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Reducing Fruit Quality Losses in Peach Fruits and Increasing Profitability during postharvest Storage Using Salicylic Acid and Aspirin

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PEACHES is one of the favorite fruit, but these fruits are sensitive through postharvest handling and it has a great loss in the crop and the fruit quality through its approach to the consumers. In the study, Salicylic acid (SA) and aspirin (AS) drugs have been used to reduce fruit losses and preserve quality of the fruit. In the current study, peach fruit cv. Tropical Snow was treated with: water (control treatment), two concentrations of aspirin as 0.5 and 1 mM and two concentrations of salicylic acid as 0.5 and 1 mM under two storage conditions (23±1 °C, 85 % ± 5 % RH and 1 °C, 85 % ± 5 % %RH) during two seasons (2020 and 2021). The results indicated that the fruit under room temperature conditions at all treatments could not be stored for more than 3 weeks while fruit under cold storage continued to 9 weeks with acceptable fruit quality. Under the room temperature, treatments did not significantly affect the firmness while SA and AS with high concentrations delayed the reduction in acidity and vitamin C and the increase of SSC and SSC/ Acid ratio. Under cold storage, SA treatments followed by AS treatments significantly preserved fruit quality via reducing weight loss, saving firmness , delaying the decline of acidity and vitamin C and the increase of SSC, SSC/ Acid ratio and antioxidant enzymes activity especially in the last 3 weeks. AS or SA resulted in improving the income by 156.5 US$/ton on the room temperature storage and by 761.5 US$/ton on cold storage conditions.

Keywords: Peaches, Salicylic acid, Aspirin, Postharvest, Postharvest cost, Profitability analysis.

Introduction

Egypt produced 246742 tons of peaches in 2018 from the area of 20341 hectares with a gross production value of 69.406998 million US$ (FAOSTAT, 2020). In developed countries, losses of fresh fruit are estimated to range from 2 to 23 percent. Therefore, the decrease of post-harvest losses can increase food availability to people around the world and save natural resources. It is well recognized that the important points from the side of wholesale and retail marketers are fruit appearance, firmness, and shelf life (Kader and Rolle, 2004). Generally, when the fruit are picked from the parent plant, they begin to decline. In fresh fruit, postharvest changes cannot be stopped, but can be slowed down by postharvest management within certain limits to enhance the shelf life of fruit. Some treatments play an important role in extending the marketable and storage life of horticultural perishables (El-Ramady et al., 2015). Reducing metabolic rates and water loss can lead to increases in the quality of fruit and minimize the decay (Watson et al., 2015). Therefore, to achieve the optimum goals of postharvest handling is keeping the product cool to slow down undesirable chemical changes and reduce weight loss to delay the decay (Sivakumar et al., 2011, El-Ramady et al., 2015, Kitinoja and Kader, 2015).

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Production and marketing of high-quality stone fruit require care to all aspects through its way from orchard until arriving in consumers. The use of cooling is consider an essential treatment through postharvest and marketing of fruit (Crisosto et al., 1995). Fruit, as living materials, have respiring tissues. Therefore, it needs to be stored at cold temperature (tempe rate and cold zone fruit need to be stored at 0 °C). Any method of increasing the relative humidity of the storage environment or reducing transpiration in addition to low temperature for the commodity and its postharvest environment will slow the rate of water loss (Kitinoja and Kader, 2015). With every 10 °C increase in temperature, the rates of decay of perishables increase two to three times (Kader and Rolle, 2004). While Crisosto et al. (1995) exhibited that the optimum temperature at postharvest storage and marketing for stone fruit is 0 °C.

Çelik et al. (2006), Kitinoja and Kader (2015) and Sun et al. (2018) concluded that the optimum postharvest storage temperature for peach and nectarines fruit is 0 to 2 °C with a relative humidity of 90–95 %.

Fruit weight loss and shriveling that occur after harvesting are consider the most important factors affecting economic loss. Therefore, Fruit must be protected to ensure the best postharvest life (Layne and Bassi, 2008). Fruit water loss could be controlled by postharvest treatments including surface coatings or by controlling the relative humidity around the fruit. In general, the stone fruit have a relatively short postharvest life (Kader and Rolle, 2004).

Peaches less than 53 N firmness at harvest time will continue to ripen after harvest in good quality compared to those over 53 N firmness. While, peaches fruit in which firmness was 0.7 N/mm^2 at harvest, their firmness reduced dramatically to less than 0.2 N/mm^2 by day 7 at 25 °C (Nakano et al., 2020). However, peach fruit with firmness below 27 N are sensitive and able to be damaged during postharvest and handling. Therefore, it was suggested to transferring peaches to markets before the 'ready to buy' stage to reduce physical damage (Crisosto, 2002). Therefore, for peaches marketing, it is recommended to store its fruit at a value of firmness is below 26.5 – 35.3 N to give a good time to be delivered for consumers to eat it at the 'ready to eat stage' (Layne and Bassi, 2008).

Shalan (2020) reported that the SSC of peach increased during the storage period. During maturation, the peach fruit content of total acids is decreased.

With a deep vision, many challenges are facing the freshness perishables horticultural commodity from harvesting to the ultimate utilization so there is an urgent need for developing feasible technologies and treatments to extend the shelf life of fruit (Workineh and Lemma, 2020).

The utilization of eco-environmentally friendly technologies such as salicylic acid (SA) and aspirin (a synthetic analog of SA), can delay fruit ripening, maintain fruit quality and reduce biotic and abiotic stress of fruit by induction of plant defense against chilling injury under cold storage conditions for stored fruit and enhance antioxidant enzymes activity in fruit during ripening (Siddiqui, 2015 and Razavi et al., 2018).

