Postharvest Ozone and Hot Water Treatments Increase Storage Life of Kent Mango Fruits at Two Maturity Stages

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ABSTRACT

The present study was carried out on mature-green Kent mango fruits directly after harvest (stage 1) and after 48 hours of storage at 20°C (stage 2). Fruit treatments included: exposure to 150 ppb ozone during storage (O_3), dipping in hot water (HW) at 55°C for 5 min before storage, and both hot water treatment before storage and ozone treatment during storage (HW+O_3). The above treatments were compared to untreated fruits (control) during the cold storage period at 13°C and 85-90 % RH. O_3 or HW treatments prolonged fruit postharvest marketability by one week with a significantly better external and internal appearance. However, O_3 treated fruits had higher weight loss than control but the differences were not significant, and HW treated fruits had the lowest significant weight loss for stage 2 fruits. Skin color did not change significantly during storage and remained green in all treatments and control, whereas the creamy flesh became orange with the decrease of hue angle. O_3 treatment significantly slowed the color changes in flesh. HW treated stage 1 fruits had the highest flesh firmness while O_3 treated stage 2 fruits were the firmest. O_3 and HW treatments slowed the increase in soluble solid content (SSC) and the decline in citric acid and V.C contents during storage compared to control. O_3 and HW treatments reduced the activities of POD and PPO enzymes in mango fruits at both maturity stages.

Key words: Mango, kent, postharvest, ozone, hot water

INTRODUCTION

Anthracnose is the major pre- and post-harvest disease of mango in all mango producing areas of the world (Dodd *et al.,* 1992). Washing with chlorinated water to prevent fruit disease is a widespread practice based on the oxidizing properties of chlorine; however, it promotes the presence of trihalomethanes and other mutagenic or carcinogenic by-products (Kronberg and Christman, 1989). Physical treatments were developed as alternatives to chemical treatments, which face severe restrictions due to their negative environmental effects (Couey, 1989). The use of hot water as a disinfestation treatment for mango has spread because of its efficacy and the low incidence of damage to the treated fruit (Jacobi *et al.*, 1995 and El-Ansary, 2001). Hot water treatment as well as fungicides such as imazalil can be used successfully to control mango pathological disorders (El-Ansary, 2001)Nevertheless, some peel disorders as well as quality losses (Jacobi and Wong, 1991), accumulation of starch grains in sub-epidermal tissues, probably resulting from heat deactivation of starch hydrolases (Jacobi and Wong,1992), negative effects on fruit color (Joyce *et al.*, 1993) and increasing in ethylene production (as a response to heat stress) which stimulate ripening processes (Mitcham and McDonald,1993)have been observed.

All these effects were more pronounced on mangoes harvested at the mature green ripening stage than at later stages (Jacobi and Wong, 1992). Ozone, in a gaseous form or dissolved in water, is a strong oxidizing agent due to O_3 molecules. It is easily depleted due to its unstable molecular structure that is lost in 15 to 20 min by breaking down into O_2 molecules (Martínez *et al.*, 2002). Since ozone has excellent ability to reduce microbial populations and does not leave a residue, its postharvest use is increasing (Parish *et al.*, 2003). Ozone destroyed micro organisms by oxidation of cellular components such as sulfhydryl groups of amino acids in enzymes and oxidation of the cells membrane (Victorin, 1992), so the ozone antimicrobial effects are a result of the microbial resistance of the plant being maintained by the ozone treatment rather than its direct effect on the plant pathogen (Skog and Chu, 2001). The use of ozone as a phytosanitary and germicidal agent had been reported on apples (Gooch, 1996), strawberries, peaches (Ridley and Sims, 1996), pears (Spotts and Cervantes, 1992), mangoes (Martínez *et al.*, 2002) and on peaches and grapes (Palou *et al.*, 2002). The aim of the present work is to investigate the effects of ozone, hot water treatments and the following storage temperature on the physical and chemical changes of Kent mango fruits at different ripening stages.

