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PHYSIOLOGICAL AND BIOCHEMICAL BEHAVIOUR OF 'WHITE SUKKARY' AND 'ZEBDA' MANGOES DURING SHELF LIFE PERIOD AFTER HOT WATER DIPPING AND CALCIUM NITRATE TREATMENTS

Bassal, M.A.* and M.A. El-Hamahmy**

*** Horticulture Department, Faculty of Agriculture, Suez Canal University, 41522, Ismailia, Egypt,**
E-mail: magdy_bassal@yahoo.com

****Botany Department, Faculty of Agriculture, Suez Canal University, 41522, Ismailia, Egypt**
E-mail: mhamahmy@yahoo.com

ABSTRACT

Thermotherapy, especially hot water dipping (HWD) is widely used in many countries for insect and decay control in mangoes. Physiological and biochemical behaviour of fruit under HWD (47±1 ◦C/20 min, 53±1 ◦C/5 min) in packaged 'White Sukkary'; (49±1 ◦C/30 min, 53±1 ◦C/8 min) in non-packaged 'zebda' and $Ca(NO_3)_2$ (4 and 6% /15min) in both cultivars during shelf life period was investigated. Overall valuable effect of 53±1 ◦C/5 min or 8min HWD or 6% $Ca(NO_3)_2$ on ripening acceleration and improvement was observed. In general, carotene content in peel was associated with up-regulation of catalase (CAT) activity under 53±1 ◦C/5 min or 8 min HWD or 6% $Ca(NO_3)_2$ treated fruit. 47(49) ±1 ◦C/ 20-30 min treatment alleviated peroxidase (POX) activity in peel and juice of both cultivars. Weight loose % and vitamin C (VC) values were maintained only with 6% $Ca(NO_3)_2$ treated fruit. HWD down-regulated Ascorbic acid oxidase activity (ASAO) compared to calcium treatments and control. High calcium content in peel or bulb was significantly correlated with fruit firmness only in 'Zebda' fruit. Also, SSC, TA%, reducing sugars and free phenols levels were estimated. Finally, using of HWD 53±1 ◦C/5 or 8 min or $Ca(NO_3)_2$ /6% treatments to accelerate and improve quality in 'White Sukkary' and 'Zebda' fruit in spite of synthetic ripening stimulators can be recommended.

Keywords: *Mangifera Indica*, ripening, shelf life, fruit quality, hot water, calcium nitrate, antioxidants, ascorbic acid oxidase.

INTRODUCTION

Mango is the second most important tropical fruit crop in the world (34.8 mTon, FAO STAT, 2008). Ripe mangoes are considered an excellent source of vitamins C, B1, B2 and provitamin A (Mukherjee 1997). In Egypt, mango cultivated area reached approximately 76000 hectares (FAO STAT, 2008). More than 40% of this areas exists in Ismailia, where the main cultivars planted are 'White Sukkary' and 'Zebda'.'White Sukkary' is in contrary to 'Zebda' is characterized by earliness, low storability period and ripen associated with thin peel yellowing (Elmasry, 2004). Bard and Kaiser (1996) reported that heat treatments are used for several objectives: controlling of insect pest; disinfesting of fungal and bacterial rots; de-sensitizing fruit to chilling injury; reducing incidence of post-harvest physiological disorders; decreasing rate of ripening and prolonging shelf life.

Exporting mangoes ordered a quarantine heat treatment consisting of exposure to 46 °C water for 65–110 min, depending on cultivar and fruit size (USDA-APHIS, 2002). But, immersion of mangoes in HW at 42-49 °C induced a range of external and internal heat injuries as skin damage, including skin scalding, lenticels damage and cavitations development, together with the retention of unripe, starchy areas in the mesocarp as the fruit ripen . Physiological interpretation of heat injuries in mangoes still obscures (Jacobi *et al.*, 2000). Effect of HWD on fruit ripening in mango was variable, it can promote, inhibit or disrupt fruit ripening process, depending on temperature degree and immersion period (Lurie 1998) . Fruit ripening has been described as an oxidative phenomenon that requires a turnover of reactive oxygen species, such as H_2O_2 and superoxide anion (Jimenez et al, 2002). Plant cells have different antioxidants to eliminate these compounds. Miyake and Asada (1996) demonstrated that, the antioxidant system includes catalase (CAT, EC 1.1 1.1.6), superoxide dismutase (SOD, EC 1.15.1.1), guaiacol peroxidise (GPX, EC 1.11.1.7), ascorbate peroxidise (APX, EC 1.11.1.11) and glutathione reductase (GR, EC 1.6.4.2).

Moreover, low fruit calcium levels have been associated with reduced postharvest life and physiological disorders in mango (Wills et al 1998). Calcium treatment had been shown to decrease respiration, reduce ethylene production and to delay the onset of ripening in mango (Tirmazi and Wills 1981). 4% or 8% $CaCl_2$ dips have been reported to increase the time to ripening of green mature mangoes (Tirmazi and Wills 1981as well as Mootoo 1991). Calcium chloride has been shown to help maintain firmness (Trindade *et al.*, 2003) and a combination of browning inhibitors (hexyl resorcinol, potassium sorbate, and ascorbic acid) have been effective in delaying surface browning of cut slices (Gonzalez-Aguilar *et al.*, 2000).Also, $Ca(NO_3)_2$ 1% delayed ripening of Bangapalli' mangoes more than 6 days over the control (Gautam *et al.*, 2003) and reduced weight loss in Dashehari mangoes at 2% concentration(Kaushik and Kumar 1991).