Salicylic acid is one of the safe natural chemicals used for postharvest quality maintenance of horticultural and ornamental produces, regulates plant growth and development, and affects postharvest physiological and metabolism of perishable crops (Davies, 2010 and Arafat, 2019).

Aspirin (AS), a trading name for acetylsalicylic acid, undergoes spontaneous hydrolysis to SA, in an aqueous solution. Exogenously applied it is rapidly convert to SA where both compounds have similar effects in plants. In addition, the low price of AS makes it an economical way to produce plants which that have increased immunity and lifetime (Hayat et al., 2007 and Siddiqui, 2015).

According to Alijo et al. (2015), SA treatment maintains the peach quality during the storage period. Junmatong et al. (2015) and Boshadi et al. (2018) illustrated that fruit (pomegranate or mangos) in which treated with SA and stored at 5 °C, showed a significant increase in total antioxidant enzymes (superoxide dismutase (SOD), catalase (CAT), and ascorbate peroxidase (APX)) and decreased decay of fruit compared to control. However, the studies of SA and AS on postharvest peach are few and their effects remain to be explored.

As SA is a safe natural compound and AS is cheap, we hypothesize treatment of peach with SA or AS may become a promising optimum postharvest management to extend the marketable and storage life of peach. The aim of the current research was to select the best treatment(s) of SA, AS and storage conditions that could extend the postharvest storage of Tropical snow peach fruit.

Materials and Methods

Fruit materials

The experiment was carried out at the Department of Horticulture, Suez Canal University, Ismailia, Egypt, during two seasons (2020 and 2021). Ten-year-old 'Tropical snow' peach trees grafted on Nemaguard peach rootstock at commercial Orchard, in Ismailia governorate - Egypt, were selected for the experiments. The trees were conducted with regular orchard management. Experimental trees were followed to determine the maturity stage of fruit. Fruit of uniform size and shape, free from visual symptoms of disease or blemishes, were harvested at the commercial maturity stage (on 21 May 2020 and 2021 seasons) from ten trees. The fruits were sorted and the identical fruits were selected and transferred immediately (at ambient temperature 24 °C) to the postharvest laboratory.

Treatments

The peach fruits were cooled for an hour at 0 °C to remove the heat of the orchard (38 - 42 °C), washed with tap water, left to dry at room temperature (22 - 24 °C) for two hours, then exposed to the following Aspirin ($C_9H_8O_4$, MW 180.159) or Salicylic acid ($C_7H_6O_3$, MW 138.12) treatments as follows:

Control: Fruit stored at room temperature after dipping in tap water for 5 min.

AS0.5: Fruit dipped in Aspirin with a concentration of 0.5 mM for 5 min.

AS1: Fruit dipped in Aspirin with a concentration of 1 mM for 5 min.

SA0.5: Fruit dipped in salicylic acid with a concentration of 0.5 mM for 5 min.

SA1: Fruit dipped in salicylic acid with a concentration of 1 mM for 5 min.

Every treatment was divided into 2 groups (one for storage under room conditions at 23 °C, 85 % ± 5 % RH (RT) and the other is cold storage conditions at 1 °C, 85 % ± 5 %RH (CS)) by 3 replicates in every treatment (at every group) with 10 fruit at every replicate.

Measurements

Weight loss (%): The weight of every fruit was measured weekly using digital balance then the weight loss percentage was calculated.

Fruit firmness (N): It was measured with an 8 mm plunger of penetrometer (Magness Taylor, Japan) on two opposite sides of the equatorial region of the fruit.

Titratable acidity percentage (%): Acidity was determined by titrating 5 ml of fruit juice with 0.1 N NaOH to pH 8 and calculating the result as malic acid equivalent.

Soluble solids content SSC %: Measured by digital refractometer (AtagoPalette PR 101, Atago Co., Tokyo).

SSC / Acid ratio: Calculated by division SSC value on acidity value.

Vitamin C (V.C) (g kg^{-1}): Measured according to a method of Malik and Singh (2005).

Antioxidant Enzyme Activity: Catalase (CAT), peroxidase (POD), and superoxide dismutase (SOD) enzymes activities were measured according to the method of Alici and Arabaci (2016) and expressed in U (1U = 1 μmol min− 1 mg^{-1} protein)

Samples were tested weekly to determine the following data when fruit were analyzed directly for the room conditions group but the fruits at cold storage were kept for 24 hours at room temperature (22 - 24 °C) before measuring firmness, acidity, SSC, V.C and antioxidant enzymes activity.

Statistical analysis

Statistical analysis was performed using CoStat 6.400 software. The experiment was designated in a completely randomized design, and the data were analyzed by analysis of variance (ANOVA). Means comparisons were performed using the Duncan's Multiple Range Test at a 5 % level of significance.

Costs and profitability

The average price of storing one ton of peach fruits at 1 °C for every week during the 2020 season in commercial packing houses in Ismailia was used to calculate the cost of cold storage. The unmarketable fruit was determined, the percentage of the nonmarketable fruit and their amount per ton were calculated. By the information of the price of one-ton peaches, the value of the loss was calculated as the price of lost kilograms per ton. The costs of AS and SA which were needed for treatments, as well as the rent for the cooling facility during the storage period, were estimated. Although that AS is a compound of salicylic acid, it is used in the current investigation because it is cheap and more available. Net income for one ton was calculated by extracting the costs from the price of one ton, and then calculated the net income from one hectare by multiply the net income from one ton by the productivity of one hectare.