MATERIALS AND METHODS

The present study was carried out during 2007 and 2008 seasons on Kent mango fruits harvested from Al-Loloa private orchard at Alexandria - Cairo desert road. Sound selected fruits at the mature-green stage (608.18 ± 65 gm weight, 12.31 ± 0.6 cm length, and 10.02 ± 0.5 cm breadth) that are uniform in size and free of mechanical damage and pathological disorders were divided to two batches (200 fruits for each). The experimental treatments were done directly on one batch of fruits (stage 1) and after 48 hours of storage at 20°C for the other batch of fruits (stage 2). Each batch was divided to 4 groups. The first group was exposed to 150 ppb ozone (O_3) during storage by using ozone generator (biofresh OZ80, UK). The second group was dipped into hot water (HW) at 55°C for 5 min, then dipped for 10 min in tap water, and kept to dry under room temperature conditions. The third group was treated by both hot water and ozone treatments (HW+O_3). The fourth group of fruits was washed then dried (control). All of the above eight (2 ripening stages x 4 treatments) groups were stored at 13°C and 85-90 % RH. Ten mango fruits were taken to determine the initial physio-chemical properties. Changes in such properties were followed up in seven-day intervals throughout the experimental period. Ten labeled mango fruits in every treatment were initially weighed to calculate fruit weight loss percentage during the storage period in relation to its original weight. Skin and flesh color of fruits was estimated visually to detect any chilling injury symptoms. Flesh color was measured by Minolta Chroma meter CR-200-Japan on four points of each fruit in the sample. The a* and b* values were used to calculate the hue angle (hue°) to follow the flesh color changes during the experiment period according the following equation (Sancho *et al.*, 2010):Hue° = arctan (b*/a*). Hue angle is a quantitative expression of color and represents the changes in fruit color (0 = red, 90 = yellow, 180 = green, and 270 = blue). Mango fruit firmness was determined in pulp by peeling two opposite sides of each given fruit in the sample and measuring the firmness by using the Effegi pressure tester with an eight mm plunger (Effegi, 48011 Alfonsine, Italy). Three samples of fruit flesh for each treatment were squeezed and the obtained juice was used to determine the percentage of SSC by the use of a hand refractometer and the percentage of titratable acidity as g citric acid /100ml of fruit juice (Chen and Mellenthin, 1981).The same above obtained juice was also used to determine V.C as mg ascorbic acid/100ml fruit juice (AOAC, 1980). Polyphynoloxidase (PPO) and peroxidase (POD) enzymes activity were determined in the crude extracts (Brenneman and Black, 1979) of three samples of fruit pulp in each treatment. The activity of PPO was measured using the method of Matta and Dimond (1963). The activity of POD was determined by the method of Chance and Maehly (1955). The end of the experiment was determined by fruit softening or by the appearance of chilling injury symptoms.All obtained data were statistically analyzed according to Snedecor and Cochran (1980). The individual comparisons were carried out by using the Least Significant Difference (LSD) according to SAS Institute(1985). Simple regression coefficient (r^2) among storage period and studied sample properties was calculated as referred by SAS Institute (1985).

RESULTS AND DISCUSSION

Fruit Appearance Quality and Storagability:

The data showed that untreated Kent mango fruits stored for 3 (stage 2) to 4 (stage 1) weeks at 13°C exhibited chilling injury symptoms with more peel discoloration and initial growth of pathogens. However, the O_3 or HW treated fruits can be stored for one week more than the above periods with a significantly better external and internal appearance. Similar results of O_3 on storage extension were reported on blackberries (Barth *et al.*, 1995) and strawberries (Allende *et al.*, 2007). Due to the high oxidative capacity of O_3 and its ability to generate toxic molecular species, it acts as potent phytotoxic agent. It elicits plant defense reactions such as the production of phytoalexins (Maharaj *et al.*, 1999), including ascorbic acid in strawberries (Pérez *et al.*, 1999) and resveratrol in grapes (Gonzâlez-Barrio *et al.*, 2006). Also, O_3 was effective in removing ethylene from the atmosphere of the storage room due to the reduction in ACC ethylene precursor or due to the oxidation of the atmospheric ethylene (Li *et al.*, 1989 on tomatoes and Skog and Chu, 2001 on apple and pear). The initial appearance of skin browning was on untreated stage 1 fruits at the third week of cold storage and one week later on untreated stage 2 fruits. Skin browning was accompanied by pulp discoloration and softening and by poor eating quality at the last week. O_3 treated fruits of stage 1 had good appearance with smaller area of discoloration than heated fruits. There were no differences among treatments in stage 2 treated fruits. The sensitivity of mangoes to temperatures below 10°C varies with the maturity of the fruit, the cultivar, and the duration and temperature of exposure (Medlicott *et al.*, 1990). Fruits at the pre-climacteric stage are generally more sensitive than those at post-climacteric stage to chilling injury (Jacobi and Wong, 1992). Bender and Brecht (1994) reported that tree-ripe (climacteric) 'Keitt' and 'Tommy Atkins' mangoes may be stored for 2 weeks at 5°C without chilling injury development at that temperature or during a subsequent 5-day period at 20°C. Induction of related stress proteins in the heat-exposed fruits such as heat shock proteins, cysteine proteases, and dehydrin, and repression of a polyphenol oxidase provide molecular evidence of candidate proteins that may prevent some of the chilling injury symptoms (Lara *et al.*, 2009).

