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MAINTAINING FRUIT QUALITY OF COLD STORED MANGO *CV.* KEITT VIA EXOGENOUS POSTHARVEST TREATMENTS

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Abstract

Mango fruit is one of the most important fruit crops especially in Egypt; mango is considered as climacteric and very perishable fruit, which limits the storage and handling potential the main objectives of our study is to prolong storage life and maintain higher quality attributes by using different postharvest treatments on Keitt mango fruits. The experiment was conducted in 2018 and 2019 seasons. Fruits at full mature stage were treated with four treatments; 100µM Sodium nitroprusside, 5mM Salicylic acid, 10mM Oxalic acid, untreated sample as control and stored at 13°C, 90% RH for 42 days and compared to untreated fruit. The quality aspects of Keitt were maintained by different postharvest treatments comparing to control treatment however SNP was recorded a better results comparing to SA and OA it suppressed the decay incidence, weight loss, respiration rate, TSS and color changes and maintain both TA and firmness longer than other treatments. Overall results suggest that SNP could extend the storage life of Keitt mango fruits with optimum quality.

Key words: Keitt *cv.*, Postharvest life, Sodium nitroprusside, Oxalic acid, Salicylic acid

Introduction

Mango (*Mangifera indica*) is one of the most cultivated fruit crop in tropical region and all over the world, where mango is considered the king of the fruits (Mukherjee and Litz, 2009; Yahia, 2011). Since the consumers are becoming aware about the nutritional and health benefits of fresh fruits, many studies proved that mango has higher content of bioactive and nutritional compounds (Policegoudra and Aradhya, 2007).

Many producing countries rely on the production of mango fruits as the main source of national income. According to FAOSTAT Database Collections October 2020 (FAOSTAT), the average global production exceeded 55 million tons in 2018. World trade in mangoes has been increasing over the years and both exports and local consumption is growing. Based on the same data of FAOSTAT, Egypt produced in 2018 about 1.5 million tons which represent 1.3% of the global production (Evans, 2008).

Losses of mango fruits quality occurs at all postharvest stages from harvesting to consumption. Hence the proper postharvest management for mango fruit is fundamental to increase the production and maintain high quality of the fruits and reduce postharvest losses which have been estimated more than 25% from harvesting to consumption stage (Menon and Goswami, 2007).

Keittmango is a climacteric fruit, which means that it may be picked at full mature stage then it can continue its ripening, however potential marketable life decreases due to the difficulty of controlling the ripening changes once they have been initiated, increased bruising susceptibility and increased decay (Brecht and Yahia, 2009). Mango harvested at a mature but unripe stage of development (mature-green) can be stored as long as the initiation of ethylene production and hence ripening is avoided. The initiation of ripening can be avoided by prompt cooling and storage at optimum temperature at which ripening can be delayed (Yahia, 1998).

Sodium nitroprusside (SNP) is one of the main sources of nitro oxide (NO), NO plays an important role as multifunctional signaling molecule and it can used to extend the storage life of many fruits because it is involved in several physiological processes in plants and it has a versus relationship with ethylene production through its ability to suppress the activities of ethylene biosynthesis enzymes (Zaharah and Singh, 2011; Manjunatha *et al.,* 2014). The exogenous pre-storage application of SNP

had positive impacts on alleviating chilling injury and the incidence of decay on mango fruit, furthermore SNP impeded the production of ethylene and reduced respiration rate, pectin methyl esterase and polygalacturonase activities and maintained both lower weight loss and higher fruit firmness (Barman *et al.,* 2014).

Oxalic acid (OA) is a natural organic acid present in plants, (Libert and Franceschi, 1987). Recently, the use of oxalic acid on fruits and vegetables has received great interest. The multiple effect of oxalic acid is shown in prolonging the storage life and impeding the ripening occurrence, furthermore, controlling postharvest diseases and alleviating the impact of chilling injury in the many commodities (Shimada *et al.,* 1997). There are many studies investigated the effects of oxalic acid on many fruits such as banana (Yoruk, 2002), mango (Zheng *et al.,* 2005; Zheng *et al.,* 2007) and litchi (Zheng and Tian, 2006).

Salicylic acid (SA) is a plant hormone that play a key role in extending the postharvest life of fruits via inhibiting the biosynthesis and action of the ethylene thus maintaining fruits quality (Zhang *et al.,* 2003; Asghari and Aghdam, 2010). The effect of exogenous application of SA on postharvest decay in horticultural crops was reported in many studies and it can also enhance the efficacy of other coating material such as chitosan which was reported that the application of SA before chitosan coating reduced fruit decay in table grape (Asghari *et al.,* 2009). However, SA can also effectively decreases ethylene production and prolonging storage life of many fruits such as banana (Srivastava and Dwivedi, 2000) and Kiwifruit during storage life (Zhang *et al.,* 2003).

