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Impact of Hot Water Treatments on the Quality of Mango Fruits During Storage

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Abstract: This study was carried out during 2009 and 2010 seasons to study the effect of hot water treatments on chilling injury occurs in 'Tommy Atkins' and 'Heidi' mango cultivars. Fruits of each cultivar were tap washed, air dried and the selected fruits were randomly divided into five experimental groups. The 1st group was stored at 20°C for 72 hr, the 2nd, 3rd and 4th group were dipped in hot water at 30, 40, 50°C for 30 min, while the 5th group was stored directly at 7°C (control). All treatments were then stored at 7°C and 85-90 % relative humidity for 4 weeks. At the end of the cold storage period, all treated fruits were stored at room temperature (20°C) for 6 days, considering as a shelf life period. Fruit samples from each treatment were taken at 0, 3 and 6 days after storage period (during shelf life) for determining chilling injury symptoms, percentage of decayed fruits, total acidity, TSS%, total sugars and total phenols. Catalase and Peroxidase specific activity was assayed at 7-day intervals during storage period (four weeks). Results indicated that 'Heidi' was more sensitive to chilling injury and decay than Tommy Atkins. Preconditioning treatment enhanced the decrement of acidity and total phenols, moreover the increment of TSS, total sugars compared with control. Heat treatments had a significant effect on Catalase and Peroxidase specific activity. The effect of enzymes activity and the developmental appearance of fruit chilling injury percentages due to oxidative stress were determined.

Key words: Heidi · Tommy Atkins · Chilling injury · Fruits physical and chemical properties

INTRODUCTION

Mango (*Mangifera indica* L.) is considered climacteric fruit with limited storage period. Fruit is susceptible to a number of biotic and abiotic stresses that leads to rapid deterioration and large postharvest losses [1-3]. For this reason, the quality of the fruit rapidly decreases once fully ripe. Also, it was observed that the heat removed as per treatment enhanced the quality of the fruit and prolonged the shelf life more than others [4].

Cold storage is essential during long transportation to increase the fruit life period, in addition to affecting ripening attributes and fruit quality. Chilling injury is the main disorder that obstructs the storage at low temperature to extend the storage period so there is a limited range of storage temperatures [5].

Storage of mango at low temperatures results in chilling injury (CI), which is manifested by grayish scald-like discoloration of the skin, skin pitting, uneven ripening, reductions in the level of carotenoids [6]. The results of Zhao *et al*. [7] suggested that stronger resistance of preyellow and yellow mangoes to CI compared to green fruit was due to their higher antioxidant capacity involved in the tolerance to chilling temperature.

Chilling injury disorders are associated with many changes in fruit quality which appear in many images such as; color development in peel and flesh, distinguished taste and aroma, firmness, also it has undesirable changes in fruit valuable appear as uneven ripen or defected fruit, ascorbic acid content, carotenoids, total phenols, TSS, acidity, total sugars content and others. Thus, the aim of this work is to investigate the effect of chemical and physical characteristics associated with chilling injury on the thermal treatments in mango cultivars (Tommy Atkins and Heidi) that considered among the recommended cultivars for export and to increase fruit storage period by dipping in hot water before cold storage whether for exportation or local consumption.

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MATERIALS AND METHODS

This study was carried out during 2009 and 2010 seasons at Pomology lab., Faculty of Agriculture, Cairo University on fresh fruits of two mango cultivars (Heidi and 'Tommy Atkins). Fruits were harvested from seven years old mango trees budded on seedling rootstocks and received the common horticultural practices. The harvested fruits were mature and homogeneous in size and free from obvious mechanical damage or pathological defects. Fruits of each cultivar were tap washed, air dried and the selected fruits were randomly divided into five experimental groups. The 1st group was stored at 20°C for 72 hr, the 2nd, 3rd and 4th group were dipped in hot water at 30, 40, 50°C for 30 min, while the 5th group was stored directly at 7°C (control). Each treatment had three replicates; each contained 6 carton boxes (9 fruits per box). All treatments were then stored at 7°C and 85-90 % relative humidity for 4 weeks. At the end of the cold storage period, all treated fruits were stored at room temperature (20°C) for 6 days, considering as a shelf life period.

Three fruits from each replicate were taken at 0, 3 and 6 days after storage period (during shelf life) for physical and chemical fruit analysis. The fruits physical prosperities as chilling injury symptoms were calculated visually according to the scale described by Lederman *et al*. [8] and Nair and Singh [9]. The percentage of decayed fruit was calculated on the bases of total fruit number according to Nasr [10]. Total acidity in the extracted juice against 0.1 N of NaOH using phenolphathalin indicator [11]. TSS% was measured according to Chen and Mellenthin [12]. The fruits flesh was used to assign; total sugars content expressed as g/100g fresh weight of fruit flesh according to Malik and Singh [13]; total phenols content expressed as mg/100g fresh weight of fruit flesh according to Swain and Hillis [14].