Fruit Weight Loss (%):

Weight loss of Kent mango fruits was affected by all treatments and the differences depended on the fruit ripening stage (Table 1). For stage 1 fruits, HW and HW+O_3 treatments had the highest significant weight loss compared with control. O_3 treated fruits had higher weight loss than control ones but the differences were not significant. For stage 2 fruits, HW treatment gave the lowest significant weight loss compared with O_3 or HW+O_3 treatments but the differences were not significant compared with control. Fruit weight loss of all treatments in both seasons increased significantly (r^2 values are highly significant) with the advancing of the storage period. Palou *et al.*, (2002) reported that 'Zee Lady' peaches exposed to 300 ppb ozone lost more weight than control fruits may be as a result of cuticle and/or the epidermal tissue damage by ozone. On the other hand, No differences in weight loss were found between ozone and control treatments on 'Flame Seedless' table grapes (Palou *et al.*, 2002) and Hayward kiwi fruits (Barboni *et al.*, 2010). However, Allende *et al.*, (2007) observed that gaseous O_3 reduced weight loss of strawberries. The increase in fruit weight loss by heat treatment was reported by Miller *et al.*, (1991) and Saucedo *et al.* (1995) on mangoes and was due to the occurrence of stress condition on fruits resulted in more water loss (Phillips, 1982). However, Fawaz (2000) mentioned that 45°C HW treatment reduce the weight loss of Alphonse mango fruits compared with control.

Flesh Color:

Table 2 shows the changes in flesh hue angle according to ozone, heat treatments and cold storage period. Ozone treated fruits had the highest significant values of flesh hue angle and there were no significant differences between HW and HW+O_3 treatments except the last week for stage 1 fruits where HW+O_3 treated fruits had higher values. Skog and Chu, (2001) and Shlluf *et al.*, (2007) reported that the color change (hue°) was significantly less pronounced for the ozone-treated fruits where it caused high inhibition of carotenoids accumulation. Kim *et al.*, (2007) reported that no differences between hot water and control fruit were observed in color values. The hue° values decreased with the advancing of the storage period and r^2 values were significant for all treatments with the change of flesh color from creamy to orange. The color change of mango is a reliable parameter to determine the extent of fruit ripening (Ninio *et al.*, 2003) and is correlated with the carotenoid content in the fruit mesocarp (Ornelas-Paz *et al.*, 2008 and Sancho *et al.*, 2010).

Table 1: Effects of ozone and hot water treatments on weight loss (%) of cold stored Kent mango fruits in 2008 and 2009 seasons.

Season	Treat.	Storage Period (days) 0	7	14	21	28	35	R^2
2008	**Stage 1**							
	O_3	0.00a	2.94bc	5.19abc	8.04abc	11.32ab	14.48a	0.997**
	Hot water	0.00a	3.77a	5.93ab	8.60a	12.09a	16.91a	0.985**
	O_3+Hot water	0.00a	3.55ab	6.04a	8.91a	12.18a	16.01a	0.996**
	Control	0.00a	2.45cde	4.11dc	6.38bc	9.39bc		0.991**
	Stage 2							
	O_3	0.00a	2.52cd	4.66bcd	8.35ab	12.69a		0.978**
	Hot water	0.00a	1.75e	3.66d	6.06c	9.15c		0.986**
	O_3+Hot water	0.00a	2.80bcd	5.44ab	8.62a	12.75a		0.991**
	Control	0.00a	2.14de	4.05cd	7.57abc			0.979**
2009	**Stage 1**							
	O_3	0.00a	2.98b	5.16bc	8.45a	12.34abc	16.54a	0.988**
	Hot water	0.00a	3.63a	5.70ab	8.37a	11.84bc	16.98a	0.980**
	O_3+Hot water	0.00a	3.71a	6.22a	9.27a	13.21ab	17.90a	0.990**
	Control	0.00a	2.52bc	4.25cd	6.61b	10.14c		0.985**
	Stage 2							
	O_3	0.00a	2.99b	5.89ab	8.47a	13.67ab		0.981**
	Hot water	0.00a	1.94d	3.84d	7.29b	11.45bc		0.967**
	O_3+Hot water	0.00a	2.73b	5.59ab	9.24a	14.30a		0.982
	Control	0.00a	2.08cd	4.13d	6.42b			0.999**

Means within a column (in same season) having a common letter are not significantly different.
r^2 =Determination coefficient.