Therefore, our investigation was conducted to study the impact of SNP, SA and OA on impeding fruit ripening and senescence and maintain the quality aspects of mango (cultivar Keitt) under cold storage conditions.

Material and Methods

Sampling

The experiment was conducted during 2018 and 2019 seasons in the laboratory of refrigeration Agriculture Development Systems (ADS) project in the Faculty of Agriculture, Cairo University. Fresh fruits of mango *Mangifera indica* L. (cultivar Keitt) were collected randomly in mid-September at commercial maturity stage (full mature) from private orchard where is located in 30°38'24"N latitude and 30°30'40"E longitude, in El-Beheira governorate, Egypt. The selection of the fresh mangoes was based on the similarity in skin color, size and free of decay and damage (Kader, 2008; Esguerra *et al.,* 2018).

Methods

The samples were carefully washed by tap water to remove debris on the fruit surface then the samples were left to dry, after that samples were divided into four groups and dipped for 1 minute into four different treatments; a) 100µM Sodium nitroprusside (SNP), b) 5mM Salicylic acid (SA), c) 10mM Oxalic acid (OA), d) untreated sample as control (Ctrl), then the samples were packed in plastic boxes and stored at 13°C and 90% relative humidity (RH). The data of the experiment were collected after 0, 14, 28 and 42 days of storage from three replicate of each treatment for following analyses.

Fruit quality assessments

Decay Percentage: Fruits that showed any decay symptoms during storage were counted and eliminated from the experiment. Decay percentage was calculated using the following formula:

$$\text{Decay \%} = \frac{E\lim inated\ fruits}{Total\ number\ of\ the\ fruit} \times 100$$

Fruit weight loss percentage: by gravimetric analysis with an electronic balance and was calculated according to the following formula;

Weight loss % =

$$\frac{Initial\ weight\ (g) - weight\ of\ the\ fruit\ at\ each\ date(g)}{Initial\ weight\ at\ the\ beginning\ of\ cold\ storage(g)} \times 100$$

Fruit Firmness: was determined by hand firmness tester (8 mm diameter probe) on pared fruit surface and the results were expressed in pound-force (lbf) (Mitcham *et al.,* 1996).

Respiration rate: was measured by analzying carbon dioxide (Khedr, 2016). Three fruits of each treatment were incubated for 24h in 1-liter airtight glass jar at 13°C and the incubated gases of the headspace were removed from the septum with a syringe and injected into food pack gas analyzer (Model 1450-Servomex 1400) to measure CO_2 production. The respiration rate was calculated and expressed as concentration of ml CO_2 Kg^{-1}.hr using the following equation (Kader and Saltveit, 2003):

Respiration rate of CO_2 (ml CO_2 Kg^{-1}.hr) =

$$\frac{CO_2 concentration(\%) \times headspace\ air\ volume(L) \times 1000}{Fruit\ weight\ (kg) \times incubation\ period\ (hr) \times 1000} \times 100$$

Total soluble solids °Brix (TSS): were measured by using a digital refractometer (Digital Hand-held Model PAL-1, Atago, Japan).

Total titratable acidity: was measured by titrating 5 ml of the fruit juice against 0.1N of NaOH using Phenol phathalin indicator then acid per cent calculated from the following equation (A.O.A.C, 1984):

$$\% \text{ acid} = \frac{(mls\ NaOH\ used \times 0.1N\ NaOH \times 0.064 \times 100)}{sample\ weight\ (g)}$$

Flesh color analysis: The flesh color was measered twice on the equatorial section of the fruits with Minolta CR-300 series, chroma meter (Minolta, Osaka, Japan), using the CIE L^* a^* b^* color space. L^* value measures color lightness (higher values are lighter), a^* indicates color direction with + a^* is the red direction and - a^* is the green direction and b^* indicates color direction with + b^* is the yellow direction and - b^* is the blue direction (Mitcham *et al.,* 1996).

Visual comparison of storage effects: The visual appearnce of the treatments was Captchered using digital camera (CanonModel IXUS 185) at harvest 0 day and 42 days of cold storage at 13°C and 90% RH.

Statistical analysis

All experimental data were subjected to ANOVA using CoStat software (Version 6400, CoHort Software Monterey, CA, USA). Sources of variation considered were treatment and preservation time. Mean separations were performed using the LSD test at probability level ($P< 0.05$).