Fruit samples from each replicate were taken at 7-day intervals during storage period (four weeks) for determining Catalase and Peroxidase specific activity. Catalase specific activity was assayed by measuring the decrease in absorbance due to disappearance of H_2O_2 at 240nm according to Sala and Lafuente [15] and Peroxidase specific activity was assayed according to El-Emaery [16]. The obtained data was statistically analyzed as factorial randomized complete design and means were compared by the least significant difference test (L.S.D) at the 5% level of probability as described by Snedecor and Cochran [17].

RESULTS AND DISCUSSION

Fruits Chilling Injuries as Affected by Different Hot Water Treatments

Fruits Physical Characters: Generally, the statistical analysis of the obtained data proved that all hot water treatments compared to control (stored at 7°C) significantly affect the means of all studied physical fruits prosperities. Regarding fruits chilling injury, columns in Figure (1) proved that chilling injury symptoms increased continuously by storage at low temperature and storage period, while hot water treatments delayed and minimized it. It is obvious that, the performance of the two cultivars was significantly differed in both seasons. In addition, the adopted heat treatments demonstrated that Heidi mango cultivar was significantly more sensitive to chilling injury compared to Tommy Atkins in both seasons. In general, in the first season in both cultivars, cold storage preconditioning treatment at 20°C for 3 days followed by hot water dipped at 40 and 50°C resulted in the lowest significant recorded values, while 50°C hot water treatment showed the significant lowest value in the second season with Tommy. Heidi treated with 40°C showed the lowest value in the second season, compared to control in both seasons. Moreover, during shelf life, hot water dipping at 40°C showed the lowest significant value in the first season, while the 50°C treatment showed the significant lowest value in the second season, compared to control in both cultivars in both seasons. Hot water treatments delayed the appearance of chilling injury for one week, compared to the control in both cultivars in both seasons. These outcomes are in harmony with those obtained by McCollum *et al.* [18] who indicated that mango tolerance to chilling temperature might increase after pre-storage heat treatments. Also Zambrano and Materano [19] reported that, immersion in hot water decreased the incidence of chilling injury.

With regard to the fruit decay percentage, the mango cultivar Tommy Atkins showed the lowest decay percentage compared to the other cultivar Heidi. Figure (2) illustrated that, preconditioning treatment at 20°C for 3 days for Tommy Atkins, showed the lowest significant value during both seasons, while control and hot water 40°C and 50°C dipping treatments showed high decay percentages in the first season. The other cultivar Heidi treated with the same preconditioning treatment produced the lowest significant value in the first season. While, in the second season, the lowest decay percentage was obtained with 20°C and 30°C treatments. On the other hand the highest significant value was realized at 50°C water dipping treatment in both seasons.

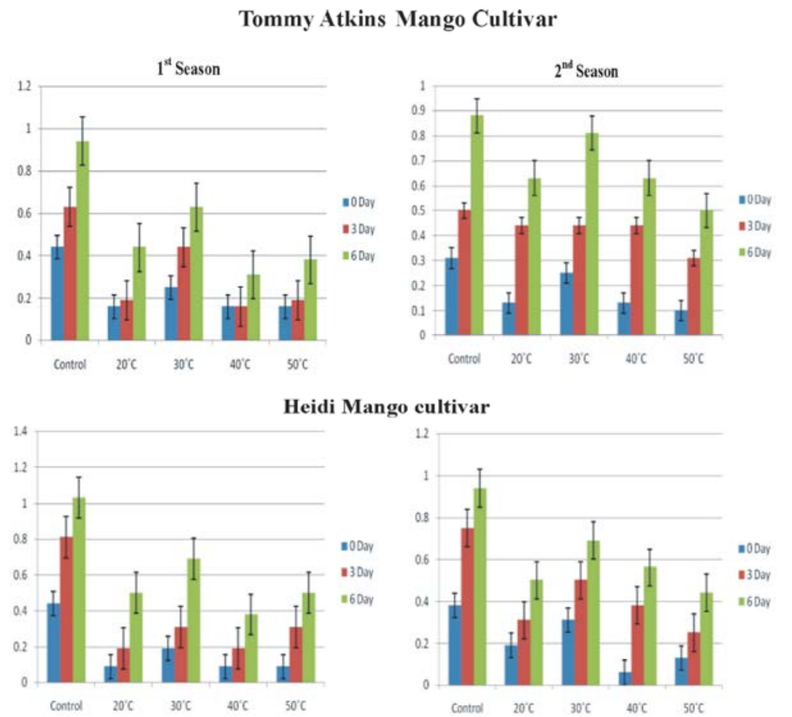

Fig. 1: Effect of hot water and cold storage treatments on fruit chilling injury index during 6 days shelf life of Tommy Atkins and Heidi mango cultivars, in both seasons.