Table 2: Effects of ozone and hot water treatments on flesh color (hue°) of cold stored Kent mango fruits in 2008 and 2009 seasons.

Season	Treat.	Storage Period (days)						R^2
		0	7	14	21	28	35	
2008	**Stage 1**							
	O_3	101.33a	100.15a	94.40a	82.33a	75.47a	73.29a	0.948**
	Hot water	101.33a	98.52bc	88.32b	76.92bc	72.78b	70.59c	0.951**
	O_3+Hot water	101.33a	99.29ab	86.93b	77.65b	74.71a	72.33b	0.935**
	Control	101.33a	97.85cde	82.44c	72.96ef	71.06c		0.938**
	Stage 2							
	O_3	98.99a	98.04cd	86.57b	76.21bcd	73.00b		0.944**
	Hot water	98.99a	97.29de	82.42c	74.04def	71.78c		0.931**
	O_3+Hot water	98.99a	96.73ef	83.70c	74.61cde	70.96c		0.954**
	Control	98.99a	95.56f	77.13d	71.69f			0.926*
2009	**Stage 1**							
	O_3	102.52a	101.50a	95.36a	84.52a	76.47a	74.17a	0.954**
	Hot water	102.52a	99.50b	89.24b	77.41b	73.99b	71.15c	0.951**
	O_3+Hot water	102.52a	98.55bcd	87.47b	77.85b	74.29b	72.88b	0.941**
	Control	102.52a	97.69cde	83.08d	74.08de	71.60d		0.952**
	Stage 2							
	O_3	100.10a	96.30e	86.91bc	76.04bc	73.04bc		0.968**
	Hot water	100.10a	98.90bc	83.35d	74.30cde	71.82cd		0.928**
	O_3+Hot water	100.10a	97.29de	84.74cd	74.97cd	71.23d		0.961**
	Control	100.10a	96.20e	77.52e	72.56e			0.919*

Means within a column (in same season) having a common letter are not significantly different.
r^2 =Determination coefficient.

Fruit Flesh Firmness (lb/in²):

The initial flesh firmness of stage 1 fruits were 36.17 and 44.17 lb/in² compared with 28.23 and 33.77 lb/in² for stage 2 fruits in 2008 and 2009 seasons, respectively (Table 3). All experimental treatments reduce the loss of fruit flesh firmness compared with control fruits except of the HW+O_3 treatment on stage 2 fruits at the beginning of the storage period. The effect of HW and O_3 depended on ripening stage of the treated fruits where HW treated fruits had the highest values of flesh firmness for stage 1 fruits in both seasons while O_3 treated fruits were the firmest ones for stage 2 fruits. The significant r^2 values reflected the reduction in flesh firmness with the progress of the storage period for all treatments. The above results of ozone effect are associated with those of Aguayo *et al.*, (2006) and Tzortzakis *et al.*, (2007a) on tomato; Allende *et al.*, (2007) on strawberries and Salvador *et al.*, (2006) on persimmon while Barboni *et al.*, (2010) recorded no significant effect of ozone on kiwi fruits firmness. The mechanisms underlying the effects of ozone on fruit firmness remain to be ascertained, but it is known that cell wall matrices, especially pectins, undergo disruption during fruit ripening and they are these modifications that are believed responsible for the decrease in tissue firmness that accompanies ripening (Tucker and Greison, 1987). Pectins that are degraded during ripening undergo both solubilization and depolymerization (Seymour *et al.*, 1990). Ozone reacts rapidly with ethylene, and for those commodities that benefit from ethylene removal during storage ozone is considered a potential tool to extend storage life with the added advantage of controlling disease proliferation (Jin et al., 1989; Aguayo *et al.*, 2006; Salvador *et al.*, 2006; Tzortzakis *et al.*, 2007a). The results of HW effect are associated with those of Jacobi and Giles (1997) on Kensington mangoes. The decrease in the rate of softening may be due to inhibition of the synthesis of cell wall hydrolytic enzymes such as polygalacturonase and a- and b-galactosidase, maintaining membrane stability and reducing the solubility of polyuronide (Yoshida *et al.*, 1984; Lazan *et al.*, 1989 and Chein, 2000).

Table 3: Effects of ozone and hot water treatments on flesh firmness (lb/in^2) of cold stored Kent mango fruits in 2008 and 2009 seasons.

