest Research and Training Centre, Institute of Horticultural Sciences, University of Agriculture, Faisalabad 38040, Pakistan[[2]Department of Agriculture, Government of the Punjab, Lahore- Pakistan; [3]Department of Horticultural Sciences, The Islamia University of Bahawalpur, Pakistan;[4]Department of Horticulture, Faculty of Agricultural Sciences and Technology, Bahauddin Zakariya University, Multan, Pakistan; [5]Mango Research Institute, Multan, Pakistan; [6]Allam Iqbal Open University, Islamabad, Pakistan.

[*] Correspondence Author's Email: malikaman1@uaf.edu.pk; malikaman1@gmail.com

ABSTRACT

'Samar Bahisht Chaunsa' and 'Sufaid Chaunsa' are highly admired commercial mango cultivars of Pakistan in domestic and international markets. Fruit fly being a quarantine pest has become a significant barrier in mango export trade and needs specific postharvest disinfestation treatment before export to certain countries. Presently, postharvest vapour heat treatment (VHT) of mangoes at a certified facility is mandatory for export to Japan, however its impact on fruit quality have not been investigated. Hence, in two separate experiments, effect of quarantine VHT (Japanese protocol; 47°C for 25 min) was evaluated on the quality of two commercial mango cultivars. After VHT, treated and non-treated (control) fruits were kept at ambient conditions (26±3°C and 50-60% RH) till ripening. At eating ripe stage, VHT-treated 'Samar Bahisht Chaunsa' mango fruits exhibited significant reduction in postharvest disease incidence and showed higher concentrations of total phenolic contents, total antioxidants, carotenoids with better eating quality (taste, flavour, texture, aroma and pulp colour) as compared to untreated control fruit. 'Samar Bahisht Chaunsa' mango fruits showed non-significant results for physiochemical attributes such as peel colour, softness, total soluble solids (TSS), titratable acidity (TA), TSS:TA ratio and vitamin C, while more shriveling percentage was observed in non-VHT fruits. In second experiment, VHT treated 'Sufaid Chaunsa' fruits exhibited higher scores for peel colour, softness and total antioxidants, and reduced disease incidence and shriveling percentage with retained eating quality (taste). Non-significant results were observed for lenticel development, TSS, TA, TSS:TA ratio and phytochemicals (vitamin C, total phenolics, antioxidants and carotenoids) respectively. In conclusion, in both cultivars, VHT-treated fruits showed better ripening and organoleptic characteristics along with lower disease severity as compared to control. Thus, vapour heat treatment can be employed as safe quarantine measure for mango fruit export to Japan.

Keywords: Vapour heat treatment; Japanese protocol; Disease incidence; Phenolics; Eating quality

Published first online January 21, 2021 Published Final August 07, 2021.

INTRODUCTION

Mango (*Mangifera indica* L.) fruit is an economically important fruit crop grown in more than 87 countries around the globe. At present India, China, Thailand, Indonesia, Philippines, Pakistan and Mexico are leading mango producers in the world. In Pakistan, mango ranks second after citrus crop in terms of production (1,735,000 tonnes) from an area of 167,899 ha with significant share in country's fruit export (>67,802.3 tonnes) (MNFSR, 2019).

Pakistan mango industry is facing challenge of fruit fly, being a major quarantine pest in export trade. Chemical treatments being parlous for human health, has been substituted with non-chemical quarantine treatments. At present, for mango export, importing countries have implemented special postharvest quarantine protocols such as irradiation for USA (Malik *et al*., 2013), hot water treatment (HWT) for China and Iran (Jabbar *et al*., 2012; Hasan *et al*., 2020), and VHT for Japan, Australia and New Zealand (Singh and Saini, 2014). The global concern in the concept of heat treatment solutions designed for high-quality protection and even restraining problems has been reflected in several documents (Aveno and Orden, 2004). Among various postharvest quarantine treatments; besides insect control VHT has been found very effective for disinfecting microbial and bacterial decays, insect control, de-sanitizing fruit to chilling damage and reduction in the rate of postharvest physiological disorders (Bard and Kaiser, 1996; Malik *et al*., 2021).

Currently, for Pakistani mango export to Japan, VHT of fruit at a certified facility is mandatory. During VHT, fruits are subjected to precisely controlled hot steam maintaining core temperature of 47ºC for 25 min. Two commercial VHT facilities have been established in Punjab, under private sector. However, no scientific information is available on the effect of such VHT protocol on shelf life and fruit quality of commercial Pakistani mango cvs., which warrants investigations. Previous studies on VHT of mangoes show variable results which could be due to variation in variety, temperature and duration of exposure. A study on mango cv. 'Keitt' indicated that VHT at 46ºC for 3-4 h or VHT at 48ºC for 5 h caused internal cavities formation near the seed surrounded by hard unripe tissue (Mitcham and McDonald, 1993). Similarly, in 'Carabao' mango VHT at 46ºC for 10 min caused internal breakdown in inner mesocarp of ripe fruit with white, starchy, tough lesions and fermented odor (Esguerra and Liazda, 1990). According to Esguerra and Liazda (1990), application of VHT at 46ºC for 10 min to mango cv. 'Carabao' resulted in yellowing of skin with increased respiration rate. Similarly, in mango cv. 'Kensington' VHT at 47ºC for 7.5-30 min or VHT at 46.5ºC for 10 min or VHT at 47ºC for 15 min resulted in yellowing of skin, uniformity of skin colour, and fruit softening (Jacobi and Giles, 1997). Evidence show that heat treatments such as VHT in cv. 'Kensington' at 50ºC for 240 min reduced ACC Oxidase activity, colour development and softness (Mitcham and McDonald, 1997). Organoleptic characters have also been found to be affected by heat treatment such as sugars, soluble solid, acidity and ascorbic acid contents in mango (Shellie and Mangan, 1994).