The aim of this work was to study the impact of HWD or $Ca(NO_3)_2$ treatments on fruit quality attributed to 'physiological and biochemical reactions of two different mango cultivars 'White Sukkary" and 'Zebda' during shelf life period

MATERIALS AND METHODS

Plant material and handling

During 2008 season, *Mangifera Indica* L cvs 'White Sukkary' and 'Zebda' commercially mature green fruit were harvested randomly from Suez Canal University Farm, Ismailia Governorate, Egypt (Latitude, 30°36' N; longitude, 32°14' E; Altitude, 10 m above sea level). Fruit were directly transported to postharvest Lab. at the Hort. Dept., in the same Univ., and then sorted to eliminate defects. Samples of fruit had uniform size and appearance were washed by chlorine solution (100 ppm/15 min), air dried and held for 24h at room temperature.

In the next day, fruits were randomly divided into five treatment groups, each of 21 'White Sukkary' or 'Zebda' fruit. The first group was used as the control dipped in distilled water for 15 min at 28±1 °C, the second group was subjected to HWD at 47±1°C/20 min for 'White Sukkary' (43°C in bulb was recorded), 49±1°C/30 min for 'Zebda'(42.5°C in bulb was measured); the third group was subjected to HWD at 53±1°C /5 min for 'White Sukkary' (41.5°C in bulb) and 8 min for 'Zebda' (37°C in bulb). HWD treatments were performed in a water bath constantly maintained within ±1°C of the required temperature by a thermostat. The forth group was subjected to $Ca(NO_3)_2$ at 4%/15 min and the final group was subjected to $Ca(NO_3)_2$ 6%/15 min for both two cultivars. All groups were left at shelf life conditions (30±2day/21± 2night°C and 35-45% RH) for 5 days in 'White Sukkary' and to 14 days in 'Zebda'.

Each treatment was packed in 3 foam plates or 3 replications (7 fruit each). 'White Sukkary' plats put in perforated polyethylene pages but 'Zebda' fruit stored without packaging. Fruit plates were used for physical properties assessments (weight loss%, Lenticels prominence and abundance and skin shriveling) and chemical characteristics (soluble solids content (SSC), total acidity (TA), peel pigments, calcium content, ascorbic acid (VC), reducing sugars, free phenols, Peroxidase (POX) activity, Catalase (CAT) activity and Ascorbic acid oxidase (ASAO).

Evaluation of firmness and fruit weight loss:

Weight loss was calculated and expressed as a percentage of the original fresh weight of fruit. Fruit firmness was measured using a penetrometer (Fruit Tester) fitted with a 6 mm diameter flat probe and results were expressed as kg cm^{-2}. Description of lenticels prominence and abundance and degree of skin shriveling were rated on 21 fruit using subjective characters: low= 25% covered skin surface; medium =50% covered skin surface; abundant or high ≥75% covered skin surface.

Chemical analysis of juice:

At zero time and after shelf life period, fruit samples (after 5 days in 'White Sukkary' and 7, 14 days in 'Zebda') were taken for determination of the chemical properties. SSC was measured by refractometer; TA and VC were determined according to AOAC (1985).

1. Free phenols and reducing sugars:

Ethanolic extract (96% ETOH) of juice was prepared according to Abdel-Rahman *et al.* (1975) and then the free phenols were determined spectrophotometricaly by using (Beckman DK-2 Spectrophotometer) at 650 nm with Folin-Ciocalteu reagent according to AOAC (1985). Reducing sugars were determined with alkaline copper and arsenomolybdate reagents spectrophotometricaly at 540 nm according to Moore (1974).

2. Pigments of peel:

0.5 g carotenoid-free peel was ground with 10ml aceton (85%), then filtered. Optical density was measured at 662,644 and 440.5 nm using a Beckman DK-2 Spectrophotometer. Concentration of Chl a, Chl b and

carotenoids as mg per g FW were calculated according to Fadl and Sari Eldeen (1978).

3. Calcium content:

0.5 g dried peel or bulb was digested with 10ml H_2SO_4 overnight, then digestion was completed with H_2O_2 and adjusted to final volume to 50 ml dionized H_2O. Calcium was determined by titration against versenate solution (Na-EDTA) and 0.1 M sodium hydroxide (pH 12-13) according to Chapman and Pratt (1961).

4. Preparation of enzyme extract in juice and peel:

At zero time and after shelf life period, fruit samples were taken for the enzymes assay. 0.5 g fresh juice or peel was homogenized by using a mortar and pestle with 0.1 M phosphate buffer (pH 6.5) at 4°C and stirred for 20 min. The suspension obtained was filtered through one layer of muslin cloth and then centrifuged at 18000g for 15 min, 4°C. The supernatant was used to determine activity of antioxidant enzymes (Urbanek *et al.*, 1991) as follow:

4.1. Peroxidase (POX) [EC 1.11.1.7] assay:

The reaction mixture consisted of 3.5 ml of 0.1 M phosphate buffer (pH 6.5), 0.3 ml of 0.1 % o-dianisidine solution, 0.2 ml of enzyme extract and 0.2 ml of 0.2 M hydrogen peroxide solution (Urbanek *et al.*, 1991). The reaction mixture was incubated at 30°C for 10 min and the oxidation of o-dianisidine was measured by changes in optical density at 430 nm (Beckman DK-2 Spectrophotometer). Corrections were done for the oxidation rate of o-dianisidine in the absence of H_2O_2 in the reaction mixture. The activity of POX was expressed as optical density per milligram of protein per minute. One unit of POX activity (AU) was taken as the change of 1.0 unit of optical density per minute.