Results

Weight loss

According to the data of weight loss percentage (Table 1), the significant differences were detected starting from 2nd week in the 1st season and 3rd week in the 2nd season among treatments during storage at room temperature (RT) of peach fruit compared to control. Data at the 3rd week of RT storage showed that AS1 recorded significantly lower values compared to AS0.5, SA0.5 treatments and control in the 1st season while AS1 and SA1 treatments recorded significantly low values compared to control in the 2nd season. However, under the cold storage (CS) conditions, there was a significant difference among all treatments compared to control, which recorded the highest weight loss percentage during all storage weeks in the two seasons. In the 9th week, the weight loss recorded 9.40 % and 9.96 % at the two seasons respectively, while it didn't record more than 5.97 and 6.3 % in other treatments.

Firmness

The fruit firmness insignificantly decreased during the RT storage at all treatments and control at the 1st season of RT storage while AS and SA treatments significantly increased the fruit firmness compared to control in the 2nd week at the 2nd season (Table 2).

The data reported herein during the two seasons of investigation showed that the loss in firmness continued during the CS period. SA1 significantly increased the fruit firmness during the early three weeks in the 1st season of CS compared to control and other treatments. While there wasn't a significant difference between all treatments and control from 4th to 7th week. However, treatments exhibited a significant difference in the 8th and 9th week of the 1st season. AS1 and SA1 treatments firstly recorded the highest values (22.47, 20.20 N and 5.93, 5.67 N) followed by AS0.5 and SA0.5 treatments (17.73, 18.87 N and 3.60, 2.07 N) compared to control (2.40 and 0.20 N) in the 8th and 9th week respectively.

Firmness in the 2nd season of CS exhibited no significant difference between treatments and control in the first three weeks but the treatments showed significant differences compared to control starting from the 4th week. AS and SA treatments from 6th to 8th weeks in the 2nd season showed the same effect on fruit firmness that previously shown in the 8th and 9th weeks of the 1st season. This means that treating peach fruit with AS and SA was maintained firmness.

Titratable Acidity

Results (Table 3) showed that the titratable acidity percentage decreased during storage time. All treatments under RT conditions were significantly high compared to control. The titratable acidity recorded more than 1.05 % in AS and SA treatments in the 2nd week at two seasons while control was 0.94 % in the 1st season and 0.93% in the 2nd season. The 3rd week on RT storage showed that the acidity percentage was significantly higher with AS0.5 and SA0.5 treatments (1.05 % and 1.02 %) compared to control (0.88 %) in the 1st season while SA0.5 and SA1 treatments in the 2nd season were recorded significantly higher acidity (0.95 % and 0.94 %) compared to control (0.82 %).

Under CS conditions, data demonstrated the effect of different treatments on peach fruit acidity. Starting from the 2nd week until the 8th week, the acidity in all treatments was significantly higher compared to control and continued to decrease during the storage period. The data in the 9th week showed significantly the highest acidity with SA0.5, AS0.5 and AS1 (0.92, 0.87 and 0.87 %, respectively) followed by SA1 (0.88 %) compared to control which recorded the lowest acidity (0.80 %) in the 1st season while SA0.5 and SA1 treatments showed significantly higher acidity (0.92 and 0.90 %) compared to AS0.5 and AS1 treatments (0.83 %) and control (0.80 %) in the 2nd season.

Soluble solids content (SSC)

Soluble solids content (SSC) increased through the RT storage in the two seasons during the current investigation. In the 3rd week at the 1st season, all treatments demonstrated significant differences with low SSC percentage values compared to control (16.70 %) as shown in Table 4. Moreover, in the 2nd season, SA1 treatment showed the lowest percentage (16.23 %) compared to control (16.63 %)

In the current experiment, cold storage resulted in a decrease in SSC loss during storage. It was significantly low SSC with all treatments compared to control until the 3rd week (12.47 % in the 1st season and 13.47 % in the 2nd season) and achieved about 11.86 to 11.89 % with SA0.5 and SA1 followed by AS0.5 and AS1 (12.13 to 12.14 %) respectively in the two consecutive seasons. Starting from the 4th week, the results of AS and SA treatments were close to each other and arrived to be not significant especially in the 8th and 9th week at the 2nd season. Therefore, the use of AS and SA on peach fruit during RT and CS resulted in a decrease of SSC compared to control.

TABLE 1. Effect of salicylic acid (SA 0.5, 1 mM) and aspirin (AS 0.5, 1 mM) on weight loss (%) of peach fruits (cv. Tropical snow) during storage period at room temperature on 22 - 24 °C (RT) or under cold storage on 1 °C (CS) .

Week	Control		AS0.5		AS1		SA0.5		SA1		LSD 0.05
1st season (2020)											
0 Time	0.00										
Storage at 22-24º C											
1st	10.59	a	11.39	a	11.46	a	10.01	a	9.21	a	3.54
2nd	21.64	ab	22.53	a	17.19	b	22.40	a	19.23	ab	4.55
3rd	31.11	a	30.09	a	19.98	b	29.45	a	26.97	ab	9.14
Storage at 1º C											
1st	1.23	a	0.86	ab	0.53	b	1.09	ab	1.03	ab	0.67
2nd	1.70	ab	1.44	ab	0.94	b	1.94	a	1.36	ab	0.83
3rd	1.97	ab	1.76	ab	1.47	b	2.43	a	1.45	b	0.92
4th	2.68	a	2.28	a	2.17	a	2.86	a	1.99	a	1.25
5th	3.52	a	2.96	a	2.65	a	3.24	a	2.39	a	1.27
6th	4.52	a	3.55	ab	3.27	ab	3.70	ab	2.81	b	1.58
7th	6.23	a	4.32	b	3.81	b	3.99	b	3.33	b	1.50
8th	7.74	a	5.17	b	4.28	b	4.01	b	3.66	b	1.53
9th	9.40	a	5.97	b	5.35	b	4.40	b	5.28	b	2.27
2nd season (2021)											
0 Time	0.00										
Storage at 22-24º C											
1st	16.68	a	16.46	a	16.09	a	16.19	a	17.16	a	2.99
2nd	23.91	a	27.65	a	22.40	a	22.20	a	26.65	a	6.42
3rd	30.99	a	27.49	ab	24.26	b	32.07	a	23.30	b	6.37
Storage at 1º C											
1st	1.37	a	0.97	abc	0.47	c	1.18	ab	0.62	bc	0.58
2nd	2.14	a	1.82	a	0.82	b	1.87	a	0.94	b	0.70
3rd	2.72	a	2.41	a	1.26	b	2.67	a	1.31	b	0.74
4th	3.46	a	3.17	a	1.40	b	3.14	a	1.71	b	1.02
5th	4.26	a	3.80	a	1.85	b	3.59	a	2.10	b	0.92
6th	5.15	a	4.32	a	2.45	b	4.12	a	2.57	b	1.12
7th	6.06	a	4.76	b	3.25	cd	4.51	bc	3.12	d	1.28
8th	7.64	a	5.41	b	4.11	c	4.79	bc	3.78	c	1.09
9th	9.96	a	5.76	b	5.54	b	6.30	b	4.97	b	2.55