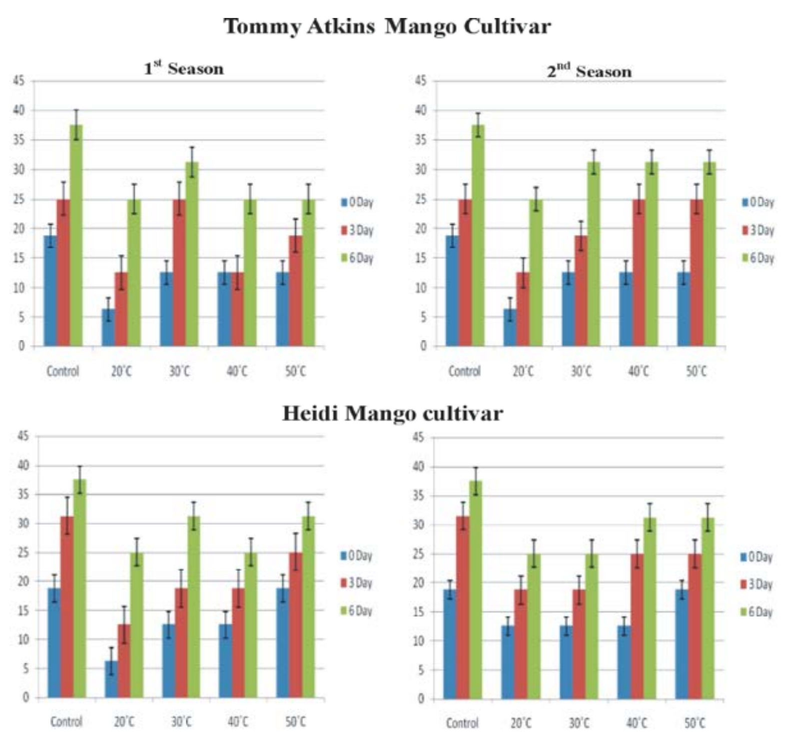

Fig. 2: Effects of hot water and cold storage treatments on fruits decay% during 6 days shelf life, of Tommy Atkins and Heidi mango cultivars, in both seasons.

Decay percentage in both cultivars increased continuously with storage period in all treatments during both seasons. Decay reached its maximum value by the end of storage period (the fourth week). The highest decay value was recorded with control fruits in Tommy Atkins, in both seasons. While Heidi treated with 50°C and control fruits showed the highest values by the same value both seasons.

The effect of hot water treatments on decay percentage during shelf life at 20°C in both seasons proved that Tommy Atkins showed more resistance compared to Heidi. So, decay reached its maximum by the sixth day, the highest value was in control fruits of both cultivars.

Data of the general appearance and decay percentage proved that; percent of decay recorded after dipping at 40 or 50°C, resulted in heat injury disorder. The highest detected decay percentage was from chilling injury disorder, by the end of the storage period and during shelf life period the decay percentage increased continuously, probably from chilling injury appeared as a residual effect or from the exposure to high temperature after cold storage, which helped many fungal diseases to become feasible. Therefore, decay might be because of one or more of the following reasons; chilling injury during cold storage or the residual effect during shelf life, heat injury because of heat treatments and over ripeness.

Many investigators were in agreement with our stated results, most of them used hot water as a quarantine treatment [20-26].

Significant differences were realized between the two cultivars in both seasons for the effect of hot water treatments on visual score general appearance of the studied fruits during storage at 7°C in both seasons. In Tommy Atkins, the 40°C hot treatment showed the highest significant score, compared to 50°C hot water treatment that showed the lowest score in both seasons. In Heidi, the 30 and 50°C hot water treatments showed the lowest significant value in the first season, while the 50°C treatment showed the lowest significant visual score in the second season as compared to 20°C and 40°C hot water treatments that showed the highest score in both seasons. It is apparently that, the general appearance score decreased continuously with storage period in all treatments in both cultivars during both seasons. For Tommy Atkins the control and 30°C hot treatment showed the lowest significant value in the 4th week during the first season, whereas 30°C hot water treatment showed the lowest significant score in the storage period in the second season. The other cultivar Heidi, in the first season, showed the lowest significant score with the control and 30°C hot water treatment in the 4th week. While, in the second season, 50°C hot treatment showed the lowest significant score in the fourth week.

The present investigation proved that chilling injury symptoms increased continuously by storage at low temperature and storage period, while hot water treatments delayed and minimized it. The present outcomes on the physical fruits characters are in agreement with those obtained by Medlicott *et al*. [27] Mohammed and Brecht [28]. There are many opinions about the main factors that cause chilling injury disorder. In Addition, Nunes *et al*. [29] found a different response of Tommy Atkins and Palmer mangoes when stored in different temperatures in chilling injury index. McCollum *et al*. [18] indicated that mango tolerance to chilling temperature might increase after pre-storage heat treatments. Zambrano and Materano [19] immersed mango fruits Palmer was dipped in hot water 38, 46 or 54°C for 30 min before storage at 5°C for 2,4 or 6 weeks then stored at 20°C until ripening. Immersion in hot water decreased the development of chilling injury.