4.2. Catalase (CAT) [EC 1.11.1.6] assay:

The reaction mixture consist of 0.01 ml enzyme extract and 2.99 ml hydrogen peroxide-phosphate buffer (pH 6.8) were prepared after dilution of 0.16 ml of H_2O_2 (10% w/v) to 100 ml phosphate buffer (Urbanek *et al.*, 1991). The oxidation of H_2O_2 was measured by changes in optical density at 240 nm in 30 sec. intervals for 5 min (Beckman DK-2 Spectrophotometer). The unit of CAT activity was defined as the amount of enzyme, which decomposes 1 mmol H_2O_2 per minute at 25°C (Urbanek *et al.*, 1991).

4.3. Ascorbic acid oxidase (ASAO) [E.C. 1.10.3.3] assay:

The reaction mixture consist of 0.1 ml enzyme extract and 2.9 ml ascorbic acid–phosphate buffer (pH 5.6) prepared as 8.8 mg ascorbic acid dissolved in 300 ml phosphate buffer. The oxidation of ascorbic acid was measured by changes in optical density at 265 nm in 30 sec. intervals for 5 min (Beckman DK-2 Spectrophotometer). The unit of ASAO activity was defined as the amount of enzyme, which decomposes 1 mmol ascorbic acid per minute at 25°C. Protein content of the extracts was determined according to Bradford (1976), using bovine albumin serum (BSA) as a standard.

Statistical analyses:

All data were statistically analyzed as randomized complete blocks design (Steel *et al.*, 1997); using the MSTAT-C statistical package (M-STAT, 1990) and means were separated by LSD test, $P \leq 0.05$.

RESULTS AND DISCUSSION

Ripening and peel pigments:

Heat treatments have been reported to accelerate the yellowness of the fruit skin and in some cases, improve the uniformity of colour development. These treatments have also been found to accelerate fruit softening of a number of mango cultivars (Ledger 1995). Data represented in Table 1 and 2 demonstrated that, $Ca(NO_3)_2$ or HWD treatments accelerated ripening of both 'White Sukkary' and 'Zebda' mangoes compared to control. 'White Sukkary' fruit reached to full yellowness after 2 days under 53±1 ^{0}C for 5 min HWD and 6% $Ca(NO_3)_2$ treatments, compared to control or other treatments, but 'Zebda' fruit obtained the maximum yellowing degree after 7 days only under 53±1 ^{0}C for 8 min HWD treatment. The mechanisms by which heat treatments accelerate mango fruit ripening are most probably associated with increasing synthesis of carotenoids, degradation of chlorophyll (by chlorophyllase) and synthesis of cell wall degrading enzymes such as polygalacturonase (Jacobi *et al.*, 2000). 'White Sukkary' fruit showed maximum significant values of carotene after 5 days shelf life (3.41 mg/g FW) and (3.31 mg/ g FW) under 53±1 ^{0}C for 5 min HWD and 6% $Ca(NO_3)_2$ treatments, respectively. In the same manner, HWD 53±1 ^{0}C for 8 min only showed the highest significant incidence of carotene (3.35 and3.53 mg/g FW) in 'Zebda' fruit after 7 and14 days shelf life, respectively compared to control and other treatments. In contrary, minimum content of chl.a and chl. b were found in fruit which showed highest significant values of carotene in both 'White Sukkary' and 'Zebda' mangoes.

This supports previous findings by Jacobi and Giles (1997) who reported that vapour heat treatment (VHT) /47°C for 15 min, or hot water (HW)/53°C for 5 min prior to VHT, combined with either storage at 10°C for 5 days followed by 22°C for 5 days or storage at 22°C for 10 days of 'Kensington mangoes had higher skin colour ratings, reflectance and chroma values, and lower hue angles thar untreated fruit, indicating an enhancement of ripening. Moreover, vapor heat (46.5°C for 40 min) maintained peel color index in 'Tuu Shien' mangoes (Le *et al.*, 2010). Furthermore, Joyce *et al.*, (2001) found that, treatment with 4% $CaCl_2$ did not extend the shelf life of fruit of four mango cultivars (Kensington, Sensation, Palmer, Irwin). Also, Calcium-treated fruit exhibited no differences in colour as compared to control fruit. Calcium treatment has been shown to decrease respiration, reduce ethylene production and delay the onset of ripening in mangoes. Dipping in either 4% or 8% $CaCl_2$ has been reported to increase the time to ripening of green mature mangoes (Yuniarti Suhardi, 1992). 'Manila' mangoes heated at 40, 42 and 43°C did not show any external or internal injury, while those subjected to 44°C developed slight injury after 10 days and severe injury after 20 days. Fruit subjected to 45°C had severe injury after storage for 10 days and the injury increased very significantly after storage for 20 days. Fruit

exposed to 49°C and stored for 20 days had 100% injury (Ortega-Zaleta and Yahia, 2000)

Table 1: Effect of $Ca(NO_3)_2$ and HWD on pigments content of fruit peel and postharvest characters in 'White Sukkary' fruit.

