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ORIGINAL ARTICLES

Role of some postharvest treatments in maintaining mango fruit quality during cold storage

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ABSTRACT

Keitt mango fruits (*Mangifera indica* L.) were harvested at maturity stage, then cold stored at10 $\pm$ 1 ^{o}C and relative humidity of 85 %, for forty days after being subjected to different concentrations of natural compounds known to be physiologically active. In this study, effects of sodium nitroprusside SNP (0.5, 1.0 and 2.0 mM. l^{-1}) a nitric oxide donor, salicylic acid SA (0.5, 1.0 and 2.0 mM. l^{-1}), hydrogen peroxide (H_2O_2) (10, 20 and 40 mM. l^{-1}) and chitosan (0.5, 1.0 and 2.0 %) on cold stored mango fruits were studied. Results revealed that all treatments reduced total sugars, respiration rate, water loss, decay percentage and maintained fruit firmness compared with the control. On the other hand, total soluble solids, titratable acidity, and fruit color showed less response to investigated treatments and concentrations.

Key words: Keitt mango – Cold storage – Fruit quality – Sodium nitroprusside – Salicylic acid – Hydrogen peroxide – Chitosan.

Introduction

Mango (*Mangifera indicca* L.) is a fruit that is widely cultivated through out the tropics and warmer subtropics. It contains vitamins, minerals and fibers that are of great importance to humans (Sethi *et al.,* 2011). After harvest, fruits deteriorate due to ripening and senescence (Wang *et al.,* 2006). Moreover, shriveling that occurs during transportation, storage and shelf life reduces fruit's market value (Rodov *et al.,* 1997).

Development of postharvest technologies related to quality maintenance and postharvest life extension is of great importance to consumer acceptability and marketing considerations (Zhong *et al.,* 2006 and Chien *et al.,* 2007). Among the compounds used for this purpose is chitosan, a high molecular weight cationic polysaccharide derived from chitin (Zhong and Xia, 2007) that happens to be nontoxic, biocompatible and biodegradable (Shigemasa *et al.,* 1994), and was reported to delay ripening of mango fruits up to 9 days (Srinivasa *et al.,* 2002). Nitric oxide (NO) can also be used for this purpose. It is one of the smallest diatomic molecules, uncharged free gaseous radicals (Thomas *et al.,* 2008), that is involved in the regulation of a wide variety of specific processes in plants, among which, its role in fruit ripening and senescence (Leshem and Pinchasov, 2000; Leshem *et al.*, 1998; Sozzi *et al.,* 2003) is of great relevance to this study, in which, sodium nitroprusside (SNP) was used as a NO donor. NO not only easily migrates in the hydrophilic regions of the cell, such as the cytoplasm, but also freely diffuses through the lipid phases of membranes (Arasimowicz and Wieczorek, 2007). Many reports have shown that low concentrations of NO can effectively extend postharvest life of several fruits such as Strawberry (Soegiarto and Wills, 2006), peach (Zhu *et al*., 2006), longan (Duan *et al*., 2007), plum (Singh *et al*., 2009) winter jujube (Zhu et al., 2009) and tomato (Lai *et al*., 2011). It is also suggested that NO exerts a great influence on fruits by inhibiting ethylene production (Leshem, 2000).

Another compound that will be investigated in this study is salicylic acid (SA), which is a natural and safe phenolic, plant hormonal substance that has a reported role in reducing deterioration in some fruits such as winter pineapple (Lu *et al.,* 2011), pomegranates (Sayyari *et al*., 2009) and peaches (Wang *et al*., 2006). The last treatment that will be investigated in this study is hydrogen peroxide (H_2O_2).

The objective of this study is to evaluate the effects of some postharvest treatments and determine the optimal concentrations which maintains physiochemical characteristics and prolongs cold storage life as a feasible technology for maintaining quality in order to expand marketability and export options and maximize profitability.

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Materials and Methods

Plant Material:

Keitt mango fruits (*M. indica* L.) were harvested at the commercial maturity stage on 20th October in the two successive seasons of 2011 and 2012, from an orchard located on Cairo- Alexandria Desert Road. Then the fruits were transported to Agricultural Development System (ADS), California Project, MOALR –Egypt. Fruits were then, graded for uniformity of shape and size after discarding blemished or diseased fruits.

Treatments:

In each season, 390 uniform intact fruits where washed in chlorinated water, dried and divided into 13 groups, each of 30, among which, 15 were used for the determination of weight loss, decay and color (three replicates x 5 fruits), while the other 15 were used for measuring fruit firmness, total soluble solids, titratable acidity and respiration rate (three replicates x 5 fruits). Treatments investigated in this study where control, salicylic acid (SA) at concentrations of 0.5, 1.0 and 2.0 mM. l^{-1}, sodium nitroprusside (SNP) at concentrations of 0.5, 1.0 and 2.0 mM. l^{-1}, hydrogen peroxide (HP) at concentrations of 10, 20 and 40 mM. l^{-1}, and chitosan at concentrations of 0.5, 1.0 and 2.0 %. Chitosan (from shrimp shells, Sigma Chemicals) was prepared according to the procedure described by Jiang *et al.* (2005). For each treatment, a group of fruits where dipped for 10 minutes in the solution while control fruits where dipped in distilled water. Afterwards, fruits where left to dry, packed in carton boxes, and stored at 10 ± 1 °C and 85 % relative humidity for forty days, during which physiochemical properties and respiration rate where recorded just before storage, then recorded periodically at intervals of 10 days afterwards, till the end of cold storage period.

Physiochemical Characteristics:

Fruit Firmness:

Was measured using a Magness-Taylor penetrometer (pressure tester). Readings were taken in three positions in each tested fruit, averaged and recorded in lb/ $inch^2$.