Fruits Chemical Characteristics: Generally, the statistical analysis of the obtained data proved that all hot water treatments significantly altered the means of all studied chemical fruits prosperities. The effect of hot water treatments on TSS% of the two studied cultivars fruits during storage at 7°C are represented in Tables (1 and 2). It is obvious that, the total soluble solids percentage was higher in Heidi fruit compared to Tommy Atkins in both seasons. In the first season, the preconditioning treatment of Tommy Atkins fruits with 20°C for 3 days showed the highest significant TSS percentages, while dipping in hot water at 50°C treatment showed the highest significant TSS% in the second season compared to control that showed the lowest percentages in both seasons. The same treatments with the other cultivar 'Heidi' showed the highest TSS% in the first season, while the preconditioning treatment at 20°C for 3 days and dipping in hot water at 40 and 50°C showed the highest TSS percentage in the second season, compared to the control that showed the lowest percentages in both seasons. It is also evident that, in both seasons, TSS percentages in the fruits of the two cultivars, increased continuously with storage period in all treatments. Hot water treatments enhanced the increasing in this percentage compared to the control in both cultivars in both seasons. In the first season, Tommy Atkins fruits that received 20°C hot water

Table 1: Effects of heat and cold storage treatments on fruits TSS% during 6 days shelf life, of Tommy Atkins and Heidi mango cultivars in 2009 and 2010 seasons.

		Shelf life days (C)				Shelf life days (C)			
		0	3	6	Mean	0	3	6	Mean
Cultivar (A)	Treatment (B)	Season 2009				Season 2010			
Tommy Atkins	Control	11.40	12.49	13.07	12.32	11.00	12.13	13.40	12.18
	20°C	13.80	13.64	14.00	13.81	13.33	13.83	14.20	13.79
	30°C	12.51	12.60	13.40	12.83	11.93	12.33	12.20	12.15
	40°C	12.60	13.00	13.43	13.01	13.13	13.40	14.13	13.55
	50°C	13.21	13.26	14.27	13.58	13.27	14.20	14.73	14.07
	Mean	12.70	12.99	13.63	13.11	12.53	13.18	13.73	13.15
Heidi	Control	11.85	12.51	13.60	12.65	11.63	12.46	13.67	12.59
	20°C	13.81	13.75	13.93	13.83	13.40	13.87	14.53	13.93
	30°C	12.92	13.03	13.40	13.12	12.73	13.07	13.43	13.08
	40°C	13.49	13.83	14.50	13.94	13.97	14.14	14.48	14.19
	50°C	13.80	14.53	15.13	14.49	14.16	14.40	15.16	14.58
	Mean	13.17	13.53	14.11	13.61	13.18	13.59	14.25	13.67

	Shelf life days (C)				Shelf life days (C)			
Treatment (B)	0	3	6	Mean	0	3	6	Mean
Control	11.63	12.50	13.33	12.49	11.32	12.29	13.53	12.38
20°C	13.80	13.70	13.96	13.82	13.36	13.85	14.36	13.86
30°C	12.71	12.82	13.40	12.98	12.33	12.70	12.82	12.62
40°C	13.04	13.42	13.96	13.47	13.55	13.77	14.31	13.87
50°C	13.50	13.89	14.70	14.03	13.72	14.30	14.95	14.32
Av. Treat.	12.94	13.26	13.87	13.36	12.85	13.38	13.99	13.41

L.S.D at 0.05 for 2009 season: A = 0.173; B = 0.300; C = 0.233; (A × B) =0.424; (A × C) = 0.329; (B × C) = 0.520; (A × B × C) = 0.735

L.S.D at 0.05 for 2010 season: A = 0.231; B = 0.214; C = 0.166; (A × B) =0.304; (A × C) =0.235; (B × C) = 0.372; (A × B × C) = 0.526

Table 2: Effects of heat and cold storage treatments on fruits acidity % during 6 days shelf life, of Tommy Atkins and Heidi mango cultivars in 2009 and 2010 seasons

		Shelf life days (C)				Shelf life days (C)			
		0	3	6	Mean	0	3	6	Mean
Cultivar (A)	Treatment (B)	Season 2009				Season 2010			
Tommy Atkins	Control	1.72	1.85	2.72	2.09	1.63	1.86	2.65	2.05
	20°C	1.74	2.70	3.95	2.79	1.74	2.73	3.91	2.79
	30°C	1.78	2.77	3.99	2.85	1.77	2.97	3.96	2.89
	40°C	1.75	2.97	3.92	2.88	1.76	2.99	4.08	2.95
	50°C	1.78	3.58	4.33	3.23	1.80	3.73	4.36	3.30
	Mean	1.75	2.77	3.78	2.77	1.74	2.86	3.79	2.79
Heidi	Control	2.26	2.85	3.48	2.87	2.30	2.87	3.56	2.91
	20°C	2.33	3.16	5.46	3.65	2.33	3.50	5.56	3.80
	30°C	2.33	3.66	5.33	3.77	2.30	3.69	5.68	3.89
	40°C	2.30	4.08	5.56	3.98	2.33	4.25	5.83	4.14
	50°C	2.27	4.23	6.58	4.36	2.30	4.43	7.02	4.58
	Mean	2.30	3.60	5.28	3.73	2.31	3.75	5.53	3.86