Season	Treat.	Storage Period (days)						R^2
		0	7	14	21	28	35	
2008	**Stage 1**							
	O_3	36.17a	20.67a	21.93a	13.50a	7.52a	3.83a	0.922**
	Hot water	36.17a	20.47ab	22.57a	14.80a	7.31a	3.53a	0.918**
	O_3+Hot water	36.17a	16.93bc	18.63b	12.00b	6.80a	3.33a	0.857**
	Control	36.17a	13.37de	14.67c	8.90c	3.50b		0.786*
	Stage 2							
	O_3	28.23a	15.90de	17.17bc	7.50cd	3.43b		0.911*
	Hot water	28.23a	12.23e	14.13c	6.27d	3.60b		0.830*
	O_3+Hot water	28.23a	12.33e	8.70d	7.60cd	3.63b		0.800*
	Control	28.23a	9.93e	6.17d	3.47c			0.813*
2009	**Stage 1**							
	O_3	44.17a	20.87b	21.27a	13.80ab	8.12a	3.57a	0.862**
	Hot water	44.17a	24.53a	20.83a	15.43a	8.43a	3.73a	0.914**
	O_3+Hot water	44.17a	17.30bc	19.87a	12.73b	7.53a	3.40a	0.795*
	Control	44.17a	13.70d	15.87b	8.33c	3.40b		0.748*
	Stage 2							
	O_3	33.77b	14.67cd	14.13bc	6.80c	3.40b		0.850*
	Hot water	33.77b	13.57d	11.60cd	6.73c	3.73b		0.801*
	O_3+Hot water	33.77b	9.47e	10.40d	7.90c	3.73b		0.696*
	Control	33.77b	9.29e	6.90e	3.40d			0.761*

Means within a column (in same season) having a common letter are not significantly different.
r^2 =Determination coefficient.

Soluble Solids Content (SSC) %:

Stage 1 fruits had lower initial SSC values (6.44 and 6.66 %) compared with stage 2 fruits (10.21 and 11.99 %), respectively in 2007 and 2008 seasons Table 4). Untreated fruits in stage 1 had the highest significant SSC percentages during the first two weeks and there were no significant differences in the third week, then those untreated fruits had the lowest significant SSC values during the forth week. During this period there were no significant differences among treatments in the first season and there was no constant trend in the second one but by the end of the storage period (5 weeks) O_3 treated fruits had the highest SSC values in both seasons. For stage 2 fruits, treatments O_3 and HW+O_3 in the first week and O_3 in the second week had the lowest significant SSC percentages. In the third week, SSC of the untreated fruits declined to be the lowest values. By the end of the storage period, O_3 treated fruits had the lowest significant SSC percentages. From the above results, it was concluded that O_3 and HW treatments slowed the increasing of SSC and maintained it high by the end of the storage period in both seasons compared with untreated fruits due to their effect on delaying ripening processes. Those results agree with the results of Lazan *et al.*, (1989); Tzortzakis *et al.*, (2007a). On the other hand, Salvador *et al.*, (2006); Shalluf *et al.*, (2007) and Barboni *et al.*, (2010) reported lower SSC values of O_3 treated fruits while Miller *et al.*, (1991); Jacobi and Giles (1997) and Whangchai *et al.*, (2010) found no significant effect of heat or O_3 treatment on SSC. The r^2 values of all treatments showed the increasing of mango fruits SSC with the advancing of the storage period that could be due to the degradation of complex insoluble compounds like starch to simple soluble compounds like sugars that are the major component of SSC content in the fruits (Chen and Mellenthin, 1981).

Titratable Acidity (%):

Ozone treatment did not affect citric acid content of Kent mango fruit at stage 1 during the first three weeks then it had higher significant content in the forth week than control fruits (Table 5). HW treated fruits had the highest significant acidity percentages during the storage period except the first week. On the other hand, the above treatments and its combination had no significant effect on the fruits of stage 2 in both seasons. Of all treated and untreated fruits, citric acid declined by the end of the storage period. Barboni *et al.*, (2010) observed significant effect of O_3 on acidity values, however, Tzortzakis *et al.*, (2007a) and Whangchai *et al.*, (2010) reported not significant effect. The highest citric acid content of heat treated fruits may be due to its effect on regulating respiration and perhaps other metabolic processes during storage. The above results and the associated discussion agree with the investigations of Lazan *et al.* (1989) on papaya and Tsuda *et al.* (1999) on mangoes.

Table 4: Effects of ozone and hot water treatments on SSC (%) of cold stored Kent mango fruits in 2008 and 2009 seasons.