Weight Loss Percentage:

Was measured by the difference between the initial and final weight of each replication. It was expressed as a percent (%) using the following equation:

$$\% \text{ Weight loss} = \frac{(\text{Initial weight of fruits - weight of fruits at inspection date}) \times 100}{\text{Initial weight of fruit}}$$

Decay Percentage:

All unmarketable fruits were considered as decayed, and decay percentage was calculated according to the following equation:

$$\text{Decay \%} = \frac{a \times 100}{b}$$

Where: a = No of decayed fruits at time of sampling. b = The initial fruits number.

Skin Color (hue angle):

The color of the peel was determined with a colorimeter Chroma Meter model CR-410® (Konica-Minolta, Japan). Measurements were made near the peduncle, in the middle of the fruit and in the pedicel. Determinations were performed using the system of CIEL, a*, b *, and the color tone was estimated [° Hue = arctg (b* · a*-1)] according to McGuire (1992).

Total Soluble Solids (TSS%):

Were determined at 22°C, with a hand refractometer using 2 to 3 drops of juice obtained by squeezing the fruits (AOAC, 1994).

Titratable Acidity (TA %):

To determine the titratable acidity of the fruit, 10 g of pulp of each fruit were first diluted with sterile distilled water to achieve 50 ml. 10 ml of the dilution were then titrated with 0.1 N NaOH according to the process reported by the AOAC (1999). The results were expressed as a percentage of citric acid present in the samples (g citric acid/ 100 g fresh pulp weight).

Total Sugars:

Was determined by using the method described by Dubois *et al.* (1956) and the concentration was calculated as g glucose per 100 g. fresh weight.

Respiration Rate:

Was determined by passing the air flow through concentrated NaOH, to insure that air flow is CO_2- free, before passing into 1-liter jar fruit container (fruit ambient) one fruit/ jar was considered as one replicate. The out –coming air-flow was then passed into 100 ml. NaOH of 0.1 N for 1 hr. Such solution was then titrated against 0.1 N HCl and CO_2 levels produced by the fruits were then calculated as mg CO_2. kg^{-1} fruits. h^{-1} (AOAC, 1970).

Statistical analysis:

The experiment was laid out using a completely randomized design (CRD). Three replicates per treatment were evaluated for physiochemical fruit quality attributes. The data was analyzed using an analysis of variance (ANOVA) which is the procedure used for testing the differences among means of two or more treatments and the differences between means were detected using least significant difference (L.S.D.)at $P \leq 0.05$ according to Gomez and Gomez (1984).

Results and Discussion

Fruit Firmness ($lb.inch^{-2}$):

As shown in table 1, firmness was significantly affected by storage period and postharvest treatments investigated, nevertheless, irregular trends were noticed in response to the interaction of investigated factors in both seasons. Regardless of storage period, treatments maintained firmness significantly compared to untreated control fruits. The only exceptions to that were noticed in season 2012, when 0.5 % chitosan recorded an insignificant decrease, while 1.0 % chitosan recoded an insignificant increase in firmness compared to control. It was also noticed that increasing concentrations of chitosan, SNP and SA was beneficial in maintaining firmness, while changing H_2O_2 concentrations was the least effective in this regard (statistically). On the other hand and regardless of treatments, significant drops in fruit firmness were recorded as storage time proceeded. The only insignificant decrease in firmness was recorded in season 2012 after 10 days of cold storage, compared to the firmness recorded at the beginning of storage period.

After 10 days of cold storage, all investigated treatments recorded values that were insignificantly different than those recorded at the beginning of storage, in season 2012. In season 2011, untreated fruits and those treated with 0.5 % chitosan recorded significant decreases in firmness after 10 days compared to values recorded at the beging of storage. Twenty days after storage, 10 $m.M.l^{-1}$ H_2O_2 and 0.5 % chitosan in season 2011 and 0.5 and 1.0 % chitosan in season 2012 where the only treatments that did not lead to significant increases in firmness compared to control fruits. Latter, after 30 days of cold storage, only 0.5 $m.M.l^{-1}$ SA and 10, 20 and 40 $m.M.l^{-1}$ H_2O_2 treatments in season 2011 and 20 $m.M.l^{-1}$ H_2O_2 treatment in season 2012, resulted in significantly firmer fruits compared to untreated controls. At the end of the investigated storage period, the firmness maintaining effect, compared to controls, recorded for different treatments in earlier stages totally diminished in season 2011 and was recorded for the 2.0 $m.M.l^{-1}$ SNP treatment only, in the latter season.

Loss of firmness during storage is agreement with the findings of Wongmetha and ke (2012), Figueroa *et al.* (2011) and Nongtaodum and Jangchud (2009), who found that chitosan played a positive role in this regard by delaying firmness loss. Kays (1991) attributed fruit softness to enzymatically mediated degredative changes in cell walls during ripening. Pectinmethylesterase (PME) and polygalacturonase (PG) might be either synthesized or activated or a combination of both at or near the onset of ripening. Figueroa *et al.* (2011) results also showed that chitosan played a positive role in decreasing firmness loss.

Table 1: Effect of postharvest treatments on firmness (lb.inch^{-2}) of Keitt mango fruits during cold storage.