Results

Decay Percentage

Results in table 1 illustrate the impact of SNP, SA and OA treatments on decay percentage compared to untreated fruits in two seasons. The percentage of decay increased continuously with storage days in all treatments in both seasons, however the difference between the treated and untreated fruit samples were significant in both seasons, in which the percentage of decay in untreated fruits were recorded significantly highest score at the end of the experiment reached to 24.24% in 2018 and 33.33% in 2019. On the other side, the results shown no significant differences between different treatments in both seasons, in which the percentage of decay at the end of the experiment did not exceeded 15.15% in the first season and 22.22% in the following season particularly with fruits treated with SA. While the fruits that treated SNP recorded lowest values in both seasons.

The data are the means of three replicate ± standard deviations (n = 3) for each season and represent the interaction between the treatments and time of the storage. While the means in right side of the table represent the difference between the treatments and means in the lower part of the table represent the difference between storage times. Values followed by different letters are significantly different at ($P<0.05$).

The percentage of weight loss

According to the data that is presented in table 2, the results were shown gradually increasing in weight loss of stored fruit samples in all postharvest treatments during storage period. Untreated fruit mangos were recorded significantly the highest value after 42 days of storage with 25.37% and 18.56% during 2018 and 2019 seasons respectively comparing to other treatments of treated fruits. While SNP treatment recorded to the lowest values significantly at the end of the experiment with 15.14% and 12.52% in both seasons respectively. In addition, Both SA, OA treatments significantly varied between them in the first season, however the results had not shown any differences in second season regarding the mentioned treatments.

The data are the means of three replicate ± standard deviations (n = 3) for each season and represent the interaction between the treatments and time of the storage. While the means in right side of the table represent the difference between the treatments and means in the lower

Table 1: The effect of SNP, SA and OA on decay (%) of mango fruits during storage at 13°C in two seasons.

Treatment (A)	Days of the storage at 13°C (B)				
	0	14	28	42	Mean
	Season 2018				
SNP	0 ±0 d	0 ±0 d	6.06 ± 10.49 cd	12.12 ± 10.49 bc	4.54 b
SA	0 ±0 d	3.03 ±10.49 d	6.06 ±10.49 cd	15.15 ±10.49 b	6.06 b
OA	0 ±0 d	3.03±10.49 d	6.06±10.49 cd	12.12 ±10.49 bc	5.30 b
Ctrl	0 ±0 d	6.06±10.49 cd	12.12 ±10.49 bc	24.24 ±10.49 a	10.60 a
Mean	0 c	3.03 c	7.57 b	15.90 a	
Treatment (A)	**Days of the storage at 13°C (B)**				
	0	**14**	**28**	**42**	**Mean**
	Season 2019				
SNP	0±0 f	0±0 f	5.55 ± 9.62 ef	16.66 ± 16.6 bcd	5.55 b
SA	0±0 f	2.77 ± 9.62 ef	8.33 ± 0.00 def	22.22 ± 9.62 b	8.33 b
OA	0±0 f	2.77 ± 9.62 ef	11.11 ± 25.45 cde	19.44 ± 25.45 bc	8.33 b
Ctrl	0±0 f	8.33 ± 0.00 def	19.44 ± 9.62 bc	33.33 ± 16.66 a	15.27 a
Mean	0 c	3.47 c	11.11 b	22.91a	

Table 2: The effect of SNP, SA, and OA on weight loss (%) of mango fruits during storage at 13°C in two seasons.

Treatment (A)	Days of the storage at 13°C (B)				
	0	14	28	42	Mean
	Season 2018				
SNP	0±0 e	5.13±0.55 de	8.93±0.41 d	15.14±1.64 bc	7.30 d
SA	0±0 e	5.58±0.58 de	10.61±1.23 cd	18.15±0.63 b	8.58 c
OA	0±0 e	6.47±1.67 d	11.06±1.06 cd	18.61±1.17 b	9.04 b
Ctrl	0±0 e	8.05±1.53 d	15.31±1.42 bc	25.37±1.53 a	12.18 a
Mean	0 d	6.31 c	11.48 b	19.32 a	
Treatment (A)	**Days of the storage at 13°C (B)**				
	0	**14**	**28**	**42**	**Mean**
	Season 2019				
SNP	0±0 g	3.01 ± 0.39 fg	8.22 ± 0.64 de	12.52 ± 0.74 b	5.94 c
SA	0±0 g	4.22 ± 0.76 f	9.47 ± 0.09 cd	15.25 ± 1.13 ab	7.23 b
OA	0±0 g	3.93 ± 0.84 f	9.39 ± 0.95 cd	14.72 ± 0.33 b	7.01 b
Ctrl	0±0 g	5.51 ± 0.43 ef	12.22 ± 0.15 bc	18.56 ± 1.38 a	9.07 a
Mean	0 d	4.17 c	9.83 b	15.26 a	

part of the table represent the difference between storage times. Values followed by different letters are significantly different at ($P<0.05$).