Treatments	pigments content mg /g FW			Postharvest characters	
	Chl.a	Chl.b	Carotene	Peel full yellowness (days)	Lenticels prominence and abundance
Zero time	1.3	1.8	0.5		
Control	1.94 a	0.58 a	2.8 b	6a	Low
$Ca(NO_3)_2$ /4%	1.76 a	0.41 a	2.86 b	4a	Medium
$Ca(NO_3)_2$ / 6%	1.37 b	0.54 a	3.31 a	2b	Medium
HWD 47±1 °C/20 min	0.77 c	0.46 a	2.93 b	4a	Abundant
HWD 53±1 °C /5 min	0.76 c	0.46 a	3.41 a	2b	Abundant
L.S.D 0.05	0.25	ns	0.22	2.1	

Values are the means of 7 fruit per replicate. Values followed by the same letter within a column are not significantly different at the 0.05% level of probability according to Duncan's multiple range test.

Table 2: Effect of $Ca(NO_3)_2$ and HWD on pigments content of fruit peel and postharvest characters in 'Zebda' fruit

Treatments	pigments content mg/g FW						Postharvest characters	
	7 days			14 days				
	Chl. a	Chl. b	Carotene	Chl.a	Chl.b	Carotene	Peel maximum yellowness (days)	peel shriveling Degree
Zero time	3.3	1.2	0.98					
Control	0.51 e	1.32 a	2.11 d	0.45 ab	1.12 ab	2.55 b	20 a	High
$Ca(NO_3)_2$ /4%	0.62 c	1.2 b	2.21 c	0.42 ab	1.06 ab	2.25 b	15 b	Low
$Ca(NO_3)_2$ / 6%	0.98 b	1.34 a	2.6 b	0.56 a	0.98 b	2.53 b	20 a	Medium
HWD 49±1 °C/30 min	1.28 a	1.16 c	1.49 e	0.33 b	1.26 a	2.4 b	15 b	High
HWD 53±1 °C/ 8 min	0.55 d	1.13 d	3.35 a	0.26 b	0.91 b	3.53 a	7 c	Low
L.S.D 0.05	0.01	0.02	0.08	0.15	0.19	0.22	2.1	

Values are the means of 7 fruit per replicate. Values followed by the same letter within a column are not significantly different at the 0.05% level of probability according to Duncan's multiple range test.

The antioxidants content:

Using low heat temperature for long period was more efficient to transport heat inside fruit. Bulb recorded approximately 43°C after 47 or 49 °C/ 20-30 min HWD treatment compared to 37-41 °C after 53 °C/5 or 8 min HWD treatment in both mango cultivars. Positive correlation between fruit ripening and antioxidants behavior was recorded. Data in Table 3 and 4 showed that POX and CAT activity were increased in fruit under all treatments and control compared to fruit in zero time. POX and CAT activity were increased approximately 3 times after 5 days shelf life in both peel and juice of 'White Sukkary' fruit and during 7, 14 days shelf life of 'Zebda' fruit treated with different HWD and calcium nitrate treatments, compared to

control. In this respect, low HWD 47±1 ^{0}C/20 min in 'White Sukkary' and HWD 49±1 ^{0}C/30 min in 'Zebda' induced the maximum level of POX activity in peel and juice but high HWD treatments (53±1 ^{0}C /5 or 8 min) increased the activity of CAT in peel and juice of both two cultivars. Acceleration of fruit ripening under 53±1 ^{0}C /8 min may contribute with CAT induction. These results are in line with those obtained by previous studies of Bassal and Elhamahmy (2011) who found that POX and CAT activities were enhanced in heat-treated fruit (HWD) at 41±1°C for 20 min or at 50±1°C for 5 min during cold quarantine in W. Navel and Valencia Late oranges. Contrary to those of Singh and Dwivedi (2008) who reported that Ethrel (ripening stimulator) treatment led to an increase in H_2O_2 and lipid peroxidation, concomitant with a decrease in the activities and isozymes of CAT and SOD in 'Dashehari' mangoes.

Table 3: Content of different antioxidants in 'White Sukkary' fruit as affected by $Ca(NO_3)_2$ and HWD treatments

Treatments	Free phenols mg/g FW	POX activity unit/mg protein.min		CAT activity unit/mg protein.min	
		peel	juice	Peel	juice
Zero time	92.4	0.02	0.04	0.12	0.09
Control	90.3 a	0.07 d	0.19 b	0.34 b	0.52 b
$Ca(NO_3)_2$ / 4%	81.5 ab	0.36 c	0.60 a	0.44 b	0.81 b
$Ca(NO_3)_2$ / 6%	87.3 ab	0.34 c	0.64 a	0.33 b	0.72 b
HWD 47±1 ^{0}C/20 min	88.2 ab	0.65 a	0.75 a	1.4 a	1.29 a
HWD 53±1 ^{0}C /5 min	74.2 b	0.44 b	0.58 a	1.3 a	1.36 a
L.S.D 0.05	10.4	0.05	0.16	0.24	0.32

Values are the means of 7 fruit per replicate. Values followed by the same letter within a column are not significantly different at the 0.05% level of probability according to Duncan's multiple range test.

Table 4: Content of different antioxidants in 'Zebda' fruit as affected by $Ca(NO_3)_2$ and HWD treatments.