Treatments (T)		Season 2011						Season 2012					
Sub.	Con.	Storage period (SP)					Mean	Storage period (SP)					Mean
		0	10	20	30	40		0	10	20	30	40	
Control	Water	17.80	7.50	7.00	4.10	3.30	7.94	17.90	17.30	7.30	5.00	2.00	9.90
SNP (mM.l^{-1})	0.5	17.80	17.40	14.30	4.20	2.10	11.16	17.90	17.30	12.00	4.10	2.60	10.78
	1.0	17.80	17.60	17.00	4.70	3.00	12.02	17.90	17.60	17.40	5.10	2.10	12.02
	2.0	17.80	17.60	17.40	5.20	4.10	12.42	17.90	17.50	17.30	5.60	5.00	12.66
SA (mM.l^{-1})	0.5	17.80	17.30	13.00	6.30	3.00	11.48	17.90	17.70	17.20	4.00	1.80	11.72
	1.0	17.80	17.40	17.30	3.50	2.30	11.66	17.90	17.30	17.20	7.10	4.00	12.70
	2.0	17.80	17.30	16.90	6.20	3.00	12.24	17.90	17.60	17.50	5.90	2.80	12.34
H_2O_2 (mM.l^{-1})	10	17.80	17.20	7.20	6.80	1.90	10.18	17.90	17.20	15.00	6.00	3.90	12.00
	20	17.80	17.10	11.20	6.70	2.50	11.06	17.90	17.40	17.10	7.30	2.10	12.36
	40	17.80	17.10	9.80	6.30	3.10	10.82	17.90	17.30	17.20	6.10	2.00	12.10
Chitosan (%)	0.5	17.80	15.20	6.00	3.10	2.40	8.90	17.90	17.60	6.50	4.50	2.10	9.72
	1.0	17.80	17.50	15.50	4.60	1.60	11.40	17.90	17.60	9.10	4.50	2.60	10.34
	2.0	17.80	17.20	15.30	5.70	2.20	11.64	17.90	17.40	17.30	4.60	2.70	11.98
Mean		17.80	16.42	12.92	5.18	2.65		17.90	17.45	14.47	5.37	2.75	
L.S.D. (5%)		SP= 0.583		T= 0.939		SP x T= 2.100		SP= 0.596		T= 0.961		SP x T= 2.149	

In this regard, and similar to Yali pears that maintained higher firmness in response to NO treatment (Qin *et al.,* 2011). Zhu *et al.* (2006) also reported that decrease of firmness recorded for peach fruits was more obvious in control fruits compared to NO- treated fruits. NO role in maintaining firmness could be explained by results reported by Qin *et al.* (2011), who reported decreased activities of polygalacturonase (PG), β-galactosidase (β-Gal) and pectin methyl esterase (PME) in response to NO treatment. They also reported retarded degradation of covalent soluble pectin, accumulation of ionic soluble pectin and water soluble pectin as a result of NO treatment. As for the role of SA in maintaining firmness, it was reported to be via its effectiveness in decreasing ethylene production in several crops such as strawberry (*Babalar et al.,* 2007), apple (Mo *et al.*, 2008) and Kiwifruit (Aghdam *et al.,* 2009). This effect is attributed to the key role ethylene plays in triggering the induction of cell wall hydrolyzing enzymes (Wills *et al.,* 1998)

Total Soluble Solids (TSS %):

As shown in table 2, both, treatments and storage periods had a significant effect on TSS % in cold stored mango fruits. In both seasons, and regardless of treatments, significant increases in TSS % have been recorded along the periods of storage. On the other hand, and regardless of storage period, different treatments led to nonsignificant differences in TSS % with control fruits in season 2011 and 2012, with only one exception in the latter season, when the 2.0 mM.l^{-1} SNP treatment resulted in a significant reduction in fruit TSS% compared to control. It was also noticed that TSS% increased as storage proceeded, for each treatment in both investigated seasons.

Table 2: Effect of postharvest treatments on TSS (%) of Keitt mango fruits during cold storage.

Treatments (T)		Season 2011						Season 2012					
Sub.	Con.	Storage period (SP)					Mean	Storage period (SP)					Mean
		0	10	20	30	40		0	10	20	30	40	
Control	Water	9.20	11.50	13.90	15.30	16.00	13.18	9.00	12.50	14.40	15.20	16.00	13.42
SNP (mM.l^{-1})	0.5	9.20	11.90	13.40	14.20	16.00	12.94	9.00	10.00	13.90	15.80	16.60	13.06
	1.0	9.20	10.30	13.90	14.70	16.90	13.00	9.00	11.20	13.80	15.20	16.00	13.04
	2.0	9.20	12.30	12.20	15.10	15.30	12.82	9.00	9.60	11.60	15.80	17.20	12.64
SA (mM.l^{-1})	0.5	9.20	11.60	14.30	15.10	17.30	13.50	9.00	12.80	13.60	15.70	17.50	13.72
	1.0	9.20	11.40	13.90	15.20	17.50	13.44	9.00	11.20	14.90	15.60	16.20	13.38
	2.0	9.20	13.30	13.70	14.40	16.10	13.34	9.00	11.30	14.20	15.70	15.80	13.20
H_2O_2 (mM.l^{-1})	10	9.20	12.00	14.10	15.10	15.90	13.26	9.00	12.50	14.20	15.40	17.00	13.62
	20	9.20	12.10	13.80	14.90	15.50	13.10	9.00	11.90	16.00	13.90	17.00	13.56
	40	9.20	11.00	14.60	15.70	15.40	13.18	9.00	11.10	14.10	15.80	17.70	13.54
Chitosan (%)	0.5	9.20	12.00	14.00	14.80	16.20	13.24	9.00	13.00	14.20	15.80	16.20	13.64
	1.0	9.20	11.60	14.80	14.70	15.10	13.08	9.00	12.00	13.40	16.00	16.70	13.42
	2.0	9.20	12.60	13.50	13.80	16.20	13.06	9.00	12.20	14.50	14.80	16.80	13.46
Mean		9.20	11.82	13.85	14.85	16.11		9.00	11.64	14.06	15.44	16.67	
L.S.D. (5%)		SP= 0.228		T= 0.368		SP x T= 0.822		SP= 0.256		T= 0.413		SP x T= 0.924	

Increased TSS could be due to increased activity of enzymes responsible for starch hydrolysis to soluble sugars (Zhong *et al*, 2006), and can be caused by the decline in the amount of carbohydrates , pectines, partial hydrolysis of protein and decomposition of glycosides into subunits during respiration (Abbasi *et al.,* 2009).