Fruit Firmness

Table 3 reveals that the firmness of the Keitt mango fruit decreases gradually during storage period in all treatments reaching the lowest value at the end of storage. Fruits treated with SNP maintained significantly higher firmness comparing to fruits treated with SA, OA and untreated fruits in both seasons. Moreover the results of treated fruits with SA and OA shown no significant differences between them in the first season while fruits treated with SA recorded significantly lower values than fruits treated with OA in the second season. Furthermore, untreated fruits were achieved significantly the lowest value than treated fruits in both seasons.

The data are the means of three replicate ± standard deviations (n = 3) for each season and represent the interaction between the treatments and time of the storage. While the means in right side of the table represent the difference between the treatments and means in the lower part of the table represent the difference between storage times. Values followed by different letters are significantly different at ($P<0.05$).

Table 3: The effect of SNP, SA, and OA on firmness (lbf) of mango fruits during storage at 13°C in two seasons.

Treatment (A)	Days of the storage at 13°C (B)				
	0	14	28	42	Mean
	Season 2018				
SNP	17.75 ± 0.10 a	17.07 ± 1.29 a	11.53 ± 1.5 cd	6.7 ± 2.5 e	13.27 a
SA	17.75 ± 0.10 a	14.70 ± 1.0 abc	7.0 ± 3.8e	4.76 ± 0.98 ef	11.05 b
OA	17.75 ± 0.10 a	16.43 ± 2.33 ab	7.36 ± 1.62 de	4.70 ± 1.90 ef	11.56 b
Ctrl	17.75 ± 0.10 a	12.33 ± 2.72 bc	6.90 ± 2.62 e	0.70 ± 0.69 f	9.42 c
Mean	17.76 a	15.13 b	8.2 c	4.22 d	
Treatment (A)	**Days of the storage at 13°C (B)**				
	0	**14**	**28**	**42**	**Mean**
	Season 2019				
SNP	17.76 ± 0.14 a	16.33 ± 1.0 ab	12.53 ± 1.79 abc	7.0 ± 2.45 def	13.408 a
SA	17.76 ± 0.14 a	14.23 ± 2.5 abc	5.63 ± 1.22 efg	4.43 ± 1.33 fg	10.516c
OA	17.76 ± 0.14 a	15.20 ± 1.77 abc	9.96 ± 1.17 cde	5.16 ± 1.85 efg	12.025 b
Ctrl	17.76 ± 0.14 a	11.26 ± 1.30 bcd	4.36 ± 0.80 fg	0.83 ± 0.41 g	8.558 d
Mean	17.766 a	14.258 b	8.125 c	4.358 d	

Respiration rate of Keitt mango fruits

Based on the results in table 4, it can be seen that there was a noticeable decrease in values of rate of respiration at end cold storage period (42 days) compared to the initial respiration rate values at harvest day in all postharvest treatments during the two seasons of investigation. Data shows significant differences between treated and untreated fruits in term of respiration rate, in which control samples was recorded significantly higher than treated samples in both seasons. Furthermore, SNP treated-fruits were achieved significantly the lowest value among all treatments. On the other side, both SA and OA were found no significant differences at the end of the experiment.

The data are the means of three replicate ± standard deviations (n = 3) for each season and represent the interaction between the treatments and time of the storage. While the means in right side of the table represent the difference between the treatments and means in the lower part of the table represent the difference between storage times. Values followed by different letters are significantly different at ($P<0.05$).

Total Soluble Solid (TSS)

Table 5 presents the effect of different type of treatments on the total soluble solid (TSS) of Keitt mango fruits during storage time comparing to the control. The results illustrated that the tested treatments have important role in delaying the increase of TSS during storage times. Data had shown significant differences between treated and untreated fruits, in which the control

Table 4: The effect of SNP, SA, and OA on the respiration rate (ml CO_2 Kg^{-1}.hr) of mango fruits during storage at 13°C in two seasons.