Treatments	Free phenols mg/g FW		POX activity unit/mg protein.min				CAT activity unit/mg protein.min			
			peel		juice		Peel		juice	
	7 d	14 d	7 d	14 d	7 d	14 d	7 d	14 d	7 d	14 d
Zero time	89.1		0.05		0.11		0.19		0.13	
Control	69.1 a	28.1 b	0.8 b	1.2 b	0.31 d	0.34 d	0.54 bc	0.63 b	0.75 d	0.43 d
$Ca(NO_3)_2$ /4%	75.6 a	20.2 c	0.16 d	0.33 c	0.69 c	0.85 b	0.67 b	0.62 b	0.69 d	0.78 c
$Ca(NO_3)_2$ / 6%	79.1 a	20.3 c	0.35 c	0.47 c	0.71 c	0.85 b	0.34 c	0.53 c	0.94 c	1.42 b
HWD 49±1 ^{0}C/30 min	78.3 a	45.5 a	0.96 a	1.4 a	1.3 a	0.59 c	1.36 a	0.63 b	1.4 b	1.55 b
HWD 53±1 ^{0}C /8 min	71.1 a	18.2 d	0.76 b	1.3 ab	0.93 b	1.7 a	1.19 a	1.32 a	1.8 a	1.8 a
L.S.D 0.05	ns	1.9	0.08	0.15	0.14	0.09	0.23	0.02	0.15	0.1

Values are the means of 7 fruit per replicate. Values followed by the same letter within a column are not significantly different at the 0.05% level of probability according to Duncan's multiple range test.

All used treatments reduced phenolic concentrations in both cultivars during shelf period compared to zero ones, but with different rates. In general, fruit-treated with 53±1 ^{0}C for 5 min or 8 min HWD showed the minimum significant content of free phenols in juice in both 'White Sukkary' and 'Zebda'. Concentration of free phenols reached 74.2 mg/g FW in 'White Sukkary' during 5 days shelf life; 18.2 mg/g FW during 14 days shelf life in 'Zebda', respectively (Table 3 and 4). This finding agreed with Gonzalez-Aguilar *et al.*, (2007) who cited that, lower decay percentage and increased shelf life of fruit under UV-C treatment were associated with increase of total phenols, total flavonoids, phenylalanine ammonia-lyase and lipoxygenase activity in 'Haden' mangoes.

The quality parameters:

Fruit shape, color homogeneity, taste, odors, SSC, TA% and others are very important characters to determine the fruit quality. Tables (4 and 5) established some quality parameters in 'White Sukkary' and zebda fruit affected with Calcium nitrate and HWD treatments.

1. Lenticels abundance and weight loss %:

If the fruit transpire too much water, they lose turgidity, and hence firmness, and may even appear slightly shriveled (Hong *et al.*, 2007). It was cleared that, HWD treatments encouraged abundance and prominence of lenticels on skin surface to abundant rate in both cultivars at the end of shelf life period compared to control or Calcium nitrate treatments (Table 1). On the other hand, this abundant sharing of lenticels on skin surface was associated with increasing of lenticellular transpiration rate or weight loss %. Although values of weight loss % showed no significant differences among all treatments in both cultivars, fruit treated with 47±1 ^{0}C for 20 min HWD and 4% $Ca(NO_3)_2$ showed the maximum values of weight loss % in 'White Sukkary' reached to 9.4 % and 8.9% respectively, during 5 days shelf life (Table 5). But 'Zebda' fruit showed the highest values of weight loss % under 49±1 ^{0}C for 30 min HWD (14.8 % and 11.5) during 7and14 days shelf life (Table 6). Moreover, 6% $Ca(NO_3)_2$ gave the minimum significant rate of weight loss % and reached 9.8 % in 'Zebda' during 14 days shelf life period. High differences in weight loss % between two cultivars attributed to polyethylene packaging. In this respect, Jacobi and Giles 1997 found that, the severity of lenticels spotting and skin browning in 'Kensington' mangoes was increased in VHT fruit. Eating quality of the fruit was not altered by any of the heat treatments. The HW-VHT treatment combined with continuous storage at 22°C produced the highest quality fruit, and was recommended for air freight marketing. Moreover, Joyce *et al.*, (2001) cited that some lenticels damage was observed as a result of Ca^{2+} infiltration into fruit of four mango cultivars (Kensington, Sensation, Palmer, Irwin). Calcium-treated fruit (4% $CaCl_2$) exhibited no differences in colour or firmness changes and weight loss during shelf life as compared to control fruit.

2. Firmness and calcium content:

Firmness values of 'White Sukkary' fruit showed no significant differences between all treatments, but fruit treated with 4% $Ca(NO_3)_2$ recorded maximum values (0.54 kg/cm^{-2}) during 5 days shelf life. 'Zebda' fruit