Obtained results are in agreement with that reported by Wongmetha and Ke, (2012) who stated that chitosan had no effect on TSS in mango fruits. A similar response was also reported in pummelo (Ratanachinakorn *et al.,* 2005) and strawberry (Munoz *et al.,* 2008). Zhu *et al.* (2006) also, reported reduced soluble solids content in peach fruits treated with NO compared to the controls. The same effect was reported by Qin *et al.* (2011) in pears, but was more pronounced after 80 days of storage. They added that different concentrations of NO showed insignificant differences in-between. Similarly, TSS in winter pineapple showed an insignificant response to SA treatment (Lu *et al.,* 2011). Such findings are in line with results obtained in this study. Contrarily, our results showing the insignificant effect of SA on TSS% contradicts results reported for banana (Srivastava and Dwivedi, 2000) and apple (Mo *et al.,* 2008) that recorded significant reductions in TSS% in response to SA treatments. Similarly, results in this investigation differ from those reported by Ismail *et al.* (2010) who reported TSS decreases in guava fruits in response to H_2O_2 treatment.

Total Sugars (TS %):

Results presented in table 3 show that regardless of treatment, fruits TS % recorded significant increases from one storage period to the other. In this regard, Wongmetha and ke (2012) reported that starch content of mango fruits tended to decrease during storage and attributed that decrease to the conversion of starch to sucrose. As a consequence of increased amylase activity leading to starch hydrolysis, total sugars increase during ripening, with sucrose, fructose and glucose constituting most of the soluble sugars (Wongmetha and ke, 2012; Lizada, 1993). TSS and soluble sugars may also increase during fruit ripening due to the action of sucrose-phosphate synthase (SPS), a key enzyme in sucrose biosynthesis (Hubbard *et al.,* 1991). This enzyme is activated by ethylene and the ripening process itself during storage (Langenkamper *et al.,* 1998).

On the other hand, and regardless of storage period, not all of the treatments showed significant differences with control fruits in regards of TS % in cold stored mango fruits. SNP treatments resulted in reduced TS % in fruits, but this reduction was significant only for 1.0 and 2.0 $mM.l^{-1}$ concentrations. This is in accordance with what Qin *et al.* (2011) reported, who stated that although soluble sugar content increased during storage of pears, but NO treatment significantly inhibited the increase of soluble sugar. Such inhibitory effect was also found in response to SA treatments in both seasons, though different concentrations showed insignificant differences in- between. This is in agreement with results reported for banana fruits by Srivistava and Dwivedi (2000). They also recorded decreased reducing sugars and invertase activity in banana in response to SA treatment. H_2O_2 treatments, also led to reduced TS% in mango fruits compared to the control, but statistical significant was detected in the latter season only for 20 and 40 $mM.l^{-1}$ concentrations. Such result is in agreement with the findings of Ismail *et al.* (2010) who reported that H_2O_2 treatment led to the decrease in total sugars of guava fruits during storage. Chitosan also reduced TS% in chitosan- treated fruits compared to the control, but significant reductions were only recorded for the 1.0 and 2.0 0 $mM.l^{-1}$ concentrations in season 2012. This effect of chitosan might be attributed to its role in reducing weight loss (to be discussed latter in this study), and consequently maintaining humidity in fruits leading to reduced TS%.

Table 3: Effect of postharvest treatments on total sugars (%) of Keitt mango fruits during cold storage.

Treatments (T)		Season 2011						Season 2012					
Sub.	Con.	Storage period (SP)					Mean	Storage period (SP)					Mean
		0	10	20	30	40		0	10	20	30	40	
Control	Water	6.38	7.47	9.73	11.47	12.80	9.57	5.85	7.34	9.94	11.72	12.64	9.50
SNP ($mM.l^{-1}$)	0.5	6.38	7.33	9.38	10.65	12.60	9.27	5.85	7.43	9.83	10.44	12.60	9.23
	1.0	6.38	7.41	9.73	10.85	11.40	9.15	5.85	7.14	9.14	9.81	12.31	8.85
	2.0	6.38	7.54	10.06	10.77	11.05	9.16	5.85	6.55	9.39	10.51	11.66	8.79
SA ($mM.l^{-1}$)	0.5	6.38	7.50	8.74	11.22	12.11	9.19	5.85	5.62	7.31	10.67	12.60	8.41
	1.0	6.38	7.99	9.36	10.51	11.76	9.20	5.85	7.31	9.11	9.99	11.38	8.73
	2.0	6.38	7.15	8.54	10.73	12.64	9.09	5.85	7.67	8.57	10.56	11.09	8.75
H_2O_2 ($mM.l^{-1}$)	10	6.38	7.60	9.34	11.22	12.13	9.33	5.85	6.79	10.43	11.21	12.60	9.38
	20	6.38	7.86	9.62	10.84	11.96	9.33	5.85	6.86	10.08	9.25	12.24	8.86
	40	6.38	7.72	9.25	11.45	12.64	9.49	5.85	6.55	8.69	10.26	10.94	8.46
Chitosan (%)	0.5	6.38	7.68	9.65	11.41	11.99	9.42	5.85	7.61	8.95	10.40	13.10	9.18
	1.0	6.38	8.12	9.32	10.79	12.36	9.39	5.85	7.02	8.63	10.56	12.42	8.90
	2.0	6.38	8.06	9.50	10.83	11.67	9.29	5.85	6.49	8.76	10.52	12.07	8.74
Mean		6.38	7.65	9.40	10.98	12.09		5.85	6.95	9.14	10.45	12.13	5.85
L.S.D. (5%)		SP= 0.191		T= 0.307		SP x T= 0.687		SP= 0.213		T= 0.343		SP x T= 0.766	

Titratable Acidity (TA %):

Results shown in table 4 show that TA % in cold stored mango fruits was significantly affected in response to extended cold storage periods and investigated postharvest treatments. Regardless of applied treatment,

significant declines in TA have been recorded throughout this study from a storage period to the next. Such decrease of TA during storage has been reported earlier by Wongmetha and ke (2012) for mango fruits. This decrease might be due to the reduction of organic acids due to their consumption or conversion to sugars during respiratory metabolism (Alves *et al.,* 2004).