Season	Treat.	Storage Period (days) 0	7	14	21	28	35	R^2
	Stage 1							
	O_3	6.44b	9.44e	14.88b	16.87a	18.20ab	18.65a	0.903**
	Hot water	6.44b	11.32e	14.21b	17.54a	17.43ab	16.63b	0.788*
	O_3+Hot water	6.44b	10.43e	15.32b	16.87a	19.20a	17.10b	0.810*
2008	Control	6.44b	13.77d	19.32a	17.10a	12.65c		0.265
	Stage 2							
	O_3	10.21a	16.65bc	14.65b	17.98a	14.40c		0.271
	Hot water	10.21a	17.98ab	17.32ab	16.87a	16.60b		0.340
	O_3+Hot water	10.21a	15.54cd	17.32ab	17.10a	16.78b		0.610
	Control	10.21a	19.98a	19.54a	14.65b			0.130
	Stage 1							
	O_3	6.66b	10.44d	15.54bc	17.54abc	17.76a	20.42a	0.920
	Hot water	6.66b	8.88e	16.20bc	18.65a	15.32bcd	18.43b	0.726*
	O_3+Hot water	6.66b	10.88d	15.10c	17.10bc	17.10ab	16.43c	0.768*
2009	Control	6.66b	13.10c	20.43a	18.20ab	14.21d		0.363
	Stage 2							
	O_3	11.99a	17.98b	16.65bc	17.10bc	14.43cd		0.068
	Hot water	11.99a	20.06a	17.98ab	17.32abc	17.76a		0.215
	O_3+Hot water	11.99a	18.76b	17.76abc	18.43ab	16.65abc		0.265
	Control	11.99a	20.20a	19.76a	16.65c			0.213

Means within a column (in same season) having a common letter are not significantly different.
r^2 =Determination coefficient.

Table 5: Effects of ozone and hot water treatments on acidity (%) of cold stored Kent mango fruits in 2008 and 2009 seasons.

Season	Treat.	Storage Period (days) 0	7	14	21	28	35	R^2
	Stage 1							
	O_3	1.05a	0.80ab	0.78ab	0.71ab	0.57ab	0.45a	0.943**
	Hot water	1.05a	0.76ab	0.89a	0.83a	0.68a	0.53a	0.752*
	O_3+Hot water	1.05a	0.89a	0.69bc	0.65ab	0.52bc	0.49a	0.943**
2008	Control	1.05a	0.85ab	0.61bc	0.53b	0.41cde		0.964**
	Stage 2							
	O_3	0.79b	0.65ab	0.61bc	0.69ab	0.35de		0.655
	Hot water	0.79b	0.83ab	0.60bc	0.57b	0.31e		0.865*
	O_3+Hot water	0.79b	0.67ab	0.64bc	0.61b	0.45cde		0.911*
	Control	0.79b	0.59b	0.55c	0.53b			0.787
	Stage 1							
	O_3	0.95a	0.79ab	0.77ab	0.76ab	0.61ab	0.55a	0.921**
	Hot water	0.95a	0.73ab	0.81a	0.80a	0.63a	0.49a	0.765*
	O_3+Hot water	0.95a	0.78ab	0.77ab	0.76ab	0.48bc	0.55a	0.823*
2009	Control	0.95a	0.89a	0.63bc	0.57c	0.40c		0.962**
	Stage 2							
	O_3	0.73b	0.80ab	0.70abc	0.64bc	0.46c		0.739
	Hot water	0.73b	0.61b	0.73abc	0.61c	0.44c		0.593
	O_3+Hot water	0.73b	0.70ab	0.69abc	0.67abc	0.44c		0.678
	Control	0.73b	0.60b	0.58c	0.55c			0.830

Means within a column (in same season) having a common letter are not significantly different.
r^2 =Determination coefficient.

V.C content (mg/100 ml juice):

The data in Table 6 showed that O_3 treated fruits had the highest V.C contents during storage at both ripening stages compared with the other treatments and control fruits in the first season. However, in the second season, all treated fruits had significant higher values compared with control and there were no significant differences between them. Allende *et al.,* (2007) mentioned that strawberries V.C content was maintained well during storage in untreated and treated samples, although reductions were observed at the end of storage in UV-C and O_3 treated samples. Also, Pérez *et al.,* (1999) and Aguayo *et al.,* (2006) reported the same finding of O_3 effect on maintaining V.C content on strawberries and tomato fruits. V.C is able to scavenge oxygen radicals and avoid oxidative stress (Klopotek *et al.,* 2005). Thus, changes in V.C of O_3-treated fruits can be attributed to the activation of an antioxidative system that promotes the biosynthesis of V.C from the carbohydrate pool (Pérez *et al.,* 1999). On the other hand, Shalluf *et al.,* (2007); Tzortzakis *et al.,* (2007a) and Barboni *et al.,* (2010) reported not significant changes in V.C due to O_3 treatment.