treated with $Ca(NO_3)_2$ 4% and 6% showed highest significant values of firmness after 7 days (1.52 kg/cm^{-2}), 14 days (0.95 kg/cm^{-2}), shelf life period. Maintenance of fruit firmness was associated with highe: concentration of calcium content in peel and mesocarp, and vice versa. Maximum significant content of calcium was recorded in fruit subjected to 6% $Ca(NO_3)_2$ (0.381, 0.084 mg/g FW in 'White Sukkary' after 5 days shelf period) and (0.066, 0.056 mg/g FW in 'Zebda' after 14 days shelf period) in peel and mesocarp, respectively. These results agreed with those of Shellie and Mangan, (1994) who reported that, mangoes and papaya treated with hot forced air for 4 h at 50°C led to faster softening after the treatment; and Le *et al.*, (2010) who mentioned that, VHT (46.5°C for 40 min) maintained firmness and total soluble solid content at 3°C of storage time in 'Tuu Shien' mangoes. Furthermore, $CaCl_2$/3% treatment was partly effective in controlling darkening of Fresh-cut slices from ripe 'Kensington' mango and significantly slowed (but did not stop) loss of tissue firmness. A combination of low oxygen and calcium allowed 'Kensington' slices to be held for at least 15 days at 3◦C (De Souza *et al.*, 2006). In addition, Joyce *et al.*, (2001) reported that, Ca^{2+} concentration ranged between 0.371 mg/g DW (skin) and 0.095 mg/g DW (inner flesh) for untreated ripened mangoes compared to 0.547-0.086 mg /g DW in treated fruit with 4% $CaCl_2$. Calcium-treated fruit exhibited no differences in firmness changes and weight loss during shelf life as compared to control fruit. Ortega-Zaleta and Yahia, (2000) found that fruit firmness losses was decreased as the temperature increased to 46°C, and then increased. Chroma of exocarp and mesocarp decreased, while hue angle value of mesocarp increased as temperature increased. Weight loss was similar in control and in heat-treated fruit. HWD 50 ◦C/30 min treatment maintained the acceptability of fresh-cut Keitt mangoes for 6 d, the yellow color, expressed by b* value, for 9 d and the firmness for 3 d compared to the control. Moreover, HWD 50 ◦C/30 min increased the total carotenoids content after 3 d compared to the control (Djiouaa *et al.*, 2009).

Table 5: Effect of $Ca(NO_3)_2$ and HWD treatments on some quality parameters of 'White Sukkary' fruit

Treatments	Weight loss %	SSC	TA%	Firmness kg cm^{-2}	Calcium content mg/g DW		Reducing sugars mg/g FW
					Peel	Flesh	
Zero time		9.87	1.7	5.4	0.366	0.043	56.2
Control	7.03 a	15.7 a	0.17 a	0.36 a	0.356c	0.075b	53.9 b
$Ca(NO_3)_2$ / 4%	8.9 a	16.2 a	0.19 a	0.54 a	0.377b	0.081a	71.1 b
$Ca(NO_3)_2$ / 6%	7.2 a	15.4 a	0.17 a	0.43 a	0.381a	0.084a	74.8 b
HWD 47±1 °C/20 min	9.4 a	15.9 a	0.2 a	0.43 a	0.156e	0.034c	69.1 b
HWD 53±1 °C /5 min	7.3 a	15.3 a	0.18 a	0.33 a	0.217d	0.025d	98.1 a
L.S.D 0.05	ns	ns	ns	ns	0.0033	0.0039	10.9

Values are the means of 7 fruit per replicate. Values followed by the same letter within a column are not significantly different at the 0.05% level of probability according to Duncan's multiple range test.

Table 6: Effect of $Ca(NO_3)_2$ and HWD treatments on some quality parameters of 'Zebda' fruit

Treatments	Weight loss %		SSC		TA%		Firmness kg cm^{-2}		Calcium content mg/g DW				Reducing sugars mg/g FW	
									peel		flesh			
	7 d	14 d	7 d	14 d	7 d	14 d	7 d	14 d	7 d	14 d	7 d	14 d	7 d	14 d
Zero time			11.8		0.61		7.5		0.863		0.057		78.3	
	7 d	14 d	7 d	14 d	7d	14 d	7 d	14 d	7 d	14 d	7 d	14 d	7 d	14 d
Control	12.9 a	10.1 ab	16.7 a	15.9 a	0.24 a	0.19 a	1.19 ab	0.82 ab	0.815c	0.81 b	0.037c	0.032 d	79.4 b	122.2 c
$Ca(NO_3)_2$ / 4%	13.9 a	10.3 ab	16.4 a	16.2 a	0.25 a	0.18 a	1.52 a	0.78 ab	0.846a	0.82 ab	0.057b	0.052 b	82.7 b	123.2 c
$Ca(NO_3)_2$ / 6%	14.1 a	9.8 b	16.1 a	15.3 a	0.2 a	0.16 a	1.3 ab	0.95 a	0.831b	0.83 a	0.066a	0.056 a	82.8 b	142.5 a
HWD 49±1 ^{0}C/30 min	14.8 a	11.5 a	15.9 a	16.1 a	0.25 a	0.17 a	1.19 ab	0.68 b	0.729d	0.61 d	0.056b	0.042 c	72.1 b	132.2 b
HWD 53±1 ^{0}C /8 min	12.8 a	10.9 ab	16.6 a	15.3 a	0.22 a	0.19 a	0.92 b	0.75 ab	0.712e	0.67 c	0.036c	0.032 d	119.7 a	143.2 a
L.S.D 0.05	ns	1.5	ns	ns	ns	ns	0.46	0.23	0.0097	0.02	0.0056	0.001	10.9	1.7

Values are the means of 7 fruit per replicate. Values followed by the same letter within a column are not significantly different at the 0.05% level of probability according to Duncan's multiple range test.

3. SSC, TA% and reducing sugars:

There is general agreement in the literatures that, mango fruit not damaged by HWD treatment, has comparable organoleptic qualities of flavor, aroma, or altered pH, total soluble solids and titratable acidity levels to those of untreated fruit (Jacobi and Giles 1997). SSC and TA% (Table 5 and 6) showed no significant differences between all treatments during 5 or 14 days shelf life in 'White Sukkary' or 'zebda' fruit, respectively. Acceptable taste of mango fruit depends on TA and reducing sugars ratio. In general, data cleared that HWD treatment up-regulated sugars mediate enzymes that metabolized starch and sucrose to glucose and fructose. In this concern, fruit treated with 53±1 ^{0}C for 5 or 8 min HWD recorded (Table 5 and 6) the maximum values of reducing sugars (98.1 mg/g FW in 'White Sukkary' during 5 days shelf period) and (119.7 and 143.2 mg/g FW in 'Zebda' after 7, 14 days shelf period, respectively).