On the other hand, and regardless of storage period, investigated treatments had a significant effect on this character in both investigated seasons. SNP treatments led to significant reductions in TA % compared to control fruits, though insignificant differences were detected between different concentrations of SNP in both seasons. Such result is accordance with the results of Lai *et al.* (2011) who reported that although tomato fruit TA decreased gradually with increasing storage duration, NO treatment significantly decreased the rate of reduction. Contrarily, all SA treatments in both seasons led to increased TA % in mango fruits, but statistical significance was recorded in the first season for the 2.0 $mM.l^{-1}$ treatment only. Lu *et al.* (2011) reported similar findings in pine apple when insignificant increases in TA value in pine apple fruits were recorded in response to SA treatment. H_2O_2 also reduced TA% in cold stored mango fruits compared to controls in both investigated seasons, but only the highest concentration recorded significant differences in both seasons. This generally agrees with the decreased total acidity recorded in guava fruits compared to control fruits during cold storage, reported by Ismail *et al.* (2010). It was also found that all chitosan concentrations reduced fruit TA% compared to control fruits in both seasons, but this reduction was insignificant, in the first season only, for the 0.5 % chitosan concentration. Here, it is worth mentioning that different concentrations of SNP, H_2O_2 and chitosan recorded insignificant differences in-between in both seasons, while such insignificant differences were recorded for SA in the latter season only.

Table 4: Effect of postharvest treatments on TA (%) of Keitt mango fruits during cold storage.

Treatments (T)		Season 2011						Season 2012					
Sub.	Con.	Storage period (SP)					Mean	Storage period (SP)					Mean
		0	10	20	30	40		0	10	20	30	40	
Control	water	1.62	1.15	0.98	0.83	0.24	0.96	1.70	1.21	0.89	0.76	0.38	0.99
SNP ($mM.l^{-1}$)	0.5	1.62	0.96	0.76	0.64	0.44	0.88	1.70	0.89	0.76	0.70	0.38	0.89
	1.0	1.62	0.83	0.70	0.64	0.38	0.83	1.70	0.76	0.70	0.64	0.32	0.82
	2.0	1.62	0.89	0.76	0.70	0.24	0.84	1.70	0.83	0.76	0.64	0.19	0.82
SA ($mM.l^{-1}$)	0.5	1.62	1.08	1.02	0.89	0.24	0.97	1.70	1.15	1.02	0.83	0.38	1.02
	1.0	1.62	1.28	1.08	0.76	0.32	1.01	1.70	1.34	1.02	0.83	0.24	1.03
	2.0	1.62	1.34	1.08	0.96	0.32	1.06	1.70	1.21	1.02	0.96	0.32	1.04
H_2O_2 ($mM.l^{-1}$)	10	1.62	0.96	0.89	0.83	0.38	0.94	1.70	1.02	0.83	0.76	0.32	0.93
	20	1.62	1.02	0.89	0.70	0.38	0.92	1.70	1.21	0.76	0.70	0.19	0.91
	40	1.62	1.02	0.76	0.64	0.38	0.88	1.70	0.89	0.76	0.70	0.44	0.90
Chitosan (%)	0.5	1.62	1.02	0.83	0.76	0.38	0.92	1.70	0.89	0.83	0.76	0.38	0.91
	1.0	1.62	0.96	0.83	0.70	0.32	0.89	1.70	0.96	0.83	0.76	0.32	0.91
	2.0	1.62	1.21	0.76	0.64	0.24	0.89	1.70	1.08	0.76	0.70	0.24	0.90
Mean		1.62	1.06	0.87	0.75	0.33		1.70	1.03	0.84	0.75	0.32	
L.S.D. (5%)		SP= 0.037		T= 0.060		SP x T= 0.135		SP= 0.043		T= 0.069		SP x T= 0.153	

Fruit Skin Color (^oHue):

As shown in table 5, both treatments and storage period significantly affected ^oHue in both investigated seasons. In season 2011, non of the treatments led to a significantly different ^oHue than that recorded for control fruits. In the latter season, all SNP, SA and chitosan concentrations led to significant reductions in ^oHue compared to the control. It was also noticed that for each investigated substance, insignificant differences where recorded in response to different concentrations. Such decrease in ^oHue during storage is in accordance with the results reported by Figueroa *et al.* (2011) who found that chitosan treatment led to a less pronounced decrease in ^oHue compared to untreated fruits. They attributed that to the less quantities of O_2 present based on the demonstrations made by several authors (Casariego *et al*., 2009; Sathivel *et al*., 2007; Miranda *et al*., 2004), that chitosan films function as a barrier to O_2, which in turn led to the delay in color generation in chitosan- coated fruits as a result of decreased ethylene synthesis that depends on the presence of O_2 (Taiz and Zeiger, 2006). Moreover, Lai *et al.* (2011) observed that NO could effectively retard pericarp color reddening in tomatoes and suppress ethylene production fruits, which indicates that NO is beneficial for delaying fruit ripening. As for the effect of SA on color, development of red color in tomato and delayed discoloration of fresh- cut chestnut have been reported by Ding and Wang (2003) and Peng and Jiang (2006), repectively, in response to SA treatments.