Means in the same row with the same letters aren't significantly different at P<0.05 according to Duncan's multiple range tests.

TABLE 2. Effect of salicylic acid (SA 0.5, 1 mM) and aspirin (AS 0.5, 1 mM) on firmness (N) of peach fruit (cv. Tropical snow) during storage period at room temperature on 22 - 24 °C (RT) or under cold storage on 1 °C (CS).

Week	Control		AS0.5		AS1		SA0.5		SA1		LSD 0.05
1st season (2020)											
0 Time	39.45										
Storage at 22-24º C											
1st	21.67	a	22.00	a	21.67	a	22.33	a	22.67	a	3.29
2nd	4.73	a	5.60	a	5.53	a	5.67	a	5.47	a	1.91
3rd	0.20	a	0.20	a	0.20	a	0.20	a	0.20	a	0.00
Storage at 1º C											
1st	31.87	b	31.40	b	33.27	ab	31.53	b	36.73	a	4.55
2nd	29.87	b	31.13	b	32.87	ab	30.80	b	35.87	a	4.00
3rd	27.93	b	28.33	b	30.87	b	30.53	b	35.00	a	3.39
4th	25.07	a	25.40	a	28.67	a	27.47	a	28.73	a	4.29
5th	24.73	a	24.93	a	27.93	a	26.93	a	26.67	a	3.92
6th	23.20	a	23.80	a	26.40	a	23.60	a	25.00	a	3.37
7th	21.13	b	22.13	ab	24.13	a	21.40	ab	23.93	a	2.75
8th	2.40	d	17.73	c	22.47	a	18.87	bc	20.20	b	2.15
9th	0.20	c	3.60	b	5.93	a	2.07	b	5.67	a	1.65
2nd season (2021)											
0 Time	38.71										
Storage at 22-24º C											
1st	21.00	ab	21.60	a	20.47	b	21.40	ab	21.73	a	1.02
2nd	3.27	b	4.93	a	4.87	a	4.33	a	4.80	a	0.75
3rd	0.20	a	0.20	a	0.20	a	0.20	a	0.20	a	0.00
Storage at 1º C											
1st	35.33	a	37.00	a	37.00	a	36.77	a	35.40	a	2.47
2nd	29.87	a	31.33	a	32.73	a	29.67	a	30.93	a	4.53
3rd	24.73	a	25.93	a	29.13	a	26.60	a	27.07	a	4.53
4th	23.07	b	25.40	ab	27.87	a	26.13	ab	26.47	ab	3.99
5th	21.93	b	24.27	ab	25.93	a	23.87	ab	25.33	a	2.62
6th	16.33	c	23.13	b	25.60	a	22.80	b	24.47	ab	2.16
7th	10.43	c	21.47	ab	23.47	a	20.73	b	23.27	a	2.21
8th	1.87	d	16.53	c	21.13	a	17.53	bc	19.80	ab	3.00
9th	0.20	c	2.67	b	5.13	a	2.07	bc	5.67	a	1.91

Means in the same row with the same letters aren't significantly different at P<0.05 according to Duncan's multiple range tests.

TABLE 3. Effect of salicylic acid (SA 0.5, 1 mM) and aspirin (AS 0.5, 1 mM) on acidity (%) of peach fruit (cv. Tropical snow) during storage period at room temperature on 22 - 24 °C (RT) or under cold storage on 1 °C (CS)

Week	Control		AS0.5		AS1		SA0.5		SA1		LSD 0.05
1st season (2020)											
0 Time	1.27										
Storage at 22-24º C											
1st	1.23	a	1.17	a	1.20	a	1.24	a	1.23	a	0.09
2nd	0.94	c	1.05	b	1.11	a	1.13	a	1.14	a	0.05
3rd	0.88	b	1.05	a	0.96	ab	1.02	a	0.98	ab	0.12
Storage at 1º C											
1st	1.21	b	1.23	a	1.23	a	1.23	a	1.23	a	0.01
2nd	1.05	b	1.19	a	1.18	a	1.23	a	1.22	a	0.12
3rd	0.85	d	1.05	c	1.07	b	1.13	a	1.11	a	0.02
4th	0.89	d	0.97	c	1.08	b	1.14	a	1.15	a	0.03
5th	0.88	d	0.92	c	1.08	b	1.15	a	1.13	a	0.03
6th	0.85	c	0.96	bc	1.08	ab	1.13	a	1.04	ab	0.12
7th	0.89	c	0.94	b	0.94	b	0.99	a	0.97	ab	0.03
8th	0.81	b	0.92	a	0.92	a	0.95	a	0.92	a	0.04
9th	0.80	c	0.87	ab	0.87	ab	0.92	a	0.88	b	0.05
2nd season (2021)											
0 Time	1.28										
Storage at 22-24º C											
1st	1.19	ab	1.19	ab	1.12	c	1.17	b	1.23	a	0.03
2nd	0.93	c	1.05	b	1.07	ab	1.11	a	1.05	b	0.04
3rd	0.82	b	0.87	ab	0.83	b	0.95	a	0.94	a	0.08
Storage at 1º C											
1st	1.24	a	1.23	a	1.23	a	1.22	a	1.23	a	0.04
2nd	1.04	d	1.17	b	1.18	b	1.10	c	1.23	a	0.04
3rd	0.88	c	1.05	b	1.12	a	1.10	a	1.12	a	0.05
4th	0.84	c	0.95	b	1.10	a	1.10	a	1.09	a	0.04
5th	0.85	c	0.95	b	0.95	b	1.08	a	1.06	a	0.07
6th	0.85	c	0.95	ab	0.93	ab	0.92	b	0.97	a	0.05
7th	0.81	b	0.94	a	0.94	a	0.98	a	0.96	a	0.05
8th	0.80	c	0.92	ab	0.87	b	0.93	a	0.86	b	0.05
9th	0.80	b	0.83	b	0.83	b	0.92	a	0.90	a	0.05