Among various commercial mango cultivars of Pakistan, 'Samar Bahisht Chaunsa' and 'Sufaid Chaunsa' exhibit great potential for export to high-end international markets (Malik and Hasan, 2019; Hasan et al., 2020) including Japan. While, VHT is now a mandatory for mango export from Pakistan to Japan, the influence of such a VHT protocol (47ºC-25 min) on quality of locally grown commercial mango cvs. has never been investigated. Hence, the purpose of this industry driven study was to assess the effect of VHT (Japanese protocol) on physical, organoleptic and biochemical quality attributes of 'Samar Bahisht Chaunsa' and 'Sufaid Chaunsa' mangoes of Pakistan.

MATERIALS AND METHODS

Fruit Material: Mango fruit was sourced from commercial orchard (30°21'35.0"N 71°47'44.4"E) of Kabir Wala district Khanewal, Pakistan. Fruit of both commercial cultivars 'Samar Bahisht Chaunsa' and 'Sufaid Chaunsa' were harvested at physiological maturity (hard green stage, TSS 13.4°Brix and 8.4°Brix respectively) and physically de-sapped using de-sapping stands as earlier described method of Hasan et al. (2020). Fruits of uniform size, colour, best in visual quality and defects free (disease, insect or blemished) were selected, packed in paper lined plastic crates and transported through refrigerated mini truck to VHT Plant at Roomi Food Pvt. Ltd. Kabirwala, Southern Punjab, Pakistan. A general process flow of mango export to Japan is given in Fig. 1.

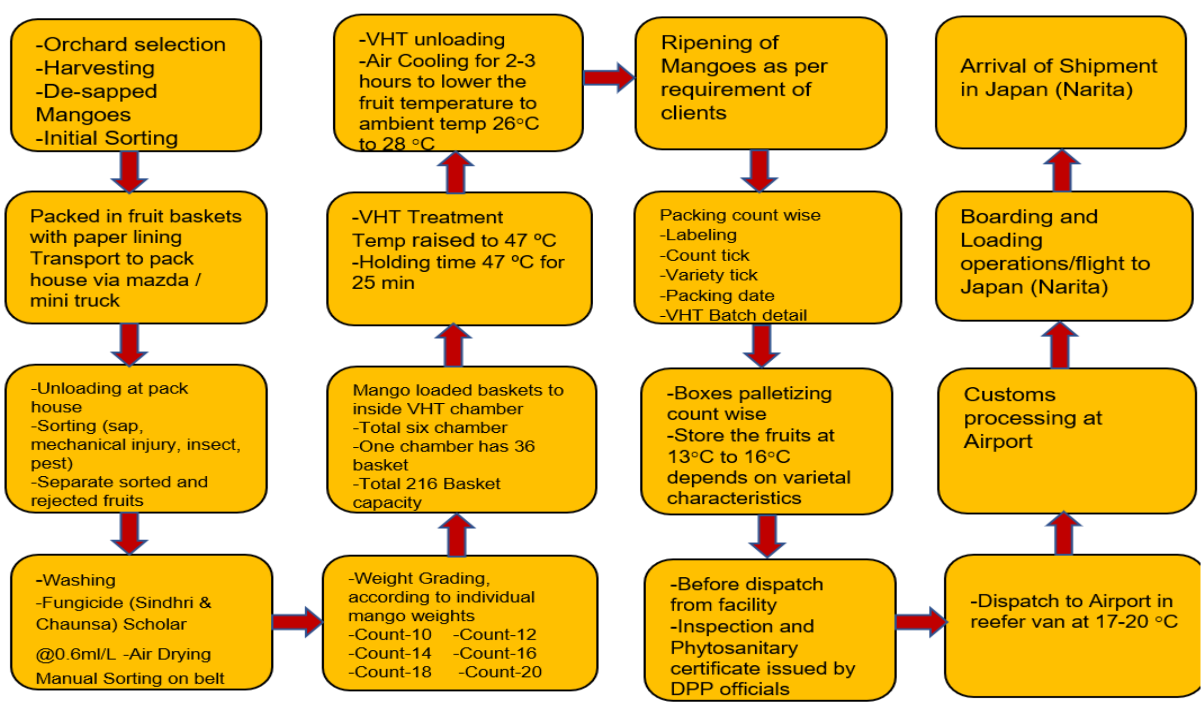

Fig. 1: Mango VHT process flow for export to Japan.

Treatments and VHT procedure: Fruits of both cvs. were separately divided into two major groups [T_1= washed + no VHT, T_2 = washed + VHT], each group contained about eight kg fruit, further divided in to three subgroups (replicates) consisting of nine fruits each. After segregation and pre-washing with 0.8mL/L Gemstar fungicide, fruits of both cvs. were aligned upside in single layer trays and placed in VHT room for 3.5 h; core pulp temperature was maintained 47ºC for 25 min. After the VHT, fruit were precooled at ambient conditions until fruit pulp attained 26-28°C temperature. To trigger fruit ripening, two sachets of ethylene ripener (each sachet weight three grams) were placed in both (treated as well as non-treated) crates, then covered with blanket for the duration of 10 h for 'Samar Bahisht Chaunsa' and 12 h for 'Sufaid Chaunsa' mango fruits respectively. Fruits of both mango cvs. were then packed in corrugated export sized boxes and brought to Postharvest Research and Training Center (PRTC), University of Agriculture Faisalabad and kept at simulated air shipment conditions (26±3°C with 60-65% RH) till ripening.

Physical and sensory fruit quality: Fruit peel colour, softness, disease incidence, shriveling and sap injury were assessed by rating scale. Fruit colour was assessed using rating scale 1-5 (1 =100% green + 0% yellow; 2 = 75% green + 25% yellow; 3 = 50% green + 50% yellow; 4 = 25% green + 75 yellow; 5 = 0% green + 100% yellow). Fruit textural softness was rated from 1 to 5 (1 = hard; 2 = sprung; 3 = slightly soft; 4 = eating soft; 5: over ripe) as mentioned by Miller and McDonald (1991). Disease incidence were assessed on 1 to 5 scale (1 = nil; 2 = <5%; 3 = 5-10%; 4 = 10-25%; 5 = > 25%) as earlier reported by Amin *et al*. (2007). At eating soft stage, fruit of both cultivars were presented to panel of judges for evaluating their sensory characters such as taste, pulp colour, flavour, aroma and texture using hedonic scale (Peryam and Pilgrims, 1957).