	Shelf life days (C)				Shelf life days (C)			
Treatment (B)	0	3	6	Mean	0	3	6	Mean
Control	1.99	2.35	3.10	2.48	1.97	2.36	3.11	2.48
20°C	2.03	2.93	4.71	3.22	2.03	3.12	4.74	3.29
30°C	2.06	3.21	4.66	3.31	2.03	3.33	4.82	3.39
40°C	2.03	3.52	4.74	3.43	2.05	3.62	4.95	3.54
50°C	2.02	3.90	5.46	3.79	2.05	4.08	5.69	3.94
Av. Treat.	2.03	3.18	4.53	3.24	2.03	3.30	4.66	3.33

L.S.D at 0.05 for 2009 season: A = 0.272; B = 0.121; C = 0.093; (A × B) =0.171; (A × C) =0.132; (B × C) = 0.209; (A × B × C) = 0.296

L.S.D at 0.05 for 2010 season: A = 0.134; B = 0.150; C = 0.116; (A × B) =0.212; (A × C) =0.164; (B × C) = 0.260; (A × B × C) = 0.368

Table 3: Effects of heat and cold storage treatments on fruits total sugars % during 6 days shelf life, of Tommy Atkins and 'Heidi' mango cultivars in 2009 and 2010 seasons.

		Shelf life days (C)				Shelf life days (C)			
		0	3	6	Mean	0	3	6	Mean
Cultivar (A)	Treatment (B)	Season 2009				Season 2010			
Tommy Atkins	Control	9.84	10.03	10.26	10.04	10.16	10.36	10.50	10.34
	20°C	10.45	10.99	11.83	11.09	10.49	11.33	11.25	11.02
	30°C	10.33	11.06	12.01	11.13	10.50	11.47	11.31	11.09
	40°C	10.33	11.35	11.99	11.22	10.55	11.85	11.73	11.37
	50°C	10.33	11.66	12.06	11.35	10.66	12.05	12.33	11.68
	Mean	10.26	11.02	11.63	10.97	10.47	11.41	11.42	11.10
Heidi	Control	10.37	10.85	11.06	10.76	9.99	10.82	11.16	10.66
	20°C	10.09	11.42	11.59	11.04	10.08	10.96	11.72	10.92
	30°C	10.11	11.55	11.91	11.19	10.26	11.61	11.89	11.25
	40°C	10.10	11.40	12.38	11.29	10.27	11.41	12.50	11.39
	50°C	10.10	11.65	12.30	11.35	10.26	11.68	12.36	11.43
	Mean	10.16	11.37	11.85	11.13	10.17	11.29	11.93	11.13

	Shelf life days (C)				Shelf life days (C)			
Treatment (B)	0	3	6	Mean	0	3	6	Mean
Control	10.11	10.44	10.66	10.40	10.08	10.59	10.83	10.50
20°C	10.27	11.21	11.71	11.06	10.28	11.15	11.48	10.97
30°C	10.22	11.31	11.96	11.16	10.38	11.54	11.60	11.17
40°C	10.22	11.37	12.19	11.26	10.41	11.63	12.11	11.38
50°C	10.22	11.65	12.18	11.35	10.46	11.87	12.35	11.56
Av. Treat.	10.21	11.19	11.74	11.04	10.32	11.35	11.67	11.11

L.S.D at 0.05 for 2009 season: A = 0.297; B = 0.178; C = 0.138; (A × B) =0.252; (A × C) =0.195; (B × C) = 0.309; (A × B × C) = 0.438

L.S.D at 0.05 for 2010 season: A = 0.135; B = 0.323; C = 0.250; (A × B) =0.457; (A × C) =0.354; (B × C) = 0.559; (A × B × C) = 0.791

treatment showed the highest TSS% in the fourth week by 13.80%. In the second season, 20, 40 and 50°C hot water treatments showed the highest values, 13.33, 13.13 and 13.27% respectively. Relatively same trend was obtained with Heidi fruits.