Means in the same row with the same letters aren't significantly different at P<0.05 according to Duncan's multiple range tests.

TABLE 4. Effect of salicylic acid (SA 0.5, 1 mM) and aspirin (AS 0.5, 1 mM) on SSC (%) of peach fruit (cv. Tropical snow) during storage period at room temperature on 22 - 24 °C (RT) or under cold storage on 1 °C (CS) .

Week	Control		AS0.5		AS1		SA0.5		SA1		LSD 0.05
1st season (2020)											
0 Time	10.50										
Storage at 22-24º C											
1st	14.30	a	13.70	b	13.50	c	13.63	bc	13.60	bc	0.17
2nd	15.10	a	14.70	b	14.50	bc	14.40	c	14.53	bc	0.23
3rd	16.70	a	16.43	bc	16.50	b	16.47	bc	16.30	c	0.18
Storage at 1º C											
1st	11.47	a	11.13	b	11.20	b	11.33	ab	11.33	ab	0.25
2nd	12.00	a	11.40	b	11.47	b	11.60	ab	11.53	b	0.43
3rd	12.47	a	12.13	b	12.13	b	11.87	c	11.87	c	0.21
4th	13.27	a	12.53	b	12.27	c	12.27	c	12.47	bc	0.21
5th	14.07	a	13.13	c	14.13	a	13.47	b	14.07	a	0.21
6th	15.07	ab	14.47	c	15.13	a	14.87	b	15.13	a	0.21
7th	15.73	a	15.60	ab	15.53	b	15.27	c	15.53	b	0.19
8th	16.07	a	16.00	ab	15.87	b	15.93	ab	15.93	ab	0.19
9th	16.47	a	16.33	ab	16.40	ab	16.27	b	16.40	ab	0.16
2nd season (2021)											
0 Time	10.30										
Storage at 22-24º C											
1st	13.97	a	13.63	b	13.43	c	13.57	bc	13.47	c	0.16
2nd	15.03	a	14.77	b	14.43	c	14.27	c	14.40	c	0.17
3rd	16.63	a	16.37	bc	16.43	ab	16.47	ab	16.23	c	0.18
Storage at 1º C											
1st	12.47	a	11.13	b	11.21	b	11.33	b	11.33	b	0.21
2nd	12.63	a	11.39	b	11.46	b	11.60	b	11.54	b	0.23
3rd	13.47	a	12.14	b	12.13	b	11.89	c	11.86	c	0.13
4th	14.27	a	12.53	b	12.27	c	12.27	c	12.47	bc	0.20
5th	14.33	ab	13.13	c	12.67	c	13.46	bc	14.65	a	0.93
6th	15.06	a	13.61	b	13.20	b	14.87	a	13.13	b	0.59
7th	15.67	a	15.65	a	14.33	c	15.27	ab	15.07	b	0.51
8th	16.06	a	15.99	a	15.87	a	15.94	a	15.93	a	0.33
9th	16.47	a	16.33	a	16.41	a	16.27	a	16.40	a	0.22

Means in the same row with the same letters aren't significantly different at P<0.05 according to Duncan's multiple range tests.

SSC/Acid ratio

SSC/Acid ratio was significantly lower with AS and SA treatments compared to control under the RT and CS conditions (Table 5). In the 1st week at the 1st season, the difference between AS and SA on SSC/Acid ratio was insignificant under RT conditions while in the 2nd season at the 1st week SA1 treatment showed the significantly low record (10.99) followed by AS0.5 and SA0.5 (11.43 and 11.57) compared to control (11.76). However, AS1 treatment had the highest ratio (12.02). The SA0.5 treatment in the 2nd week of RT storage recorded the significant lowest difference in SSC/Acid ratio (12.90) compared to other treatments and control. The difference of SSC/Acid ratio in the 3rd week showed the significantly lowest values with SA0.5 and SA1 treatments (17.41 and 17.37) compared to AS0.5, AS1 and control (18.88, 19.88 and 20.21, respectively) in the 2nd season.

In the 1st week under CS conditions, the SSC/Acid ratio with AS and SA treatments were 9.05 to 9.21 compared to 9.45 with control in the 1st season and recorded values from 9.07 to 9.26 compared to 10.03 with control in the 2nd season. Although SSC/Acid ratio varied between treatments during the storage period in the two seasons, all treatments significantly reduced this ratio compared to control until the 9th week and the 8th week in the first and second seasons respectively. Additionally, under the same conditions at the 9th week in the 2nd season, SA0.5 and SA1 treatments showed significantly the lowest ratios (17.78 and 18.18) compared to AS0.5, AS1 and control (19.73, 19.75 and 20.48) respectively.