POD and PPO Activities (O.D.):

Ozone and heat treatments reduced the activities of POD (Table 7) and PPO (Table 8) enzymes of mango fruits at both stages. The HW+O_3 treatment had the highest effect in reducing both enzymes activities where it had the lowest significant POD activity values in most intervals of both stages and the lowest significant PPO activity values for stage 1 fruits, however, O_3 treated fruits had the lowest PPO activity of stage 2 fruits. The results of O_3 treatment on reducing POD and PPO activities are consistent with the reported effects of O_3 on blackberries (Barth *et al.,* 1995) and longan fruits (Whangchai *et al.,* 2006), respectively. The same effect of heat treatment was reported by El Saedy and El Naggar (2009) on cactus pear.

Table 6: Effects of ozone and hot water treatments on V.C content (mg/100ml juice) of cold stored Kent mango fruits in 2008 and 2009 seasons.

Season	Treat.	Storage Period (days) 0	7	14	21	28	35	R^2
2008	**Stage 1**							
	O_3	8.55a	16.53a	24.46a	18.29a	6.28a	3.34a	0.172
	Hot water	8.55a	13.20b	18.68bc	12.62b	4.73b	2.97a	0.293
	O_3+Hot water	8.55a	13.57b	19.77bc	17.45a	4.72b	2.97a	0.196
	Control	8.55a	10.13c	17.80c	8.63cd	3.54cd		0.125
	Stage 2							
	O_3	10.40a	12.95b	21.32ab	15.92a	4.25bc		0.054
	Hot water	10.40a	11.86bc	17.01c	11.04bc	3.05d		0.241
	O_3+Hot water	10.40a	11.31bc	18.67bc	12.62b	3.05d		0.144
	Control	10.40a	10.18c	10.08d	7.19d			0.682
2009	**Stage 1**							
	O_3	7.93b	14.92a	20.13a	17.26a	5.90a	3.00a	0.181
	Hot water	7.93b	11.70cd	18.89a	15.70ab	5.76a	2.59a	0.171
	O_3+Hot water	7.93b	10.37de	19.00a	16.92ab	4.74ab	2.41a	0.142
	Control	7.93b	13.57ab	16.37b	9.97de	3.44bc		0.158
	Stage 2							
	O_3	12.93a	13.20bc	18.31a	14.39abc	4.58abc		0.239
	Hot water	12.93a	12.95bc	17.04a	12.36cd	3.41bc		0.382
	O_3+Hot water	12.93a	12.09bc	16.67b	14.03bc	3.25c		0.294
	Control	12.93a	9.59e	9.88c	7.70e			0.843

Means within a column (in same season) having a common letter are not significantly different.
r^2 =Determination coefficient.

Table 7: Effects of ozone and hot water treatments on POD activity (O.D.) of cold stored Kent mango fruits in 2008 and 2009 seasons.

Season	Treat.	Storage Period (days)						R^2
		0	7	14	21	28	35	
2008	**Stage 1**							
	O_3	0.047b	0.016c	0.022c	0.040bc	0.057bc	0.092b	0.510
	Hot water	0.047b	0.021c	0.024bc	0.041bc	0.061b	0.118a	0.546
	O_3+Hot water	0.047b	0.015c	0.017c	0.032c	0.046bcd	0.061c	0.272
	Control	0.047b	0.034ab	0.035b	0.051b	0.096a		0.514
	Stage 2							
	O_3	0.067a	0.020c	0.027bc	0.043bc	0.051bcd		0.005
	Hot water	0.067a	0.031b	0.048a	0.066a	0.039cd		0.043
	O_3+Hot water	0.067a	0.021c	0.026bc	0.043bc	0.035d		0.135
	Control	0.067a	0.041a	0.058a	0.077a			0.158
2009	**Stage 1**							
	O_3	0.073a	0.050bc	0.072bc	0.091bc	0.085ab	0.138a	0.657
	Hot water	0.073a	0.047bc	0.046c	0.066c	0.075bc	0.157a	0.467
	O_3+Hot water	0.073a	0.039c	0.046c	0.063c	0.069c	0.112b	0.394
	Control	0.073a	0.069abc	0.081bc	0.102b	0.099a		0.802
	Stage 2							
	O_3	0.110a	0.074abc	0.083bc	0.105b	0.062cd		0.254
	Hot water	0.110a	0.089ab	0.099ab	0.117b	0.067c		0.219
	O_3+Hot water	0.110a	0.055abc	0.066bc	0.084bc	0.048d		0.363
	Control	0.110a	0.095a	0.139a	0.180a			0.768

Means within a column (in same season) having a common letter are not significantly different.
r^2 =Determination coefficient.