Biochemical fruit quality: Total soluble solid (TSS) contents of ripe mango fruit juice samples were evaluated using digital refractometer (ATAGO, PAL-1, Japan). Titratable acidity (TA) of ripe mango was evaluated using titration method with 0.1N NaOH and was expressed in percentage (%). TSS:TA ratio was calculated by dividing TSS with the corresponding TA values (Hasan *et al*., 2020). For ascorbic acid contents, 10 ml of mango juice (extracted from pulp) was added in 0.4% oxalic acid solution (90ml) and filtered, 5 mL aliquot titrated against 2,6-dicholorophenolindophen till appearance of light pink colour (Ali *et al*., 2016). Total phenolic contents (TPC) from frozen mango pulp samples were determined using Folin-Cicolteu reagent method (Bozin *et al*., 2008). Briefly, 1 g mango pulp sample was homogenized with 5 mL extraction mixture (90:8:2; Methanol: Acetone: HCL), and centrifuged (Z-326K, HERMLE Labortechnik GmbH, Germany) at 11,200 rcf for 3 min. The supernatant (100 µL) was mixed with 200µL FC reagent homogenized for 2 min using vortex machine. About 800 µl Na_2CO_3 (700 mM) was added and vortexed again for the duration of 2 min. Afterwards, sample was incubated at room temperature and absorbance of 100 µL sample was recorded at 765 nm using ELISA plate reader (ELX 800 Microplate reader, Bio-tek Instrument Inc.) and was expressed as mg gallic acid equivalent (GAE) per mL sample. Antioxidant activity of mango pulp sample was determined by scavenging of 2,2-diphenyl-1-picrylhydrazyl (DPPH) (Bozin *et al*., 2008). About 50-150 µL supernatant of various concentration was added to 5 mL 0.004% methanolic solution of DPPH (dark purple colour). After 30 min incubation at room temperature, the absorbance was taken against a blank at 517 nm using ELISA plate reader. The DPPH value was expressed in % inhibition. Carotenoid contents were determined using the method described by Nagata and Yamashita (1992). Mango pulp (1 g) was homogenized with 0.05 magnesium carbonate ($MgCO_3$) and finely ground in pestle and mortar with 20 mL extraction buffer (75:60; acetone: n-hexane). Prepared sample was centrifuged at 2800 × *g*, and 100 µL sample was used to record absorbance at 663, 453, 645, and 550 nm wavelength using ELISA plate reader. Level of total carotenoids in the sample was expressed as mg/g.

Statistical Analysis: Both experiments were conducted separately using completely randomized design (CRD) with two treatments and three replications. For data analysis, computer software STATISTIX 8.1. was used, while treatment means were compared by least significant difference test (LSD at $P \leq 0.05$) (Steel *et al*., 1997).

RESULTS

Effect of VHT on quality of 'Samar Bahisht Chaunsa' mango fruit

Physical and sensory fruit quality: At eating soft stage, 'Samar Bahisht Chaunsa' fruits exhibited non-significant difference regarding fruit peel colour and softness compared with control. However, comparatively higher score for peel colour was observed in VHT-treated fruits (2.36 score) as compared with non-VHT fruits (2.31 score). Similarly, slightly more softness was recorded in VHT-treated fruits (2.63 score) in contrast with untreated control (2.57 score) fruits (Table 1). A significant difference was observed in fruit shriveling, sap injury and disease incidence (anthracnose, stem end rot, body rot and lenticel development) between treated and non-treated fruits. Higher shriveling percentage and sap injury (2.14 score and 1.24 score) were observed in non-VHT-treated than VHT-treated (1.75 score and 1.07 score) fruits, respectively (Table 2). Higher disease incidence including anthracnose, stem end rot, body rot and minimum lenticel development were found in non-VHT-treated fruits (1.72, 1.70, 1.86, and 1.72 score) in contrast with VHT treated fruits (1.45, 1.35, 1.40 and 2.05 score), respectively (Table 2). Pulp color score of VHT treated fruits was significantly higher (6.71) in comparison with control (4.71).

VHT treated fruits displayed higher values of taste, flavour, aroma and texture (6.14, 6.57,6.42,6.85 score) as compared to control (non-VHT), while non-significant results were observed for fruit pulp color, although the score (6.71) was higher in VHT fruits compared with Non-VHT (4.71) (Table 1).

Biochemical fruit quality: A non-significant relationship of vapour heat was found in case of biochemical quality when fruit reached at ripe stage. However, maximum SSC, SSC:TA ratio (21.53 °Brix, 191.10 respectively) were estimated in VHT-treated fruits as compared non-VHT control fruits (18.90 °Brix, 147.98), respectively (Fig. 2A and C).

Whereas, fruit acidity and Vitamin C contents were found slightly lower in fruits treated with VHT in contrast with control fruits, respectively (Fig. 2B and 3A). VHT treated fruits displayed higher total phenolic contents, total antioxidants and carotenoid contents (266.91 mg GAE/100g, 51.67 % DPPH inhibition, and 0.32 mg/g) as compared with control (Non-VHT) fruits, respectively (Fig. 3B, C and D).

Effect of Vapour heat treatent on quality of 'Sufaid Chaunsa' mango fruit

Physical and sensory fruit quality: VHT treatment showed significant influence on fruit of mango cv. 'Sufaid Chaunsa' in terms of peel color, softness, shriveling, and disease incidence (anthracnose, stem end rot, body rot) at eating ripe stage. More pronounced peel color (2.11 score) was observed in VHT treated fruits as compared to non-VHT fruits (1.84 score) (Table 1). Similarly, more softness (2.14 score) was determined in VHT treated fruits as compared to control (1.71 score) after six days of ambient storage (Table 1). At best eating stage, higher shriveling (1.31 score) was exhibited by non-VHT fruits as compared to VHT treated fruits (1.11) (Table 1). Clear visual difference after six days at ambient conditions was observed in disease incidence (anthracnose, stem end rot, body rot) with higher disease score (1.33, 1.28, 1.46) in non-VHT fruits as compared to VHT treated fruits (Table 2). While cv. 'Sufaid Chaunsa' fruits showed non-significant results for sap injury and lenticel development. Among organoleptic characteristics; pulp color, flavor, texture and aroma showed non-significant difference between treated and non-treated fruits of cv. 'Sufaid Chaunsa' fruits. However, VHT treated fruits showed significantly higher taste score (7.57) as compared to non-treated fruits (5.57) (Table 1).