Vitamin C

Vitamin C content in peach fruit decreased during the storage period. Under RT storage, SA1 and AS1 treatments had significantly the greatest values of vitamin C followed by AS0.5 and SA0.5 compared to control during the 1st and 2nd weeks in the 1st season (Table 6). In the 3rd week in the 1st season of RT storage, vitamin C was significantly higher with AS1 and SA1 treatments (15.0 and 14.3 g kg^{-1}) followed by SA0.5 treatment (12.3 g kg^{-1}) compared to AS0.5 and control (11 and 10 g kg^{-1}). Although all treatments in the 1st week at the 2nd season demonstrated significant differences in the fruit content of vitamin C compared to control, there was no significant difference between AS and SA treatments. In the 2nd week at the 2nd season, vitamin C was significantly higher with AS1 and SA1 treatments (23.7 and 23.4 g kg^{-1}) followed by AS0.5 and SA0.5 compared to control (13.7 g kg^{-1}).

Under CS conditions, there was no significant difference between treatments and control for its effect on vitamin C content until the 4th week of storage during the two seasons of investigation. The difference started to be significant from the 5th week in the two seasons with the highest value with AS1 and SA1 (44.0, 42.3 and 44.0, 43.3 g kg^{-1}) followed by AS0.5 and SA0.5 (41.7, 42.0 and 42.0, 48.0 g kg^{-1}) compared to control (38.3 and 40.7 g kg^{-1}). The difference of vitamin c content between treatments varied from the 6th week of CS until the 9th week but it was generally significantly higher with AS and SA treatments compared to control.

Antioxidant Enzymes Activity:

Catalase enzyme activity significantly recorded high values with AS1 (30.67, 29.67 and 32.67, 31.67 U) and SA1 (30.00, 30.33 and 33.33, 31.67 U) followed by AS 0.5 (28.67, 27.00 and 31.33, 29.67 U) and SA0.5 (29.33, 27.33 and 30.67, 30.00 U) compared to control (25.67, 24.00 and 29.67, 27.33 U) during 1st and 2nd weeks of RT storage in the two seasons of the current research (Table 7). Moreover, in the 3rd week of the 1st season SA1 treatment, recorded the highest activity of CAT enzyme (28.33 U) followed by AS1 (27.00 U) then AS0.5 (25.67 U) and SA0.5 (25.00 U) compared to control (22.33 U). In the 2nd season, there was no significant difference between AS0.5, AS1 and SA0.5 although the activity was high with SA1 treatment (29.67 U) compared to these treatments and control, which recorded the significantly lowest values (24.33 U).

Generally, under CS conditions during storage weeks, AS1 and SA1 treatments resulted in a significantly high increase in CAT activity followed by AS0.5 and SA0.5 treatments compared to control which recorded the significantly lowest values in the two seasons of the investigation. The activity of CAT was increasing during storage time until the 7th week, and then started to decrease slowly during the 8th and 9th weeks. The data recorded the highest values with SA1 (33.00, 31.67 and 32.33, 31.00 U) followed by AS1 (31.00 and 30.33 U) then SA0.5 (30.00, 25.00 U and 29.33, 24.33 U) and AS0.5 (29.00, 25.00 U and 28.33, 23.67 U) compared to the lowest values with control (27.00, 24.00 U and 26.33, 23.33 U) in the two seasons respectively.

TABLE 5. Effect of salicylic acid (SA 0.5, 1 mM) and aspirin (AS 0.5, 1 mM) on SSC/acid ratio of peach fruit (cv. Tropical snow) during storage period at room temperature on 22 - 24 °C (RT) or under cold storage on 1 °C (CS).

Week	Control		AS0.5		AS1		SA0.5		SA1		LSD 0.05
1st season (2020)											
0 Time	8.27										
Storage at 22-24º C											
1st	11.68	a	11.68	a	11.24	a	11.00	a	11.03	a	0.70
2nd	16.00	a	13.97	b	13.01	c	12.80	c	12.79	c	0.51
3rd	19.07	a	15.69	b	17.26	ab	16.24	b	16.60	b	1.97
Storage at 1º C											
1st	9.45	a	9.05	b	9.08	b	9.21	b	9.19	b	0.21
2nd	11.39	a	9.58	b	9.72	b	9.49	b	9.43	b	0.95
3rd	14.61	a	11.59	b	11.34	c	10.53	d	10.72	d	0.22
4th	14.85	a	12.92	b	11.39	c	10.77	d	10.88	d	0.32
5th	15.98	a	14.24	b	13.13	c	11.68	e	12.41	d	0.35
6th	17.65	a	15.14	b	14.06	bc	13.30	c	14.51	bc	1.44
7th	17.75	a	16.67	b	16.49	bc	15.47	d	16.07	c	0.59
8th	19.84	a	17.41	b	17.25	b	16.79	b	17.33	b	0.83
9th	20.47	a	18.70	b	18.86	b	17.64	c	18.72	b	0.97
2nd season (2021)											
0 Time	8.07										
Storage at 22-24º C											
1st	11.76	ab	11.43	b	12.02	a	11.57	b	10.99	c	0.35
2nd	16.14	a	14.12	b	13.44	c	12.90	d	13.68	bc	0.50
3rd	20.21	a	18.88	a	19.88	a	17.41	b	17.37	b	1.45
Storage at 1º C											
1st	10.03	a	9.07	b	9.11	b	9.26	b	9.19	b	0.22
2nd	12.19	a	9.71	c	9.71	c	10.58	b	9.40	c	0.32
3rd	15.24	a	11.58	b	10.80	c	10.78	c	10.59	c	0.60
4th	16.92	a	13.25	b	11.13	c	11.15	c	11.40	c	0.53
5th	16.79	a	13.89	b	13.40	bc	12.49	c	13.78	b	1.21
6th	17.79	a	14.38	c	14.20	cd	16.25	b	13.50	d	0.84
7th	19.23	a	16.69	b	15.28	c	15.56	c	15.70	c	0.81
8th	19.99	a	17.48	bc	18.24	bc	17.24	c	18.44	bc	1.08
9th	20.48	a	19.73	a	19.75	a	17.78	b	18.18	b	1.06

Means in the same row with the same letters aren't significantly different at P<0.05 according to Duncan's multiple range tests.