Flavor characteristics of fruit can be affected by a heat treatment. Titratable acidity declines with HWD for 15 min at 35, 45 or 55°C in strawberries for decay control (Garcia *et al.*, 1995), while soluble solids concentration was not affected by the treatment. Dea *et al.*, (2010) founded that visual quality, electrolyte leakage, firmness, and aroma volatile production did not differ between the fresh-cut slices prepared from HW and non-HW-treated mango fruit under 46 ◦C water for 65–110 min (a quarantine heat treatment). The fresh-cut slices from non-HW treated fruit had higher soluble solids content than the HW-treated samples. There were also differences between the treatments for respiration rate, titratable acidity, and pH; but, the results were contradictory between the two harvests. Overall, the results suggest that the HW quarantine treatment applied to whole mangoes does not significantly affect the quality of fresh-cut 'Kent' mango slices stored at 5 ◦C. Conditioning of mature 'Kensington' mango fruit at 40°C prior to HWT (45°C for 30 min or 47°C for 15 min) accelerated the ripening of fruit, increased weight loss, reduced fruit firmness, increased brix and lowered titratable acidity compared to untreated fruit and fruit receiving other heat treatments. These treated fruit were also more resistant to postharvest diseases (Jacobi *et al.*, 2000).

V C and ASAO:

The content of VC in fruit and vegetables can be influenced by various factors such as genotypic differences, preharvest climatic conditions and cultural practices, maturity and harvesting methods, and postharvest handling procedures. Temperature management after harvest is the most important factor to maintain VC of fruit and vegetables; losses are accelerated at higher temperatures and with longer storage durations. However, some chilling sensitive crops show more losses in VC at lower temperatures. Conditions favorable to water loss after harvest result in a rapid loss of VC especially in leafy vegetables (Lee and Kader 2000). In our study, content of VC was doubled in both fruit cultivars during shelf life period compared to zero ones, then decreased with prolonged postharvest period especially in 'Zebda'

(Figure 1). Maximum significant content of VC occurred in 'White Sukkary' fruit treated with both Calcium nitrate concentrations 4 and 6% (16.1 and 17.3 mg/ml juice, respectively) compared to HWD treatments. Reduction of VC content in fruit under HWD treatments was associated with higher activity of ASAO by 2-3fold (Figure 2) compared to Calcium nitrate treatments which recorded 0.73 and 0.69 unit/mg protein.min under $Ca(NO_3)_2$ /4 and 6 %, respectively compared to 1.43 and 1.23 unit/mg protein.min in the two HWD treatments. The same trend was observed in 'Zebda' fruit, recorded maximum significant values of VC after 7 days shelf life only under different calcium nitrate concentrations, paralleled to decrease of ASAO activity to half, compared to HWD treatments (Figure 1 and 2).

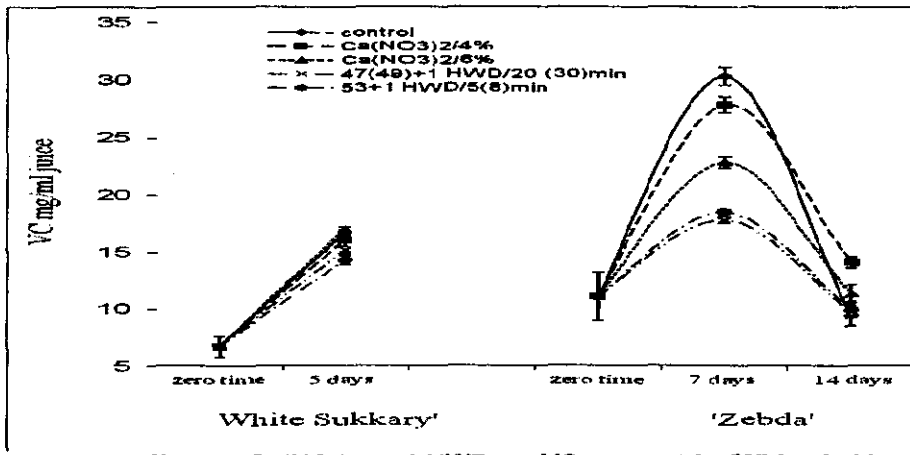

Figure 1: Effect of $Ca(NO_3)_2$ and HWD on VC content in 'White Sukkary' and 'Zebda' fruit during shelf life storage. (means±SE, n = 4). P≤0.05 as determined by Duncan's test.