Treatm -ent (A)	Days of the storage at 13°C (B)				
	0	14	28	42	Mean
	Season 2018				
SNP	4.56 ± 0.50 f	4.76 ± 0.57 f	8.97 ±1.48 e	10.91 ± 0.68 bcd	7.30 c
SA	4.56 ± 0.50 f	4.93 ± 0.26 f	9.90 ± 0.37 de	11.95 ± 1.23 bc	7.83 b
OA	4.56 ± 0.50 f	5.05 ± 0.29 f	10.02 ± 0.91 de	12.36 ± 2.06 ab	8.0 b
Ctrl	4.56 ± 0.50 f	5.42 ± 0.11 f	10.36 ± 1.20 cde	13.69 ± 0.97 a	8.51 a
Mean	4.56 d	5.04 c	9.81 b	12.22 a	
Treatm -ent (A)	Days of the storage at 13°C (B)				
	0	14	28	42	Mean
	Season 2019				
SNP	2.67 ± 0.59 c	12.37± 1.47 abc	8.27 ±0.41abc	5.01 ± 1.16 bc	7.08 c
SA	2.67 ± 0.59 c	6.11 ± 0.78 abc	9.55 ± 0.57 abc	13.75 ± 0.37 ab	8.02 b
OA	2.67 ± 0.59 c	5.73 ± 0.99 abc	9.01 ± 0.94 abc	13.55 ± 0.75 ab	7.74 b
Ctrl	2.67 ± 0.59 c	6.83 ± 0.68 abc	10.73 ± 0.99 abc	15.29 ±1.16 a	8.88 a
Mean	2.67 d	7.76 c	9.39 b	11.90 a	

Table 5: The effect of SNP, SA, and OA on TSS (°Brix) of mango fruits during storage at 13°C in two seasons.

Treatm -ent (A)	Days of the storage at 13°C (B)				
	0	14	28	42	Mean
	Season 2018				
SNP	8.36 ± 1.10 g	11.50 ± 1.80 f	14.4 ± 2.50 de	17.06 ± 2.54 bc	12.83 b
SA	8.36 ± 1.10 g	12.36 ± 1.61 ef	15.10 ± 1.63 cd	18.19 ± 0.121 b	13.50 b
OA	8.36 ± 1.10 g	11.96 ± 3.36 f	15.4 ± 1.44 cd	18.23 ± 2.73 b	13.49 b
Ctrl	8.36 ± 1.10 g	13.60 ± 1.31 def	17.20 ± 2.45 bc	21.13 ± 4.27 a	15.07 a
Mean	8.36 d	12.36 c	15.52 b	18.65 a	
Treatm -ent (A)	Days of the storage at 13°C (B)				
	0	14	28	42	Mean
	Season 2019				
SNP	10.23 ± 1.27 g	10.9 ± 0.34 fg	13.2 ± 0.52 defg	16.4 ± 0.72 bcd	12.68 c
SA	10.23 ± 1.27 g	11.96 ± 3.00 efg	14.43 ± 0.94 cde	18.46 ± 0.46 b	13.77 b
OA	10.23 ± 1.27 g	11.23 ± 0.50 efg	13.63 ± 0.94 def	17.36 ± 0.64 bc	13.11 c
Ctrl	10.23 ± 1.27 g	13.73 ± 0.64 def	17.23 ± 0.61 bc	22.06 ± 0.90 a	15.81 a
Mean	10.23 d	11.95 c	14.625 b	18.57 a	

samples recorded the highest TSS during storage. While treated samples were recorded the lowest. However the results did not show significant differences regarding the type of material during storage in the first season, while both SNP and OA were recorded the lowest TSS comparing to SA during storage period. Evaluating the interaction effect between storage periods and the tested treatments, data show that the interactions of six weeks of cold storage, registered the highest values of fruit total soluble solids percentage, especially untreated fruits (control) in both seasons.

The data are the means of three replicate ± standard deviations (n = 3) for each season and represent the interaction between the treatments and time of the storage. While the means in right side of the table represent the difference between the treatments and means in the lower part of the table represent the difference between storage times. Values followed by different letters are significantly different at ($P<0.05$).

Titratable acidity (TA)

Different types of tested materials retarded the reduction of acidity (TA) thus delaying fruit ripening in both seasons table 6. Indeed, SNP had significantly the highest value of TA comparing to other treatments and comparing to untreated fruits (Ctrl) in two seasons, while SA and OA treatments had shown no significant difference during storage time. In contrast, untreated samples failed to maintain the acidity in the fruits during storage and recorded significantly the lowest value.

The data are the means of three replicate ± standard deviations (n = 3) for each season and represent the interaction between the treatments and time of the storage. While the means in right side of the table represent the difference between the treatments and means in the lower part of the table represent the difference between storage times. Values followed by different letters are significantly different at ($P<0.05$).