TABLE 6. Effect of salicylic acid (SA 0.5, 1 mM) and aspirin (AS 0.5, 1 mM) on vitamin C (g kg^{-1}) of peach fruit (cv. Tropical snow) during storage period at room temperature on 22 - 24 °C (RT) or under cold storage on 1 °C (CS) .

Week	Control		AS0.5		AS1		SA0.5		SA1		LSD 0.05
1st season (2020)											
0 Time	69.3										
Storage at 22-24º C											
1st	23.3	c	31.0	b	56.7	a	33.7	b	63.7	a	0.7.3
2nd	15.0	c	24.0	b	28.7	a	24.0	b	31.0	a	0.3.4
3rd	10.0	c	11.0	c	15.0	a	12.3	b	14.3	a	0.1.3
Storage at 1º C											
1st	62.7	a	63.0	a	62.7	a	62.0	a	62.3	a	0.3.0
2nd	58.3	a	56.3	a	54.7	a	54.7	a	55.7	a	0.4.7
3rd	49.0	a	49.3	a	51.7	a	51.7	a	52.0	a	0.4.2
4th	38.3	a	47.3	a	49.3	a	47.7	a	48.7	a	0.3.1
5th	38.3	b	41.7	ab	44.0	a	42.0	ab	44.0	a	0.4.9
6th	34.0	b	39.0	a	41.7	a	40.7	a	41.7	a	0.4.5
7th	33.7	b	36.3	a	37.7	a	36.3	a	38.0	a	0.1.7
8th	24.3	b	28.0	a	29.0	a	26.3	ab	28.7	a	0.2.8
9th	19.7	d	25.0	c	30.0	a	28.0	b	30.0	a	0.1.7
2nd season (2021)											
0 Time	65.5										
Storage at 22-24º C											
1st	26.7	b	36.1	a	35.4	a	34.7	a	36.3	a	0.2.8
2nd	13.7	c	14.5	a	23.7	c	20.3	b	23.4	a	0.2.2
3rd	08.3	d	12.4	c	19.5	b	15.7	a	17.3	ab	0.3.2
Storage at 1º C											
1st	60.4	a	60.8	a	60.6	a	60.1	a	61.4	a	0.3.4
2nd	56.2	a	54.2	a	53.4	a	53.2	a	54.4	a	0.3.8
3rd	45.9	a	48.5	a	46.7	a	47.2	a	45.0	a	0.5.3
4th	43.7	c	45.0	ab	46.5	a	45.4	ab	47.6	a	0.2.8
5th	40.7	c	42.0	abc	42.3	ab	40.8	bc	43.3	a	0.1.5
6th	36.2	c	38.8	b	41.6	a	39.8	ab	40.7	ab	0.1.9
7th	26.7	b	35.6	a	37.1	a	35.7	a	37.4	a	0.4.9
8th	23.0	d	26.5	bc	28.1	ab	25.6	c	28.6	a	0.1.9
9th	19.8	d	24.1	c	29.6	a	26.6	b	28.7	ab	0.2.4

Means in the same row with the same letters aren't significantly different at P<0.05 according to Duncan's multiple range tests.

TABLE 7. Effect of salicylic acid (SA 0.5, 1 mM) and aspirin (AS 0.5, 1 mM) on Catalase enzyme activity (U) of peach fruit (cv. Tropical snow) during storage period at room temperature on 22 - 24 °C (RT) or under cold storage on 1 °C (CS) .

Week	Control		AS0.5		AS1		SA0.5		SA1		LSD 0.05
1st season (2020)											
0 Time	12.40										
Storage at 22-24º C											
1st	25.67	d	28.67	c	30.67	a	29.33	bc	30.00	ab	1.24
2nd	24.00	c	27.00	b	29.67	a	27.33	b	30.33	a	1.41
3rd	22.33	d	25.67	c	27.00	b	25.00	c	28.33	a	1.15
Storage at 1º C											
1st	13.33	d	15.33	c	19.33	a	17.13	b	19.33	a	1.00
2nd	15.33	c	18.67	b	23.00	a	19.33	b	23.33	a	1.24
3rd	21.33	e	24.00	d	27.67	b	25.67	c	28.67	a	0.94
4th	29.67	c	31.33	b	35.33	a	32.00	b	35.00	a	1.15
5th	31.00	c	33.33	b	35.67	a	34.00	b	36.00	a	1.56
6th	32.33	c	33.67	b	36.00	a	33.67	b	36.00	a	1.15
7th	34.67	b	33.67	c	36.67	a	34.00	b	37.00	a	1.41
8th	27.00	d	29.00	c	31.00	b	30.00	bc	33.00	a	1.15
9th	24.00	b	25.00	b	31.00	a	25.00	b	31.67	a	1.69
2nd season (2021)											
0 Time	14.27										
Storage at 22-24º C											
1st	29.67	c	31.33	b	32.67	a	30.67	bc	33.33	a	1.33
2nd	27.33	c	29.67	b	31.67	a	30.00	b	31.67	a	1.24
3rd	24.33	c	27.67	b	28.33	b	28.33	b	29.67	a	1.05
Storage at 1º C											
1st	12.67	c	16.00	b	18.00	a	16.57	b	18.00	a	1.31
2nd	13.33	c	18.00	b	21.67	a	18.00	b	22.67	a	1.63
3rd	20.67	c	24.67	b	27.00	a	25.00	b	28.00	a	1.33
4th	29.00	c	30.00	bc	34.00	a	30.67	b	33.67	a	1.33
5th	32.33	b	32.67	b	35.00	a	33.33	b	35.33	a	1.24
6th	31.67	c	33.00	b	35.33	a	33.00	b	35.33	a	1.15
7th	30.00	c	33.00	b	36.00	a	33.33	b	36.33	a	2.53
8th	26.33	d	28.33	c	30.33	b	29.33	bc	32.33	a	1.05
9th	23.33	c	23.67	bc	30.33	a	24.33	b	31.00	a	0.94