On the other hand, and regardless of treatment, color values decreased as storage elapsed. It was also noticed that the reductions recorded from 10 to 20 days in both seasons, and the reduction recorded from 20 to 30 days in the latter season only, were insignificant. Here, it worth mentioning that at the end of the storage period in both seasons, none of the treatments investigated significantly maintained color compared to controls.

Table 5: Effect of postharvest treatments on skin color of Keitt mango fruits during cold storage.

Treatments (T)		Season 2011						Season 2012					
Sub.	Con.	Storage period (SP)					Mean	Storage period (SP)					Mean
		0	10	20	30	40		0	10	20	30	40	
Control	Water	132.0	125.8	120.3	118.6	21.4	103.6	138.0	111.9	102.2	100.6	24.7	95.50
SNP ($mM.l^{-1}$)	0.5	132.0	123.7	118.9	118.0	16.9	101.9	138.0	123.8	118.9	118.0	18.5	103.4
	1.0	132.0	119.5	116.6	108.1	27.5	100.7	138.0	118.4	118.2	112.9	31.2	103.7
	2.0	132.0	131.6	125.8	125.7	16.6	106.3	138.0	122.9	118.5	118.1	22.7	104.0
SA ($mM.l^{-1}$)	0.5	132.0	115.6	115.5	103.1	28.8	99.0	138.0	123.4	122.9	116.2	21.0	104.3
	1.0	132.0	123.1	121.9	117.2	23.5	103.5	138.0	124.7	121.8	115.1	22.1	104.3
	2.0	132.0	123.1	119.4	114.8	26.9	103.2	138.0	120.7	120.5	120.3	21.2	104.1
H_2O_2 ($mM.l^{-1}$)	10	132.0	127.6	118.1	104.3	12.9	99.0	138.0	117.6	114.5	106.4	13.1	97.92
	20	132.0	118.7	116.9	110.9	26.8	101.1	138.0	119.2	119.0	115.6	15.6	101.5
	40	132.0	122.5	119.2	118.0	18.1	102.0	138.0	117.2	112.1	111.4	24.6	100.7
Chitosan (%)	0.5	132.0	123.9	123.0	114.4	16.3	101.9	138.0	125.2	122.0	119.1	20.0	104.9
	1.0	132.0	122.8	119.9	119.1	19.2	102.6	138.0	131.6	130.5	128.5	19.6	109.6
	2.0	132.0	129.6	126.7	122.1	17.4	105.6	138.0	136.7	133.5	123.6	19.8	110.3
Mean		132.0	123.7	120.2	114.9	21.0		138.0	122.6	119.6	115.8	21.1	
L.S.D. (5%)		SP= 3.728		T= 6.011		SP x T= 13.44		SP= 3.816		T= 6.153		SP x T= 13.76	

Weight Loss (%):

Results demonstrated in table 6 show that not all investigated concentrations of SNP, SA, H_2O_2 and chitosan led to significant reductions in weight loss % during cold storage of mango fruits. In both seasons, all SA concentrations significantly reduced weight loss % compared to the control. SA weight loss inhibition during cold storage has been reported earlier for strawberry fruits (Shafiee *et al.,* 2010). A significant reduction in weight loss % in response to SNP was found in fruits treated with 1.0 and 2.0 $mM.l^{-1}$ SNP in season 2011 and fruits treated with the highest concentration in the latter season. As for the effect of H_2O_2 on this character, different investigated concentrations led to significant reductions in weight loss % compared to control fruits. Such a beneficial impact was reported for guava fruits also in an earlier study (Ismail *et al*., 2010). And finally, chitosan with concentrations of 1.0 and 2.0 $mM.l^{-1}$ significantly reduced weight loss % compared to the control fruits in both investigated seasons. This contradicts the findings of Wongmetha and Ke (2012) who reported that chitosan insignificantly reduced weight loss of mango fruits during cold storage. Contrarily, Nongtaodum and Jangchud (2009) reported that chitosan can retard weight loss of fresh cut mango significantly. Figueroa *et al.* (2011) noted that such effect may be due to less structure destabilization of cuticle cells caused by chitosan treatment.

Table 6: Effect of postharvest treatments on weight loss (%) of Keitt mango fruits during cold storage.

Treatments (T)		Season 2011					Season 2012				
Sub.	Con.	Storage period (SP)				Mean	Storage period (SP)				Mean
		10	20	30	40		10	20	30	40	
Control	Water	1.92	5.45	7.22	13.80	7.10	1.92	5.45	7.22	13.80	7.10
SNP ($mM.l^{-1}$)	0.5	1.69	5.54	7.01	10.26	6.12	2.02	5.59	6.92	11.35	6.47
	1.0	1.87	5.31	6.84	10.15	6.04	1.60	5.11	6.81	11.39	6.23
	2.0	1.28	4.54	5.73	9.44	5.25	1.35	4.62	5.86	10.74	5.64
SA ($mM.l^{-1}$)	0.5	1.54	4.63	6.39	9.34	5.48	1.05	4.75	6.37	9.48	5.41
	1.0	0.99	3.17	4.25	6.14	3.64	1.44	4.43	6.15	7.57	4.90
	2.0	0.87	3.15	4.24	7.17	3.86	0.61	4.26	5.72	8.28	4.72
H_2O_2 ($mM.l^{-1}$)	10	2.06	5.72	7.79	10.97	6.64	1.55	5.48	6.57	7.72	5.33
	20	1.73	5.03	6.58	9.49	5.71	1.40	4.64	6.30	7.97	5.08
	40	1.02	3.66	5.19	7.32	4.30	1.12	3.61	5.06	7.24	4.26
Chitosan (%)	0.5	2.17	5.98	7.63	10.83	6.65	1.22	3.79	9.81	9.34	6.04
	1.0	1.69	5.37	7.06	9.94	6.01	1.99	4.65	5.50	8.94	5.27
	2.0	1.40	4.97	6.16	8.64	5.29	1.33	4.36	5.60	6.59	4.47
Mean		1.56	4.86	6.38	9.36		1.43	4.67	6.45	9.26	
L.S.D. (5%)		SP= 0.512		T= 0.923		SP x T= 1.845	SP= 0.749		T= 1.350		SP x T= 2.701