Biochemical fruit quality: 'Sufaid Chaunsa' cultivar depicted non-significant effect of VHT for biochemical properties of ambient stored fruits. However, maximum total soluble solids (20.13°Brix) were determined in VHT treated fruits as compared to non-VHT (19.90°Brix) (Fig. 2D). While decrease in total acidity percentage (0.15 %) was found in non-VHT fruits as compared to VHT fruits (0.17%) (Fig. 2E). Whereas, higher SSC:TA ratio (134.95) was observed in non-VHT fruits compared with fruits treated with VHT (117.81) (Fig. 2F).

Among phytochemicals, a non-significant behavior was observed in vitamin C, total phenolic contents, antioxidants and carotenoids. However, higher phenolic content and antioxidants (278.69 mg GAE/100g, 49 DPPH inhibition percentage) were estimated in Non-VHT fruits as compared to the fruits treated with VHT (261.87 mg GAE/100g, 47.88 % DPPH inhibition) (Fig. 3F and G). Maximum pulp carotenoids content (0.18 mg/100g) were estimated in Non-VHT fruits compared with treated ones (0.08 mg/100g) (Fig. 3H).

Table 1: Effect of quarantine vapour heat treatment (VHT) on physical and organoleptic quality of mango fruit at ripe stage.

Cultivars	Treatments	Physical Fruit Quality				Organoleptic Fruit Quality			
		Shriveling (%)	Softness (Score)	Peel colour (Score)	Pulp colour (Score)	Taste (Score)	Flavour (Score)	Texture (Score)	Aroma (Score)
Sammar	Non-VHT	2.14b	2.57	2.31	4.71a	4.42a	4.00a	5.00a	4.24a
Bahist Chaunsa	VHT	1.75a	2.63	2.36	6.71b	6.14b	6.57b	6.85b	6.42b
LSD values ($P \leq 0.05$)		*	NS	NS	*	*	*	*	*
Sufaid	Non-VHT	1.31b	1.71a	1.84a	6.28	5.57a	5.71	6.28	6.00
Chaunsa	VHT	1.11a	2.14b	2.11b	7.28	7.57b	6.42	7.57	6.57
LSD values ($P \leq 0.05$)		*	*	*	NS	*	NS	NS	NS

Means not sharing similar letters are significantly different ($P \leq 0.05$); NS = non-significant.

Table 2: Effect of quarantine vapour heat treatment (VHT) on sap injury, lenticel spotting and disease incidence of mango fruit at ripe stage.

Cultivars	Treatments	Sap injury (Score)	Lenticel Spotting (Score)	Anthracnose (Score)	Stem End Rot (Score)	Body Rot (Score)
Sammar Bahist	Non-VHT	1.04a	1.72a	1.72b	1.70b	1.86b
Chaunsa	VHT	1.27b	2.05b	1.45a	1.35a	1.40a
LSD values ($P \leq 0.05$)		*	*	*	*	*
Sufaid Chaunsa	Non-VHT	1.13	1.15	1.33b	1.28b	1.46b
	VHT	1.28	1.17	1.08a	1.17a	1.15a
LSD values ($P \leq 0.05$)	*	NS	NS	*	*	NS

Means not sharing similar letters are significantly different ($P \leq 0.05$); NS = non-significant.