The data as for acidity and total soluble substances in the fruits of the studied two cultivars proved that, 'Heidi' fruits contained a lower acidity percentage than Tommy Atkins fruit. While, acidity and TSS were higher in 'Heidi' fruit compared to 'Tommy Atkins' in both seasons. In Tommy Atkins, the preconditioning treatment at 20°C for 3 days and dipping in 50°C hot water resulted in the lowest significant acidity percentage. In Heidi, the preconditioning treatment at 20°C for 3 days, 40 and 50°C hot water treatments gave the lowest significant values, compared to the control that recorded the highest percentage in both seasons during cold storage. Moreover, during cold storage in Tommy Atkins, the preconditioning treatment at 20°C for 3 days recorded the highest significant acidity percentage in the first season and the preconditioning treatment at 20°C for 3 days and dipping in hot water at 50°C resulted in the highest significant values in the second season.

It is well known that, ascorbic acid is considered one of the antioxidant substances. The antioxidant activity in fruit varies among species and cultivars [30, 31]. There is a wide range of cultivars fruit content of vitamin C. some fruit are rich in ascorbic acid, although there is little information on this antioxidant activity in tropical fruit [32, 33]. Moreover, Tasneem [34] studied the effect of storage of "Tommy Atkins" at low temperature (1, 4, 7, 10°C), the affected fruit pulp has low ascorbic acid content. Ascorbic acid declined in mango fruits during ripening [35]. Thomas and Oke [6] suggested the reduction ascorbic acid is presumably due to oxidative destruction.

Data of the total sugars and phenol percentages in the fruits of the two studied cultivars are presented in Tables (3 and 4). It is obvious that, total sugars percentage was higher in Heidi fruit compared with Tommy Atkins in both seasons. In Tommy Atkins the preconditioning treatment at 20°C for 3 days recorded the highest total sugars percentage. Reversely, in Heidi the preconditioning treatment at 20°C for 3 days and dipping in 40 and 50°C hot water showed the highest values compared to control that showed the lowest values in both seasons. For phenols percentages it is clear that,

Table 4: Effects of heat and cold storage treatments on fruits total phenols % during 6 days shelf life, of Tommy Atkins and Heidi mango cultivars in 2009 and 2010 seasons

		Shelf life days (C)				Shelf life days (C)			
		0	3	6	Mean	0	3	6	Mean
Cultivar (A)	Treatment (B)	Season 2009				Season 2010			
Tommy Atkins	Control	1.05	1.23	1.33	1.20	1.04	1.21	1.36	1.20
	20°C	1.06	1.26	1.43	1.25	1.03	1.40	1.46	1.29
	30°C	1.06	1.53	1.61	1.40	0.99	1.50	1.70	1.39
	40°C	0.97	1.56	1.67	1.40	1.01	1.56	1.80	1.46
	50°C	0.99	1.66	1.74	1.46	0.99	1.70	1.86	1.52
	Mean	1.03	1.45	1.55	1.34	1.01	1.47	1.64	1.37
Heidi	Control	1.03	1.25	1.34	1.21	1.06	1.29	1.31	1.22
	20°C	0.99	1.35	1.46	1.27	1.00	1.39	1.53	1.31
	30°C	1.04	1.62	1.69	1.45	0.99	1.61	1.70	1.43
	40°C	0.99	1.63	1.79	1.47	0.98	1.66	1.78	1.47
	50°C	1.03	1.77	1.88	1.56	1.00	1.78	1.89	1.56
	Mean	1.02	1.52	1.63	1.39	1.01	1.55	1.64	1.40

	Shelf life days (C)				Shelf life days (C)			
Treatment (B)	0	3	6	Mean	0	3	6	Mean
Control	1.04	1.24	1.33	1.20	1.05	1.25	1.34	1.21
20°C	1.03	1.31	1.45	1.26	1.01	1.39	1.50	1.30
30°C	1.05	1.57	1.65	1.42	0.99	1.55	1.70	1.41
40°C	0.98	1.60	1.73	1.44	0.99	1.61	1.79	1.46
50°C	1.01	1.72	1.81	1.51	0.99	1.74	1.88	1.54
Av. Treat.	1.02	1.49	1.59	1.36	1.01	1.51	1.64	1.38

L.S.D at 0.05 for 2009 season: A = 0.048; B = 0.081; C = 0.063; (A × B) =0.115; (A × C) =0. 089; (B × C) = 0.141; (A × B × C) = 0.200

L.S.D at 0.05 for 2010 season: A = 0.069; B = 0.070; C = 0.054; (A × B) =0.098; (A × C) =0.076; (B × C) = 0.121; (A × B × C) = 0.171

Heidi fruits contained lower total phenols percentage than Tommy Atkins fruit. In 'Tommy Atkins, the 40 and 50°C hot water treatments revealed the lowest significant values in the first season, while the 20, 40 and 50°C treatments resulted in the lowest significant values in the second season. In Heidi, the 40 and 50°C hot water treatments showed the lowest values compared to control that showed the highest values in both seasons during cold storage. During shelf life period, 40 and 50°C hot water treatments recorded the lowest significant values in the first season in Tommy Atkins, the 20, 40 and 50°C treatments showed the lowest significant values in the second season. In Heidi, the 50°C hot water treatment showed the lowest significant value in the first season and the 20, 40 and 50°C heat treatments showed the lowest significant values in the second season compared to control that showed the highest values in both seasons.