Table 8: Effects of ozone and hot water treatments on PPO activity (O.D.) of cold stored Kent mango fruits in 2008 and 2009 seasons.

Season	Treat.	Storage Period (days)						R^2
		0	7	14	21	28	35	
2008	**Stage 1**							
	O_3	0.142b	0.098cd	0.158bc	0.134b	0.102cd	0.090ab	0.276
	Hot water	0.142b	0.081d	0.157bc	0.126bc	0.130bc	0.095a	0.049
	O_3+Hot water	0.142b	0.076d	0.112c	0.113bcd	0.076d	0.065b	0.478
	Control	0.142b	0.110bcd	0.196b	0.185a	0.203a		0.613
	Stage 2							
	O_3	0.201a	0.109bcd	0.175b	0.083d	0.101cd		0.487
	Hot water	0.201a	0.153ab	0.190b	0.092cd	0.106cd		0.663
	O_3+Hot water	0.201a	0.146abc	0.207b	0.099cd	0.160ab		0.214
	Control	0.201a	0.185a	0.264a	0.138b			0.074
2009	**Stage 1**							
	O_3	0.171a	0.133abc	0.163bc	0.117bcd	0.100b	0.098a	0.763*
	Hot water	0.171a	0.107bc	0.148c	0.141bc	0.112b	0.111a	0.367
	O_3+Hot water	0.171a	0.087c	0.142c	0.099cd	0.085b	0.085a	0.494
	Control	0.171a	0.155abc	0.210b	0.214a	0.200a		0.514
	Stage 2							
	O_3	0.185a	0.173ab	0.185bc	0.088d	0.118b		0.611
	Hot water	0.185a	0.188a	0.215ab	0.144b	0.193a		0.026
	O_3+Hot water	0.185a	0.172ab	0.214ab	0.140bc	0.128b		0.444
	Control	0.185a	0.198a	0.268a	0.217a			0.346

Means within a column (in same season) having a common letter are not significantly different
r^2 =Determination coefficient.

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الملخص العربى

معاملات الأوزون والماء الساخن بعد الحصاد تزيد من فترة تداول ثمار المانجو كنت عند مرحلتين من مراحل إكتمال النمو

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أجريت معاملات هذه الدراسة على ثمار المانجو كنت مكتملة النمو مباشرة بعد الجمع (مرحلة أولى) أو بعد ٤٨ ساعة من التخزين على ٢٠°م (مرحلة ثانية). اشتملت معاملات الثمار على ما يلي: تعريض الثمار لغاز الأوزون بتركيز ١٥٠ جزء في البليون أثناء التخزين، وغمر الثمار في الماء الساخن عند ٥٥°م لمدة ٥ دقائق قبل التخزين، وغمر الثمار في الماء الساخن قبل التخزين ثم تعريضها لغاز الأوزن أثناء التخزين. وقد تمت مقارنة هذه المعاملات بثمار غير معاملة (كنترول) خلال مدة التخزين على ١٣°م ورطوبة نسبية ٨٥–٩٠ %. وقد أطالت كلا من معاملة الأوزون والماء الساخن من فترة تسويق الثمار بعد الحصاد بأسبوع مع مظهر خارجي وداخلي أفضل للثمار. كان للثمار المعاملة بالأوزون أكبر نسبة فقد في الوزن بالمقارنة بالكنترول، لكن الفروق لم تكن معنوية، ولقد أعطت المعاملة بالماء الساخن أقل فقد في الوزن لثمار المرحلة الثانية. لم يكن هناك تغير معنوي في لون جلد الثمار وقد ظلت الثمار خضراء خلال فترة التخزين بينما تغير لون اللحم من الكريمي إلى البرتقالي. ولقد أبطأت المعاملة بالأوزون من تغيرات اللون فى اللحم. كان لثمار المرحلة الأولى المعاملة بالماء الساخن أعلى قيم لصلابة اللحم في كلا الموسمين بينما كانت ثمار المرحلة الثانية المعاملة بالأوزون الأعلى في قيم صلابة لحم الثمار. أبطأت كلا من معاملة الأوزون والماء الساخن من زيادة المواد الصلبة الذائبة ومن أنخفاض الحموضة وفيتامين ج خلال فترة التخزين مقارنة بالكنترول. قللت كلا من معاملة الأوزون والماء الساخن من نشاط إنزيمات البيروكسيديز والبولي فينول أوكسيديز لثمار كلا المرحلتين وقد كان أعلى تأثير للمعاملة بالماء الساخن مع الأوزون.