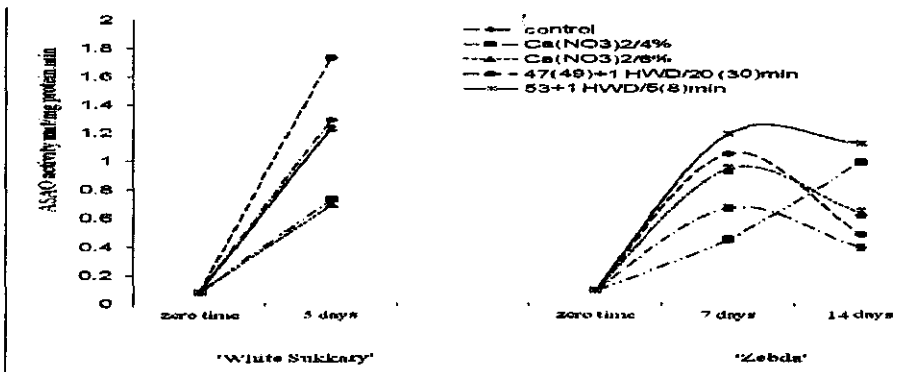

Figure 2: Effect of $Ca(NO_3)_2$ and HWD on ASAO activity in 'White Sukkary' and 'Zebda' fruit during shelf life period. (means±SE, n = 4). P≤0.05 as determined by Duncan's test.

These results coordinated with Bassal and Elhamahmy, (2011) who found that HWD treatments mostly increased VC content, especially in W. Navel orange, while reduced ASAO activity. Also, although ascorbic acid content decreased during storage, HWD 50 ◦C/30 min was the less degrading condition of the heat treatments. In previous report, HWD 50 ◦C/30 min was selected as the optimal heat treatment to improve the quality of fresh-cut 'Keitt' mangoes (Djiouaa, *et al.*, 2009). Moreover, the higher level of fructose in an orange juice product, the greater the loss of VC. (Nagy, 1980). Phenolics were reported to protect VC against oxidative decomposition in fruit juices (Miller and Rice-Evans, 1997).

Conclusion:

HWD 53±1 ◦C/5 or 8 min or $Ca(NO_3)_2$ /6% accelerated ripening of 'White Sukkary' and 'Zebda' mangoes and recorded high level of carotene synthesis in peel. Peroxidase and catalase activities were increased 3 times in treated fruit, compared to untreated ones. Weight loose % and VC values were maintained only in Ca $(NO_3)_2$ /6% treated fruit, may be contributed with low Ascorbic acid oxidase activity compared to HWD treatment or control. Fruit firmness was not significantly affected by calcium treatments only in 'Zebda' and associated with high level of calcium content in peel and juice.

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السلوك الفسيولوجى والكيموحيوى لثمار المانجو صنفى السكرى الابيض والزبدة اثناء فترة التخزين العادى بعد معاملة الغمر فى الماء الساخن ونترات الكالسيوم

مجدى محمد بصل* و محمد على محمود الحماحمى**

*** قسم البساتين – كلية الزراعة – جامعة قناة السويس- ٤١٥٢٢ الاسماعيلية – مصر**

**** قسم النبات الزراعى-كلية الزراعة -جامعة قناة السويس-٤١٥٢٢ الاسماعيلية-مصر**

عادة ماتستخدم المعاملات الحرارية خاصة الغمر فى الماء الساخن للحد من الاصابة بذبابة الفاكهة ومن تلف الثمار. تم دراسة السلوك الفسيولوجى والكيموحيوى لثمار المانجو بعد معاملة بالغمر بالماء الساخن (٤٧م ± ١ لمدة ٢٠ دقيقة و٥٣م ± ١ لمدة ٥ دقائق) لصنف السكرى الابيض و (٤٩ م ± ١ لمدة ٣٠ دقيقة و ٥٣م ± ١ لمدة ٨ دقائق) لصنف الزبدة وكذلك المعاملة بنترات الكالسيوم ٤ و ٦ % لمدة ٢٠ دقيقة فى كلاهما اثناء فترة التخزين العادى. اظهرت الدراسة تاثير قويا على سرعة وتحسين خواص النضج لكلا من معاملتى الغمر فى الماء الساخن ٥٣م ± ١ لمدة ٥ او ٨ دقائق او معاملة نترات الكالسيوم ٦% فى كلا من الصنفين . لوحظ زيادة مستوى صبغة الكاروتين في جلد الثمار مرتبطا بارتفاع نشاط انزيم الكتا ليز فى ثمار كلا الصنفين تحت تاثير المعاملة بـ٥٣م ± ١ لمدة ٥ او ٨ دقائق او معاملة نترات الكالسيوم ٦% . بينما لوحظت زيادة معنوية فى نشاط انزيم البيروكسيديز فى كلا من جلد وعصير الثمار المعاملة بـ ٤٧ م او٤٩ م ± ١ لمدة ٢٠ او ٣٠ دقيقة . احتفظت الثمار المعاملة بـ نترات الكالسيوم ٦% بنسبة منخفضة من فقد الوزن وفيتامين ج. معاملة الماء الساخن ادت لخفض نشاط انزيم اسكوربيك اسد اوكسيديز مقارنة بمعاملات نترات الكالسيوم والكنترول . هناك ارتباط معنوى بين تركيز الكالسيوم فى جلد اولب الثمرة وصلابة ثمار الصنف الزبدة فقط. ايضا تم تقييم مستوى المواد الصلبة الكلية والحموضة الكلية والسكريات المختزلة والفينولات الحرة. يمكن التوصية بامكانية استبدال المعاملة بالماء الساخن (٥٣م ± ١ لمدة ٥ او ٨ دقائق او معاملة نترات الكالسيوم ٦%) لاسراع وتحسين انضاج ثمار المانجو صنفى السكرى الابيض والزبدة بدلا من استخدام منظمات الانضاج الصناعية.

قام بتحكيم البحث

أ.د / محمد نصر الدين هلالى	كلية الزراعة – جامعة المنصورة
أ.د / عبد الغنى عمر باز	كلية الزراعة – جامعة الاسماعيليه