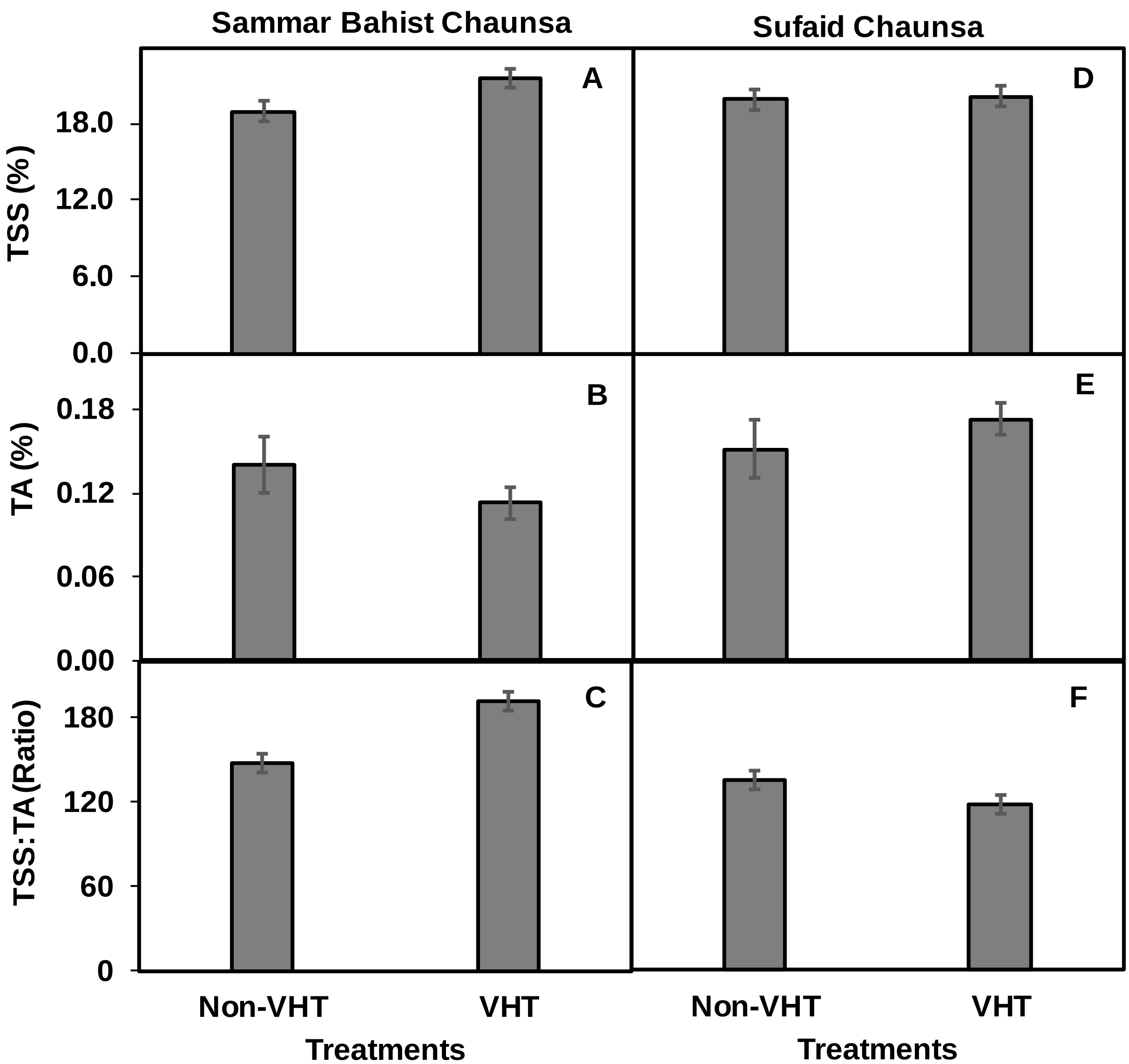

Fig. 2: Effect of quarantine vapour heat treatment (VHT) on total soluble solids (A and D), total acidity (B and E), and SSC: TA ratio (C and E) of 'Sammar Bahisht Chaunsa' and 'Sufaid Chaunsa' mango fruits at eating ripe stage. Vertical bars represent the SE ± of means. n=3.

DISCUSSION

Fruit of commercial cultivars 'Samar Bahisht Chaunsa' and 'Sufaid Chaunsa' treated with VHT as quarantine measure and tested in a simulated condition for export to Japan showed different response for various fruit quality parameters. 'Samar Bahisht Chaunsa' fruits depicted non-significant difference between VHT and non-VHT treated fruits for peel colour development and softness at ripe stage. Whereas, 'Sufaid Chaunsa' mango fruit showed significant results and VHT-treated fruits exhibited higher score (2.11, 2.14) for fruit peel colour and softness, respectively (Table 1), which can be attributed to difference in varietal characters. Changes in fruit quality *i.e*, skin and flesh color, and firmness found closely associated with changes during fruit ripening (Brecht and Yahia, 2009; Hasan *et al*., 2020). Textural softness indicates disruption of the cell wall polymers by distinct cell wall degradation of enzymes (Paliyath and Droillard, 1992). Colour change in mango is due to degeneration of chlorophyll and various metabolic activity which leads to yellowing of color and carotenoids development (Doreyappa-Gowda and Huddar, 2001). Due to the action of pectic enzymes including esterase and polygalacturonidase during ripening might be attributed to the conversion of insoluble pectic substances into physiochemical changes substantially reduced fruit firmness. Jacobi *et al*. (2000) revealed that 'Carabao' mango fruit under heat treatment through hot air at ripe stage depicts more softness as compared to control (Non-VHT) fruits. In the present study, irrespective of mango cultivars (Samar Bahisht Chaunsa and Sufaid Chaunsa), higher shriveling score (2.14, 1.31) was observed in untreated control fruits as compared to VHT-treated fruit (Table 1). Similar findings were reported by Doreyappa-Gowada and Hudder (2001) that 'Alphonso' mango showed more weight loss, less respiration and shriveling when exposed to VHT. Packaging of mango cv. 'Tommy Atkins' in heat shrinkable film displayed lower shriveling percentage on fruit surface (Rodov *et al*., 2003). Less shriveling in VHT fruits could be possibly due to gradual process of ripening.

Mango sap is highly acidic material that cause detrimental effect on mango skin colour and effect on consumer preference. Postharvest diseases including stem end rot and anthracnose are considered as major barrier during export of mango fruit in the international markets (Amin *et al.*, 2007). However, in current study, postharvest disease development (anthracnose, stem end rot and body rot) was found to be reduced in VHT-treated fruits of both mango cvs. (Samar Bahisht Chaunsa and Sufaid Chaunsa) as compared with untreated control fruit (Table 2). According to Mansour *et al* (2006), postharvest VHT retarded disease development in mango fruits. Similarly, VHT (46.5ºC for 10 min) in 'Kensington' mango cultivar was found effective to control stem end rot disease (Coates *et al*., 2003). More lenticel development in mango fruit affect the cosmetic look and consumer acceptance. While cv Sufaid Chaunsa did not show any difference between VHT and non-VHT fruit, lenticel development was observed in VHT treated cv. 'Sammar Bahisht Chaunsa' fruits which might be due to thin peel as compared to cv. 'Sufaid Chaunsa fruits. Lenticels development on fruit surface is due to stress imposed by pre-harvest and post factors (Bagshaw and Brown, 1989).

Fruits of both cvs. Samar Bahisht Chaunsa and Sufaid Chaunsa revealed non-significant results for changes in total soluble solids (°Brix) and SSC:TA ratio, while maximum values were recorded for VHT-treated mango fruits (Samar Bahisht Chaunsa) in contrast with control (non-VHT). It might be due to higher metabolic activity and rapid conversion of carbohydrates into sugars under heat treatments. Similar results were stated by Burdon *et al* (1994) that mango cultivar "Keitt" heated at higher temperature 38±2°C for 48 h showed increased TSS at ripe stage. For acidity percentage and vitamin C, both cultivars showed different response; lower acidity (%) and vitamin C contents were estimated in 'Samar Bahisht Chaunsa' and 'Sufaid Chaunsa' fruits treated with VHT as compared with untreated control fruit. Decrease in acidity percentage might be due to substantial loss of organic acids in triggered ripening during prolonged storage (Kelany *et al*., 2010). Similar results for acidity (%) were ascribed by McCollum *et al* (1993) who reported lower acidity in "Keitt" mango fruits heated at 38°C for two days. Our results showed non-significant difference for ascorbic acid contents for both cultivars and found contradictory to the earlier findings of Hoa *et al*. (2010) who reported that hot air treatment 47ºC for 120-180 min decreased the ascorbic acid content of fruit as compared to control (untreated).