The data viewed in Figures 3 and 4 shows the effect of heat treatments on Catalase and peroxidase enzymes activity during storage at 7°C in both seasons. The differences between the two cultivars were significant in both seasons. Catalase activity in Heidi was higher than Tommy Atkins fruit in both seasons.

Tommy Atkins fruits that treated with 30°C hot water dipping recorded the highest significant activities, compared to 20°C hot water treatment in the first season and 40°C hot water treatment in the second season that showed the lowest activities. In Heidi, the untreated control showed the highest significant activity in the first season, whereas control and 30°C hot water treatment showed the highest significant activity in the second season, compared to 20°C hot water treatment in both seasons showed the lowest activities. For peroxidase activity in Tommy Atkins, the 20 and 50°C hot water treatments showed the lowest significant activities in both seasons. In Heidi, the 50°C hot water treatment showed the lowest significant activities, compared to control that showed the highest activities in both seasons

So, Catalase and Peroxidase activities increased then decreased continuously with storage period in all treatments in both cultivars during both seasons. Hot water treatments obstruct a fluctuation in activity by increasing and decreasing of Catalase and Peroxidase activities compared to the control in both cultivars. However, Tommy Atkins untreated fruits (control) showed the highest significant Catalase activity in the second week. The corresponded scored Catalase activity

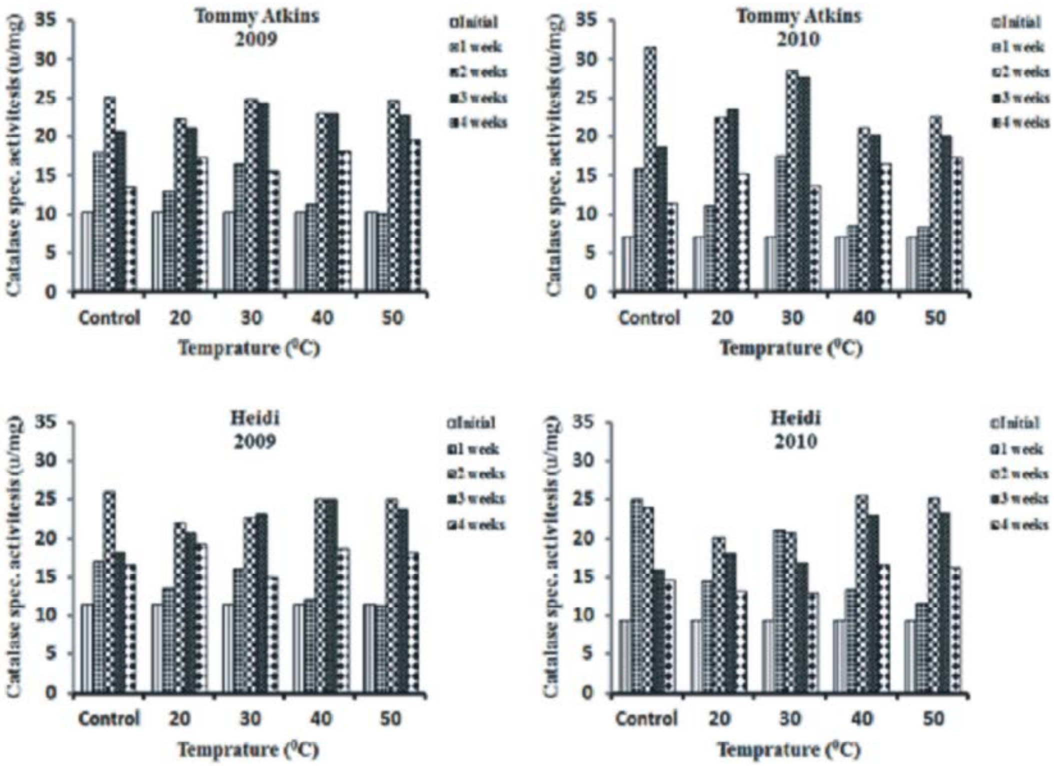

Fig. 3: Effects of hot water and cold storage treatments on Catalase specific activities on the fruits of Tommy Atkins and Heidi mango cultivars stored in studied seasons.