Flesh color measurements

Based on data in table 7, results illustrated the effect of different types of postharvest treatments on the flesh lightness (L*) comparing to untreated samples during cold storage in both two seasons. SNP treatment was recorded significantly the highest value among all treatments, while both SA and OA treatments were statistically similar without significant differences. Moreover, the control treatment were shown more ripen and significantly lowest value comparing the other treatments.

On the other side, data in table 8 presents the effect of the treatments on the flesh brightness (b*) during cold storage in both two seasons. In agreement with results of table 7, SNP treatment was significantly higher brightness among all treatments, while the control

Table 6: The effect of SNP, SA, and OA on acidity % of mango fruits during storage at 13°C in two seasons.

Treatm -ent (A)	Days of the storage at 13°C (B)				
	0	14	28	42	Mean
	Season 2018				
SNP	2.78 ± 0.87 a	1.94 ± 0.55 b	1.67 ±0.35 bc	0.79 ± 0.32 defg	1.80 a
SA	2.78 ± 0.87 a	1.64 ± 0.34 bc	1.16 ± 0.26 cde	0.64 ± 0.42 efg	1.55 b
OA	2.78 ± 0.87 a	1.31 ± 0.29 cd	0.93 ± 0.19 def	0.52 ± 0.23 fg	1.39 bc
Ctrl	2.78 ± 0.87 a	1.19 ± 0.15 cde	0.77 ± 0.10 defg	0.31 ± 0.17 g	1.26 c
Mean	2.78 a	1.52 b	1.13 c	0.57 d	
Treatm -ent (A)	**Days of the storage at 13°C (B)**				
	0	**14**	**28**	**42**	**Mean**
	Season 2019				
SNP	3.04 ± 0.06 a	2.21 ± 0.39 b	1.77 ± 0.089 bc	0.62 ± 0.082 de	1.91 a
SA	3.04 ± 0.06 a	1.97 ± 0.14 b	1.05 ± 0.05 d	0.21 ± 0.10 e	1.57 b
OA	3.04 ± 0.06 a	2.04 ± 0.29 b	1.15 ± 0.12 cd	0.33 ± 0.08 e	1.64 b
Ctrl	3.04 ± 0.06 a	1.72 ± 0.58 bc	0.58 ± 0.10 de	0.08 ± 0.07 e	1.36 c
Mean	3.04 a	1.99 b	1.14 c	0.31 d	

Table 7: The effect of SNP, SA, and OA on L* value of mango fruits during storage at 13°C in two seasons.

Treatm -ent (A)	Days of the storage at 13°C (B)				
	0	14	28	42	Mean
	Season 2018				
SNP	72.64±0.73 a	70.57±1.25 ab	65.84 ±0.39 d	60.9±0.43 f	67.49 a
SA	72.64±0.73 a	69.39±1.08 bc	64.64± 0.68 de	59.94±0.66 f	66.65 b
OA	72.64±0.73 a	69.76±0.61 bc	64.41±1.01de	59.03±0.65 fg	66.46 b
Ctrl	72.64±0.73 a	68.24±0.70 c	63.27±1.18 e	57.11±0.50 g	65.31 c
Mean	72.64 a	69.49 b	64.54 c	69.24 d	
Treatm -ent (A)	**Days of the storage at 13°C (B)**				
	0	**14**	**28**	**42**	**Mean**
	Season 2019				
SNP	70.44±0.84 a	66.88±1.31 ab	64.02±0.35 bcd	62.17±0.34 cdef	65.88 a
SA	70.44±0.84 a	65.41±0.55 bc	62.40±0.91 cde	60.42±1.01 def	64.67 b
OA	70.44±0.84 a	64.97±0.75 bc	62.16±0.43 cdef	60.13±1.47 ef	64.42 b
Ctrl	70.44±0.84 a	63.27±1.18 b-e	58.61±0.79 fg	56.32±1.00 g	62.16 c
Mean	70.44 a	65.13 b	61.8 c	59.76 d	

treatment had recorded the lowest values. Furthermore, the results had shown no significant differences between treatments of SA and OA in both seasons.

In contrast, table 9 shows the changes of the appearance of the fruit flesh during the storage time. The results had shown significant differences between untreated mango fruits and treated fruits, in which the control samples were recorded significantly the highest values, while SNP treatment was recorded the lowest value among other treatments. In addition, both SA and OA treatments recorded no significant differences between them.

The data are the means of three replicate ± standard deviations (n = 3) for each season and represent the interaction between the treatments and time of the storage. While the means in right side of the table represent the difference between the treatments and means in the lower part of the table represent the difference between storage times. Values followed by different letters are significantly different at ($P<0.05$).