SSC:TA ratio described the actual taste of the fruit and both cultivars displayed significant increase in sugar: acid ratio in fruits treated with VHT. Moreover, taste of VHT treated mango fruit was significantly higher (6.14, 7.57 score) for both cultivars as compared to control (4.42, 5.57 respectively). Linked organoleptic characters including pulp colour, flavor, texture and aroma scored maximum in VHT fruits in contrast with non-VHT fruits (Table 1). During mango fruit ripening, conversion of starch into soluble sugars takes place with an increase in relative amount of sugar content (Rathore *et al*., 2007). In mango fruits, substantial change (increase) of soluble sugars considered an important indicator of sweetness during ripening associated with significant change in flavor. During fruit development, increase of chloroplast starch contents which hydrolyzed into simple sugars onset of fruit maturity. According to Fuchs *et al*, (1980), increased activity of alpha amylase also enhances starch hydrolysis. During starch hydrolysis conversion of total sugars in mango increases during ripening, mainly in the form of glucose and fructose (Castrillo *et al*., 1992). Higher flavor characteristics depicted higher sugars content and volatile compound in the fruits at mature ripe stage (Singh *et al*., 2004). While our results of organoleptic characters in cv. Samar Bahisht Chaunsa contradict with the findings of Miller *et al*. (1991) who reported that "Tommy Atkins" mango fruit heated at 51.5°C for 125min and after storage at 12°C for 1-2 weeks, had no effect on fruit organoleptic characteristics.

'Samar Bahisht Chaunsa' mango fruit treated with VHT exhibited higher TPC (mg GAE 100^{-1}) as compared to Non-VHT fruit. Phenolic content is considered essential component in flavor and astringency. Loss in astringency means loss in phenolic content (Mitra, 1997). Increase in phenolic content might be due to change in cellular structure, improved enzymatic activity due to higher temperature (Lorinda *et al*., 1987). Earlier finding by Wang *et al*. (2017) described that higher TPC was observed in Ivory mango when heated at 60°C for 1 min. Likewise, mango fruits treated with hot water treatments showed higher TPC as compared to control fruits (Hasan *et al*., 2020). Moreover, antioxidants (% DPPH scavenging activity) were found to be non-significant between treated fruits and non-VHT fruits of both commercial cultivars. Higher antioxidants were observed in VHT fruits compared to Non-VHT fruits (Fig. 3 C and G). No report has earlier described the antioxidant (DPPH scavenging activity) affected by phytosanitary heat treatments.

Regarding pulp carotenoids, both cultivars responded differently, pulp carotenoids were increased in VHT fruits of 'Samar Bahisht Chaunsa' as compared to Non-VHT and vice versa in 'Sufaid Chaunsa' fruits (Fig. 3D and H). Higher pulp carotenoids in VHT fruit of 'Samar Bahisht Chaunsa' may be due to varietal difference and contradict to previous findings that hot water treatment had no significant effect on fruit texture and pulp carotenoids in cv 'Sammar Bahisht Chaunsa' fruits (Jabbar *et al*., 2012).

Conclusion: Quarantine VHT protocol (47°C for 25 min) exhibited positive effect in terms of reducing postharvest diseases (anthracnose, stem end rot and body rot) in both commercial mango cultivars. Fruit of both cultivars did not show any significant negative change in their biochemical and phytochemical fruit quality after VHT. Hence, VHT treatment of 47°C for 25 min can be effectively used as a postharvest quarantine treatment in 'Samar Bahisht Chaunsa' and 'Sufaid Chaunsa' mango fruits for export to Japan and other countries with similar VHT protocol.

Acknowledgements: We are highly grateful to Roomi Foods (Pvt.) Ltd. Kabir Wala, Punjab, Pakistan for providing VHT facilities for this study. We also acknowledge the cooperation of staff at Postharvest Research and Training Centre, University of Agriculture, Faisalabad, for facilitating these simulated studies.

Novelty statement: Vapour heat treatment (VHT) is an alternate quarantine treatment to irradiation and hot water treatment (HWT), and being accepted by various importing countries including Japan, Australia and New Zealand, for fresh mangoes import. However, VHT impacts have been exploited only to a limited extent globally while no information is available on local mango cultivars. Research on two commercial Pakistani mango cultivars (Sammar Bahisht Chaunsa and Sufaid Chaunsa) revealed that VHT can be employed as an effective quarantine treatment with maintained fruit quality (no deleterious impacts on quality) for export of these varieties to Japan and other countries. This is very useful study for local mango industry.