On the other hand, and regardless of treatments, significant reductions in weight were recorded in both seasons as storage proceeded. These findings agree with those of Wongmetha and Ke (2012) who recorded weight loss increases during cold storage of mango fruits. In this regard, it was reported that increased weight loss is caused by reduced metabolic activity and moisture evaporation through skin (Alves *et al.,* 2004). It is also worth mentioning that the rate at which water is lost depends on the storage temperature and water pressure gradient between the fruit tissue and the surrounding atmosphere (Munoz *et al.,* 2008).

Decay (%):

Results presented in table 7 show that all the investigated postharvest treatments significantly affected decay percentage of cold stored mango fruits. Regardless of storage period, all the treatments, except the 0.5 $m.M.l^{-1}$ SA, significantly reduced decay compared to the control untreated fruits. Moreover, the highest concentration investigated for each treatment completely prevented the occurrence of fruit decay throughout the whole storage period in both seasons. This total prevention of decay was also recorded in the first season when fruits where treated with 1.0 $m.M.l^{-1}$ of SNP and SA and 2.0 $m.M.l^{-1}$ of H_2O_2.

On the other hand, and regardless of treatments, decay was first recorded, thirty days after cold storage and ten days latter, a significant increase in decay percentage was recorded in both seasons. Similarly, the interaction of storage periods and treatments significantly impacted this character and a general trend was noticed, in which, low concentrations and extended storage, were correlated with increased decay percentages (in the incidence of decay occurrence).

Table 7: Effect of postharvest treatments on decay (%) of Keitt mango fruits during cold storage.

Treatments (T)		Season 2011					Season 2012				
Sub.	Con.	Storage period (SP)				Mean	Storage period (SP)				Mean
		10	20	30	40		10	20	30	40	
Control	water	0.00	0.00	20.00	33.32	13.33	0.00	0.00	20.00	33.32	13.33
SNP ($mM.l^{-1}$)	0.5	0.00	0.00	0.00	33.32	8.33	0.00	0.00	0.00	40.00	10.00
	1.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	33.32	8.33
	2.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SA ($mM.l^{-1}$)	0.5	0.00	0.00	20.00	33.32	13.33	0.00	0.00	20.00	40.00	15.00
	1.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20.00	5.00
	2.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H_2O_2 ($mM.l^{-1}$)	10	0.00	0.00	0.00	20.00	5.00	0.00	0.00	0.00	20.00	5.00
	20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chitosan (%)	0.5	0.00	0.00	13.33	20.00	8.33	0.00	0.00	0.00	20.00	5.00
	1.0	0.00	0.00	13.33	20.00	8.33	0.00	0.00	0.00	20.00	5.00
	2.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mean		0.00	0.00	5.13	12.30		0.00	0.00	3.08	17.43	
L.S.D. (5%)		SP= 1.613		T= 2.908		SP x T= 5.816	SP= 1.192		T= 2.149		SP x T= 4.298

Chitosan have been reported to control decay of many fruits such as mango, pear, table grape and strawberry (Wongmetha and Ke, 2012; Lin *et al.*, 2008; Meng *et al.*, 2008; Munoz *et al*., 2008). This might be attributed to its antifungal (Hernandez *et al*., 2007) and antimicrobial (Gil *et al*., 2004) properties reported. Such properties have been reported to be due to the disruption and death of the microbial cell as a result of interactions between its positively charged molecules and the negatively charged microbial cell membrane (Helander *et al.*, 2001). Abbasi *et al.* (2009) attributed chitosan's decay control to its induction of chinitase, a defense enzyme, which catalizes the hydrolysis of chinitin, a common component of fungal cell walls, thus preventing fungi growth on fruits. In this regard, Wang *et al.* (2007) and Zhu *et al.* (2008) reported that pathogenic microorganisms were diminished when mango fruits were coated with chitosan.

As for the effect of NO on stored edible parts, Leshem *et al.* (1998) reported that commodities (strawberry, broccoli, cucumber, Chinese broccoli, kiwi and mushroom) took significantly longer to deteriorate to a level that was considered unacceptable for commercial marketing than produce that was untreated with NO. The average extension in postharvest life for the six commodities was 117 %. It is worth mentioning that previous studies have shown that application of exogenous NO could retard ripening and senescence in postharvest tissue through increasing the content of endogenous NO and inhibiting the production of ethylene (Radi *et al*., 1991; Leshem and Wills, 1998; Leshem *et al*., 2001; Qin *et al.,* 2011). As for the application of exogenous SA at nontoxic concentrations, it was reported that it enhances resistance to pathogens and controls post-harvest decay in table grape, pear and strawberry (Asghari *et al*., 2009; Asghari *et al*., 2007; Babalar *et al*., 2007). In this regard, it is worth mentioning that the onset of systemic acquired resistance (SAR) is associated with increased levels of SA, locally at the site of infection and often also systemically in distant tissues (Klessig and Malamy, 1994; Malamy and Klessig, 1992; Tsuda et al., 2008). It was also reported that SA may facilitate H_2O_2 accumulation during the oxidative burst (OB) induced by infection with the virulent pathogens. The increased reactive oxygen species (ROS) associated with the OB may contribute to resistance via several mechanisms, including directly killing the invading pathogen and/or activating cell wall crosslinking and lignification, thereby strengthening the cell wall and helping confine the pathogen to the infection site (Dempsey *et al.,* 1999). Finally, H_2O_2 also have been reported to have a positive effect in regards of decay reduction in guava fruits (Ismail *et al.,* 2010).