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Visual comparison of storage effects

Fig. 1 shows of mango fruits at the begeninig and the end of storage period, It can be seen that cotrol treatment (Ctrl) has showed decay and chilling injury saymptoms and there is clear changes in the color of the fruit comparing to the treated samples which they were less affected with long storage time. Therefore, the mango fruits treated with SNP, SA and OA looked better, while fruits treated with SNP were the best of all.

Discussion

As it was mentioned, mangoes is a climacteric fruit which means it has a peak of respiration and it able to continue ripening even it was detached (Mukherjee and Litz, 2009). Thus, our experiment was conducted to control rapid internal changes in the fruits during storage and impeding ripening and senescence of mango fruits, in addition maintain optimum quality of the fruits during

Table 8: The effect of SNP, SA, and OA on b* value of mango fruits during storage at 13°C in two seasons.

Treatm -ent (A)	Days of the storage at 13°C (B)				
	0	14	28	42	Mean
	Season 2018				
SNP	60.48±0.96 a	58.16±0.76 b	52.60±0.76 d	47.35±0.51 f	54.64 a
SA	60.48±0.96 a	57.10±0.42 bc	51.58±0.79 d	45.39±1.04 fg	53.76 b
OA	60.48±0.96 a	57.01±0.36 bc	51.57±0.69 d	45.98±0.28 fg	53.64 b
Ctrl	60.48±0.96 a	55.52±0.90 c	49.45±0.76 e	44.30±0.70 g	52.43 c
Mean	60.48 a	56.94 b	51.30 c	45.75 d	
Treatm -ent (A)	Days of the storage at 13°C (B)				
	0	14	28	42	Mean
	Season 2019				
SNP	58.20±00.54 a	56.10±0.54 ab	50.68±0.69 de	44.28±0.61 gh	52.32 a
SA	58.20±00.54 a	54.26±0.78 bc	48.88±0.39 ef	42.58±0.68 h	50.98 b
OA	58.20±00.54 a	54.17±0.35 bc	48.02±0.58 ef	42.44±0.83h	50.41 b
Ctrl	58.20±00.54 a	52.39±0.93 cd	46.44±1.00 fg	39.43±0.72 i	49.11 c
Mean	58.20 a	54.23 b	48.50 c	42.18 d	

Table 9: The effect of SNP, SA, and OA on the appearance of mango fruit flesh (a* value) during storage at 13°C in two seasons.

Treatm -ent (A)	Days of the storage at 13°C (B)				
	0	14	28	42	Mean
	Season 2018				
SNP	10.49±0.71 f	12.33±0.66 e	12.85±0.35 de	13.37±0.48 cde	12.26 c
SA	10.49±0.71 f	13.37±0.52 cde	13.42±0.76 b-e	13.80±0.46 a-d	12.75 b
OA	10.49±0.71 f	13.59±0.76 a-e	13.61±0.09 a-e	13.95±0.15 a-d	12.91 b
Ctrl	10.49±0.71 f	14.62±1.17 abc	14.73±0.28 ab	14.91±0.38 a	13.69 a
Mean	10.49 a	13.48 b	13.65 b	14.01 a	
Treatm -ent (A)	Days of the storage at 13°C (B)				
	0	14	28	42	Mean
	Season 2019				
SNP	9.39±0.88 e	10.45±0.43 de	11.62±0.54 cd	12.04±0.67cd	10.85 c
SA	9.39±0.88 e	11.27±0.59 cd	12.03±0.57 cd	12.69±0.55 bc	11.35 b
OA	9.39±0.88 e	11.30±0.57 cd	12.30±0.84 bcd	12.83±0.50 bc	11.46 b
Ctrl	9.39±0.88 e	12.97±0.13 bc	14.14±0.28 ab	14.95±0.15 a	12.86 a
Mean	9.39 d	11.49 c	12.52 b	13.13 a	

storage. Sodium nitroprusside is a good alternative to prolong the storage life of the fresh mango fruits and other fresh horticultural commodities (Zaharah and Singh, 2011). It was reported that nitric oxide (NO) is released from SNP by using different reducing agents in plants. Postharvest exogenous application of NO can impede the biosynthesis pathway of ethylene and significantly impact the fruits ripening. NO is known as a bioactive molecule and can acts through suppressing the enzymes involved in ethylene biosynthesis production (Rudell and Mattheis, 2006; Wilson *et al.,* 2008). It was reported that low concentration of SNP has been inhibited ethylene production in apple, banana, mango and peach (Zhu *et al.,* 2006; Wang *et al.,* 2008; Cheng *et al.,* 2009; Zaharah and Singh, 2011). Since ethylene is well-known as a ripening hormone in the plant particularly climacteric fruits like mango, therefore our investigation in agreement with other studies proved that SNP could significantly control fruit ripening *via* reducing the respiration rate and weight loss and delaying fruit softening by reducing the activity of softening enzymes, furthermore maintain the TSS and TA levels and reducing fruit deterioration during cold storage (Sozzi *et al.,* 2003; Zhu *et al.,* 2010). Regarding Salicylic acid SA, several studies indicated that SA has direct antifungal effect, the exogenous postharvest