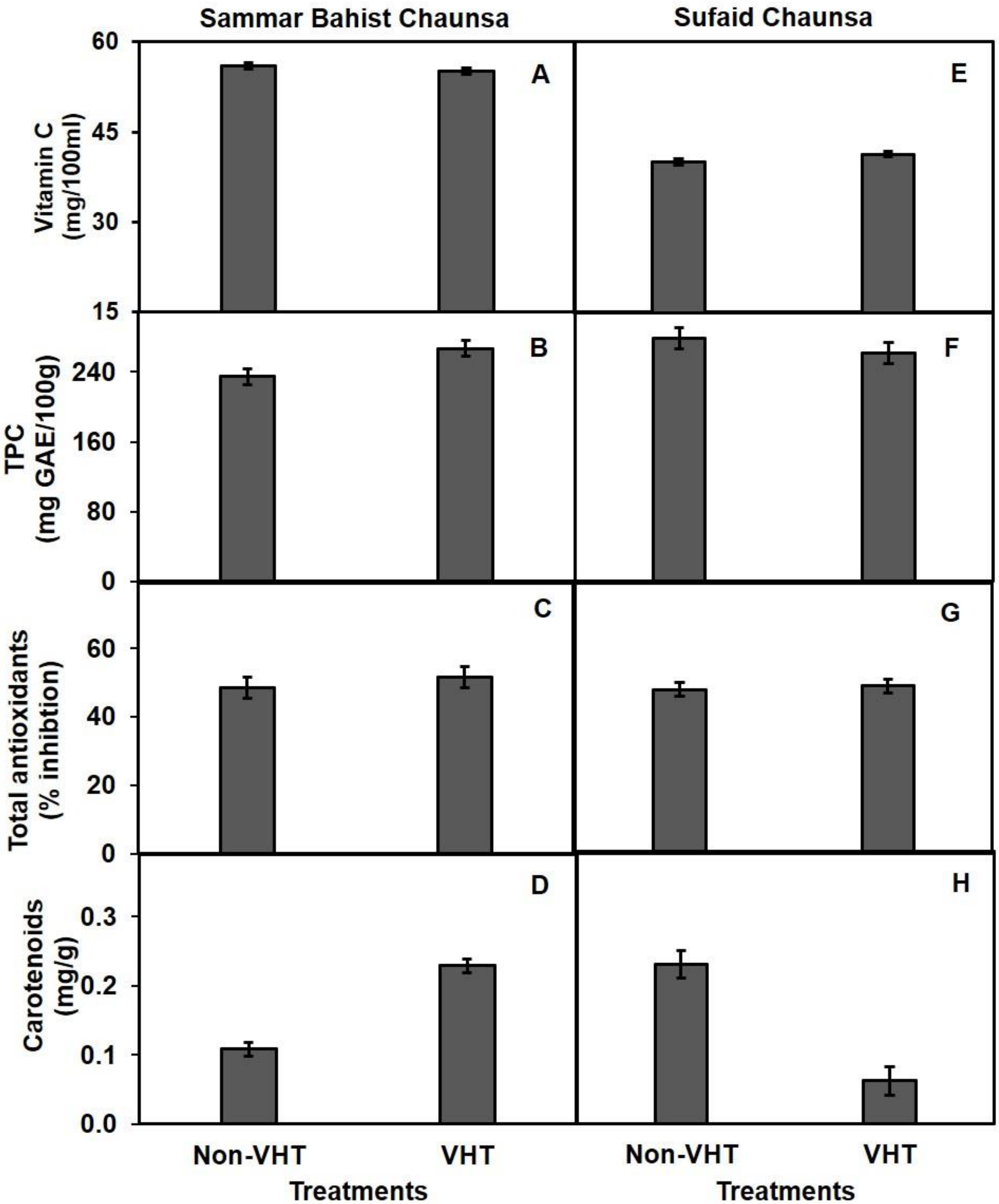

Fig. 3: Effect of quarantine vapour heat treatment (VHT) on vitamoin C (A and E), TPC (B and F), total antioxidants (C and G), and carotenoids (D and H) contents of 'Sammar Bahisht Chaunsa' and 'Sufaid Chaunsa' mango fruits at ripe stage. Vertical bars represent the SE ± of means. n=3.

REFERENCES

Ali, S., A.S. Khan, A.U. Malik, and M. Shahid (2016). Effect of controlled atmosphere storage onpericarp browning, bioactive compounds and antioxidant enzymes of litchi fruits. FoodChem. 2016: 18-29.

Amin M, A.U. Malik, N. Din, A. Jabbar, and I. Ahmad (2007). Mango soft nose disorder and fruit quality in relation to pre- and postharvest treatments. Life Sci. Int. J. 1: 455-462.

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.

Aveno, J.L. and M.E.M. Orden (2004). Hot water treatment of mango: A study of four export corporations in the Phillipines, 4(1). ISSN:1685-2044.

Bagshaw, B. and B. Brown (1989). Disorders. In: Mango Pests and Disorders. Queensland Department of primary Industries, Brisbane.

Bard, Z.J. and C. Kaiser (1996). Post-harvest vapor heat shock treatments of Fuerte avocado fruit. South African Growers' Assoc. Yearbook. 19: 116-118.

Bozin, B., N. Mimica-Dukic, I. Samojlik, A. Goran and R. Igic (2008). Phenolics as antioxidants in garlic (*Allium Sativum* L., Alliaceae). Food Chem. 111: 925-929.

Brecht and Yahia (2009). Postharvest physiology in: Litz, R.E. (ed.), The mango, pp: 484-528. CAB International, UK.

Burdon, J.N., S. Dori, E. Lomaniec, R. Mariansky, and E. Pesis, 1994. Effect of pre-storage treatments on mango fruit ripening. Ann. App. Biol. 125:581-587.

Castrillo, M. and A. Bermudez (1992). Postharvest ripening in wax-coated Bocado mango. Int. J. Food Sci. Technol. 27: 457-463.

Coates. L.M, G. Johnsoll, and A.W. Cooke (1993). Postharvest disease control in mango" using high humidity hot air and fungicide treatmets. Ann. App. Biol. 123 (2): 441-448.

Doreyappa-Gowda, I.N.D. and A.G. Huddar (2001). Studies on ripening changes in mango (*Mangifera indica* L) fruits. J. Food Sci. Tech. 38: 135-137.

Esguerra, E.B. and M.C.C. Liazda (1990). The postharvest behavior and quality of 'Carabao' mangoes subjected to vapour heat treatment. ASEAN Food. J. 5: 6-11.

Fuchs, Y., E. Pesis, and G. Zauberman (1980). Changes in amylase activity, starch and sugars contents in mango fruit pulp. Sci. Hortic. 13: 155-160.

Hasan, M.U., A.U., Malik, A.S., Khan, R., Anwar, A., Amjad, M.S., Shah, M. Amin (2020). Impact of postharvest hot water treatment protocol on two commercial mango cultivars of Pakistan during simulated conditions for air freight to China. Pakistan J. Agric. Sci. 57:1381-1391.