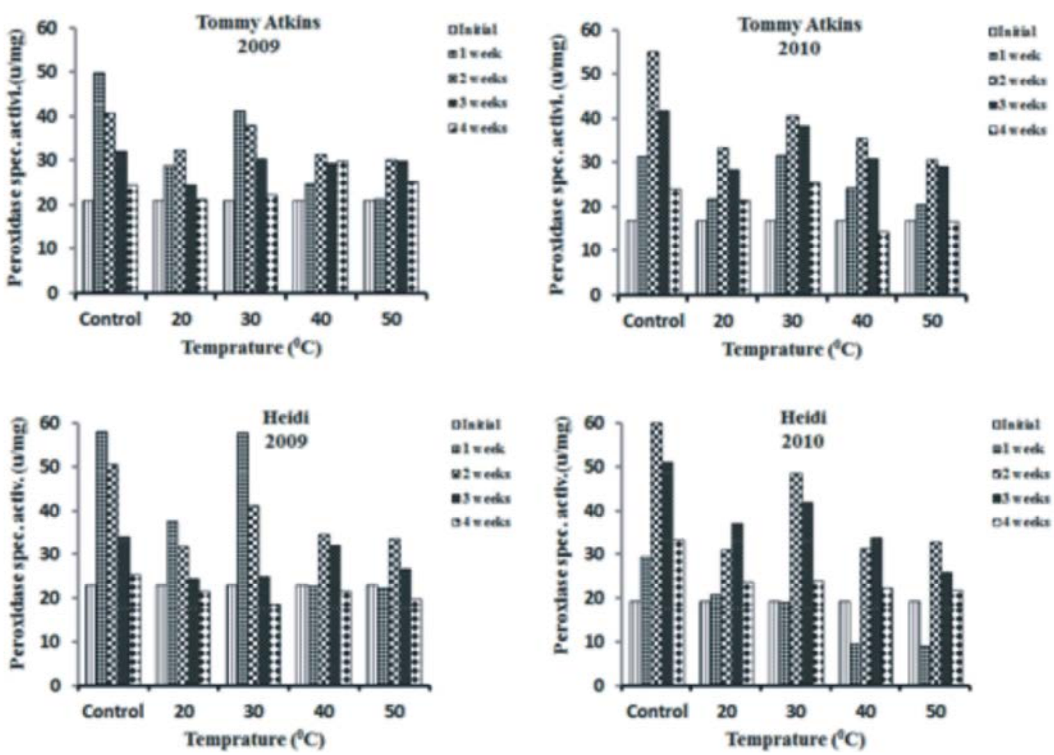

Fig. 4: Effects of hot water and cold storage treatments on Peroxidase specific activities on the fruits of Tommy Atkins and Heidi mango cultivars stored in studied seasons.

in Heidi showed that control scored the highest significant value in the second week in the first season, whereas the 40°C treatment showed the highest significant value in the second week in the second season. Regarding the Peroxidase activity data in figure (4) revealed that, in Tommy Atkins, the control showed the highest significant values in the first week in the first season and in the second week in the second season. Relatively comparable values were recorded in Heidi, where the control and 30°C treatment showed the highest significant values in the first week in the first season. But the control showed the highest significant value in the second week of the second season.

From the above mentioned outcomes, it is realized that data inferred that mango fruits treated with preconditioning at 20°C, or hot water dipping at 40 or 50°C showed remarkable decrease in fruits acidity, while TSS and total sugars increased. Acidity decrement was previously observed by many investigators [36-40]. Moreover, the increment in sugars content may be due to the starch that accumulated in the mature fruit was rapidly lost during ripening [41]. Starch granules completely disappear in the ripe fruit that usually contains negligible levels of starch [42, 43].

Total phenols decreased continuously with storage period, phenols decreased significantly after preconditioning at 20°C, or hot water dipping at 40 or 50°C treatments. Rensburg and Engelbrecht [44] and Cruz [45] suggested that the hot water treatment played a noticeable role in inhibition of browning which causes the structural changes in the phenolic compounds caused by some oxidative substances especially polyphenol oxidase, data also showed that by the end of storage, fruits that had been dipped in 40 or 50°C, or 20°C treatment showed lower values, which might be caused by the faster entrance of fruits into the ripening stage compared to control or 30°C treatment. Mayer [46]; Inze and Van Montagu [47]; Mitra and Baldwin [48] distinguished a similar trend in some tropical plants.

Catalase activity showed continuous elevation within the first two weeks then it decreased sharply. This change might be related to chilling injury as the control fruits showed significant stability in Catalase activity that differs from the other hot treatments, the increase occurred at the beginning of cold storage period might illustrate the cold shock of fruits because of the storage at low temperature as a way to disposal of free radicals, the decrease after that might be resulted of imbalance between antioxidant substances and free radicals [15].

Peroxidase took a similar trend to catalase and it might be played as an assistant with catalase in protection of cells, the highest values appeared in control and 30°C treatment fruits compared with the other treatments, This relation may be illustrating as a defense way of the storage at low temperature against chilling injury disorder [47]. Marin and Cano [49] found a similar trend for peroxidase in Lippens and Smith mango cultivars stored at 12°C and 85-90% RH. Mattoo and Modi [50] found that Catalase decreased continuously but peroxidase increased then decreased during ripening of mango.

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