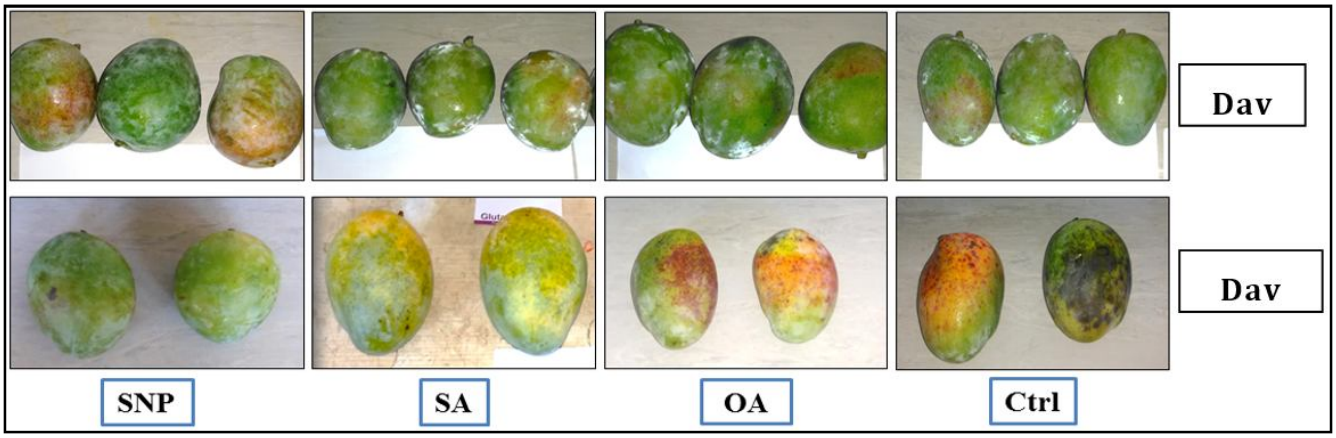

Fig. 1: Photos of SNP-dipped by Sodium nitroprusside, SA-dipped by Salcycilic acid, OA-dipped by Oxalic acid and Ctrl-Control, respectivily. Upper part-day 1, Lower part-day 42.

application of SA significantly reduced postharvest decay during of pear (Asghari *et al.,* 2007) and mango fruit (Zeng *et al.,* 2006). Exogenous application of SA effectively decreases ethylene production in several horticultural crops, which leads to extended shelf life. Increased retention of firmness as the result of SA treatment has also been reported in several horticultural crops (Srivastava and Dwivedi, 2000). Our study proved the ability of SA in reducing TSS and maintains fruit firmness and acidity. Since the total soluble solids (TSS) content increases during fruit ripening due to the action of sucrose-phosphate synthase, an ethylene activated enzyme (Asghari and Aghdam, 2010). SA found to be able to inhibit the rise in TSS, by reducing enzyme activities, thereby effectively preventing the increase in TSS content and maintain acidity thus extend storage life during cold storage (Srivastava and Dwivedi, 2000; Valero *et al.,* 2011). In additional, Oxalic acid (OA) has diverse effects of ripening and senescence, control postharvest decay and alleviating chilling injury in the fruits and mainly in mango including all quality aspects such as TSS, TA, respiration rate, weight loss, color changes and firmness as it was reported in many fruit species (Zheng *et al.,* 2007; Wijewardane, 2014; Razzaq *et al.,* 2015).

Conclusion

This experiment falls within the framework of the improving postharvest technology and the preservation of fresh fruits with optimum fruit quality. Since mango fruits have been given great interest by the consumers. Looking for the most proper techniques to prolong the storage life and maintain fruit quality attributes to be appreciated by the consumers, our investigation revealed that SNP was the best alternative among other materials (SA and OA) that can be used with low concentration and long effect on storage life and optimum fruit quality attributes under cold storage conditions. Moreover our postharvest treatments are considered as safe and simple materials which could be employed for long storage and for long distance shipping for export of Keitt mango fruits.

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