Respiration Rate (mg CO_2. kg^{-1} fruits. h^{-1}):

As presented in table 8, significant differences in respiration rates were recorded in response to different storage periods and treatments investigated in this study. Regardless of storage period, except for the 10 $mM.l^{-1}$ H_2O_2 treatment in season 2012, all treatments in both seasons significantly inhibited respiration rate compared to controls. It was noticed in both seasons that increasing the concentrations of SNP, SA, chitosan and H_2O_2 (in season 2012 only) was correlated with reduced respiration rates. Detected reductions were not statistically significant. Presented results show that regardless of treatments, respiration rates recorded at the beginning of storage declined 10 days latter, and this declination was followed by a increase after 20 days of cold storage and another increase after 30 days representing the top respiration rate (climacteric peak), followed by a final decrease in respiration rate at the end of the investigated storage period. Here, it is worth mentioning that the inclinations and declinations were significantly different in- between. It was also noticed that all treatments, except 40 $m.M.l^{-1}$ H_2O_2, in season 2012, delayed climacteric peak compared to control fruits. This delay was recorded for 0.5 and 1.0 $m.M.l^{-1}$ SNP and 10 $m.M.l^{-1}$ H_2O_2 only, in the earlier season.

Table 8: Effect of postharvest treatments on respiration rate (mg CO_2. kg^{-1} fruits. h^{-1}) of Keitt mango fruits during cold storage.

Treatments (T)		Season 2011						Season 2012					
Sub.	Con.	Storage period (SP)					Mean	Storage period (SP)					Mean
		0	10	20	30	40		0	10	20	30	40	
Control	Water	11.7	7.0	20.6	26.5	15.1	16.2	12.4	4.5	26.2	19.4	14.9	15.5
SNP ($mM.l^{-1}$)	0.5	11.7	4.2	11.5	13.1	11.4	10.4	12.4	3.6	14.5	18.5	10.7	11.9
	1.0	11.7	4.2	10.6	13.6	14.2	10.9	12.4	5.7	10.5	10.7	15.4	10.9
	2.0	11.7	4.2	11.5	13.1	11.4	10.4	12.4	6.3	10.3	15.3	9.3	10.7
SA ($mM.l^{-1}$)	0.5	11.7	5.2	18.8	14.2	12.3	12.4	12.4	3.7	11.1	14.0	14.9	11.2
	1.0	11.7	1.4	8.6	24.7	12.5	11.8	12.4	3.1	12.9	14.9	11.7	11.0
	2.0	11.7	5.0	7.7	16.4	15.6	11.3	12.4	3.5	6.3	16.2	15.5	10.8
H_2O_2 ($mM.l^{-1}$)	10	11.7	7.3	9.6	10.7	13.5	10.6	12.4	5.8	18.1	22.3	18.8	15.5
	20	11.7	3.5	9.1	15.1	14.8	10.8	12.4	7.0	16.0	19.2	17.0	14.3
	40	11.7	4.8	6.2	14.8	14.3	10.4	12.4	9.9	17.7	13.0	12.2	13.0
Chitosan (%)	0.5	11.7	5.2	18.9	16.0	14.2	13.2	12.4	6.8	14.8	15.7	16.8	13.3
	1.0	11.7	9.7	14.9	13.8	13.1	12.6	12.4	5.8	10.1	15.2	18.7	12.4
	2.0	11.7	5.8	9.9	16.8	13.4	11.5	12.4	4.5	10.9	12.1	12.8	10.5
Mean		11.7	5.2	12.2	16.3	13.9		12.4	5.4	13.8	15.9	14.5	
L.S.D. (5%)		SP= 0.426		T= 0.687		SP x T= 1.536		SP= 0.428		T= 0.690		SP x T= 1.542	

Inhibited respiration in response to chitosan treatment is in agreement with the findings of Figueroa *et al.* (2011), who attributed that effect to the chitosan film that acts as a barrier to O_2 and to a less extent, to less structure destabilization of cuticle cells caused by chitosan. Here, it is worth mentioning that Bégin *et al*. (2004) found between 30 and 50% lower rate of respiration in mango fruits coated with chitosan, seem to support the hypothesis that gas exchange is the factor that attenuates the process of fruit ripening. On the other hand, a previous report indicated that the impact of NO on ethylene production (which is correlated with respiration) was concentration dependent in whole Bartlett pear fruit (Sozzi *et al.,* 2003). Moreover, delayed climacteric peak in response to NO postharvest treatment have been reported in tomato (Lai *et al.,* 2011), while reduced ethylene production was reported for tomato and peach (Lai *et al.,* 2011; Zhu *et al.,* 2006). SA also, has been reported to decrease respiration rate in fruits such as banana and apple (Srivastava and Dwivedi, 2000; Mo *et al*., 2008). Wills *et al.* (1998) attributed its role to its effectiveness in inhibiting ethylene production, which in turn triggers respiration. Asghari and Aghdam (2010) reported that SA decreases ethylene production by decreasing ACS and ACO production and activity, and a similar effect was reported in kiwifruit earlier by Zhang *et al.* (2003) during early stages of fruit ripening in response to postharvest treatment with acetyl salicylic acid (ASA).

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