Hoa, T.T., D.M. Hien, G. Self, and M.N. Ducamp (2010). Effects of hot air treatment on postharvest quality of 'cat Hoa loc' mangoes. Fruits. 65:237-244.

Jabbar, A., A.U. Malik, M. Maqbool, M. Amin, M. Saeed, and R. Hameed (2012). Anti-sap chemicals and hot water quarantine treatment effects on storage life and fruit quality of mango cv. Samar Bahisht Chaunsa. Pakistan J. Bot. 44(2): 757-764.

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.

Jacobi, K. K., E.A. Macrae, and S.E. Heatherington (2000). Effects of hot air conditioning of 'Kensington' mango fruit on the response to hot water treatment. Postharvest Biol. Technol. 21: 39-49.

Jacobi, K.K. and J.E. Giles (1997). Quality of 'Kingston' mango (*Mangifera indica* L) fruit following combined vapour heat disinfestation and hot water disease control treatments. Postharvest Biol. Technol. 12:285-292.

Kelany, A.E., M. Sahar, A. Wahab, A.A. Hafeez, and M.T. Osman (2010). Using modified atmosphere and different temperatures for storing 'Kent' mango fruit. J. Hort. Sci. Ornamen. Plants. 2:46-56.

Lorinda, F., I.A. Dubery, and J.C. Schabort (1987). Biochemical changes involved in stress response and ripening behavior of gamma irradiation mango fruit. Phytochem. 26:681-686.

Malik, A.U. and M.U. Hasan (2019). Road testing the mango quality manual in Pakistan-A case study of enhancing Mango Fruit Quality in Asian Mango Chains. Australian Centre for International Agricultural Research. Available at: www.apmangonet.org/research/mango-quality-quality-kit-study-pakistan/ (Assessed: 24 December 2019).

Malik, A.U., M. Umar, R. Hameed, M. Amin, H. U. Asad, O. Hafeez, and P. Hoffman (2013). Phytosanitary irradiation treatments in relation to desapping and processing types affect mango fruit quality. Proceedings of 7th International Postharvest Symposium. 1012: 681-692.

Malik, A.U., M.U. Hasan, W.U. Hassan, A.S. Khan, M.S. Shah, I.A. Rajwana, M. Latif, and R. Anwar (2021). Postharvest quarantine vapour heat treatment attenuates disease incidence, maintains eating quality andimproves bioactive compounds of 'Gola' and 'Surahi' guava fruits. J. Food Meas. Character. https://doi.org/10.1007/s11694-020-00763-z

Mansour, F.S., S.A. Abd-El-Aziz, and G.A. Helal (2006). Effect of fruit heat treatment in three mango varieties on incidence of postharvest fungal disease. J. Plant. Pathol. 88: 141-148.

McCollum, T.G., S, D' Aquino, and R.E. McDonald (1993). Heat treatment inhibits mango chilling injury. Hort. Sci. 28:197-198.

Miller, W.R., R.E. McDonald, and J.L. Sharp (1991). Quality changes during storage and ripening of 'Tommy Atkins' mangoes treated with heated forced air. Hort. Sci. 26:395-397.

Mitcham, E.J. and R.E. McDonald (1993). Respiration rate, internal atmosphere, ethanol and acetaldehyde accumulation in heat-treatment mango fruit. Postharvest Biol and Technol. 3:77-86.

Mitcham, E.J. and R.E. McDonald (1997). Effects of postharvest heat treatments on inner and outer tissue of mango fruit. Trop. Sci. 37:193-205.

Mitra, S. (1997). Postharvest Physiology and storage of tropical and subtropical fruits. New York: CAB International.

MNFSR, (2019). Fruit, vegetables and condiments statistics of Pakistan 2017-18. Ministry ofNational Food Security & Research. Available at:http://www.mnfsr.gov.pk/pubDetails.aspx (Assessed: 23 December 2019).

Nagata, M. and I. Yamashita (1992). Simple method for simultaneously determination of chlorophyll and carotenoids in tomato fruit. J. Japan. Soc. Food. Sci. Technol. 39:925-928.

Paliyath, G. and M.J. Droillard (1992). The mechanism of membrane deterioration and disassembly during senescence. Plant Physiol. Biochem. 30: 789-812.

Peryam, D.R. and F.J. Pilgrim (1957). Hedonic scale method of measuring food preferences. Food Technol. 11:9-14.

Rathore, H.A., T. Masud, S. Sammi, and A.H. Soomro (2007). Effect of storage on physico-chemical composition and sensory properties of Mango (*Mangifera indica* L.) variety Dosehri. Pakistan J. Nutr. 6: 143-148.

Rodov, V., R.D.L. Asuncion, J. Perzelan, T. Koltai, and S. Ben-Yehoshua (2001). Testing perforated heat-shrinkable films and carbon dioxide absorbers for packaging of 'Tommy Atkins' mango. Adv. Hort. Sci. 17(3): 127-134.

Shellie, K.C. and R, Mangan (1994). Disinfestation: effect of non-chemical treatments on market quality of fruit. In: Champ, B.C Highley, E. Johson, G.I (Eds.). Postharvest handling of tropical fruit. ACIAR Proceedings No. 50. pp. 304-310.

Singh, S.P. and M.K. Saini (2014). Postharvest vapour heat treatment as a phytosanitary measure influences the aroma volatiles profile of mango fruit. Food Chem. 167: 387-395.

Singh, Z., H.J.D. Lalel, and N. Suresh (2004). A review of mango fruit aroma volatile compounds state of the art research. Acta. Hort. 645:519-527.

Steel, R.G.D., J.H. Torrie, and D.A. Dicky (1997). Principles and Procedures of Statistics, A Biological approach, 3rd ed. McGraw Hill Book Co. Inc., New York, USA.

Wang, H., Z. Yang., F. Song, W. Chen, and S. Zhao (2017). Effects of heat treatment on changes of respiration rate and enzyme activity of ivory mangoes during storage. J. Food Process Preserv. 41(1): 1-8.