Means in the same row with the same letters aren't significantly different at P<0.05 according to Duncan's multiple range tests.

Peroxidase enzyme activity was significantly high during 1st and 2nd weeks of RT storage with AS1 and SA1 treatments followed by AS0.5 and SA 0.5 treatments compared to control. In the 3rd week, SA1 treatment resulted in significantly the highest values of POD activity (13.63 and 13.03 U) followed by AS1 (13.00 and 12.33 U) then AS0.5 and SA0.5 (9.67 and 9.00 U) treatments compared to control (8.17 and 7.83 U) in the two seasons (Table 8).

Under CS conditions, POD activity increased during storage weeks until the 6th week in the two seasons of the experiment while it decreased with the advance of storage from the 7th week until the 9th week with all treatments. The data generally showed significant difference high values with AS1 and SA1 followed by AS0.5 and SA0.5 compared to control during storage weeks except for some variations in the 1st and 2nd weeks at 1st season and also 3rd and 4th weeks at the 2nd season. Data of POD in the 9th week for fruit treated with AS1 recorded the highest activity (13.5 and 13.83 U) followed by SA1 (13.17 and 13.50 U) then SA0.5 (10.50 and 10.83 U) which was higher than AS0.5 (10.17 and 10.50 U) compared to control (8.17 and 8.50 U).

Superoxide dismutase enzyme activity was significantly high with SA1 treatment followed by AS1 then AS0.5 and SA0.5 treatments compared to control in the 1st season during RT storage from the 1st week until 3rd week and the 1st week at the 2nd season. The SA1 showed the highest values at the 2nd season in the 2nd and 3rd weeks followed by AS1 treatment then AS0.5 and SA0.5 treatments compared to control. The SA1 treatment in the 3rd week of RT storage resulted in the increase of SOD activity (22.46 and 22.21 U) more than AS1 treatment (21.76 and 20.91 U). These were higher than the AS0.5 (18.78 and 18.55 U) and SA0.5 (18.62 and 18.04 U) which recorded values higher than control (16.69 and 15.97 U) as shown in Table 9.

Under CS conditions, SOD activity increased during storage periods until the 7th week then decreased during the 8th and 9th weeks of storage. The SOD activity was significantly high with AS1 and SA1 treatments during the 3rd to 7th weeks at the 1st season and 4th to 6th weeks at the 2nd season of CS while SA1 recorded the highest activity during other weeks followed by AS1. The AS0.5 and SA0.5 treatments followed AS1 and SA1 on the increase of SOD activity compared to control, which recorded the significantly lowest values during the two seasons of the investigation. In the 9th week of CS, the AS1 significantly recorded the highest values (36.80 and 36.53 U) followed by AS1, AS0.5 and SA0.5 (33.33, 33.13, 32.60 U and 32.67, 32.20, 32.07 U) compared to control with the lowest values (29.40 and 28.60 U) during the two seasons respectively.

Data showed that treating peach fruit with AS and SA resulted in the increase of antioxidant enzymes (CAT, POD, and SOD) activities during the storage period either on RT or CS compared to control. Antioxidant enzymes activities under all treatments were higher in fruit under CS than those stored under RT, but the rise in the enzymes activities were increased slowly under cold storage compared to the fast changes in enzymes activities in fruit on RT storage. Generally, treating peach fruit with AS1 and SA1 significantly increased antioxidant enzymes activities, followed by AS0.5 and SA0.5 treatments compared to control, at different storage conditions (RT and CS) during the storage period.

To show the interaction effect of the temperature with AS and SA treatments, data of the 3rd week of storage was analyzed as two factors in statistical analysis where the first factor was temperature and the AS and SA treatments as second factor that tabulated in three sections (interaction between AS, SA treatments and storage temperature, storage temperature, and AS and SA treatments) as recorded in Table 10.

Interestingly, variation in the data of interaction between storage temperatures (RT and CS) and the AS and SA treatments was very high (Table 10). Generally, the data of acidity, V.C, CAT, POD and SOD enzymes activity, recorded significantly high values with AS and SA treatments, either RT or CS, compared to control on RT conditions, while data of weight loss, SSC of fruit and SSC/Acid ratio recorded significantly lower values with AS and SA treatments compared to control on the RT storage. However, data on CS of AS and SA treatments recorded significantly high values compared to control on RT conditions.

TABLE 8. Effect of salicylic acid (SA 0.5, 1 mM) and aspirin (AS 0.5, 1 mM) on peroxidase enzyme activity (U) of peach fruit (cv. Tropical snow) during storage period at room temperature on 22 - 24 °C (RT) or under cold storage on 1 °C (CS) .

Week	Control		AS0.5		AS1		SA0.5		SA1		LSD 0.05
1st season (2020)											
0 Time	10.46										
Storage at 22-24º C											
1st	20.57	d	24.13	c	26.67	a	24.70	b	26.97	a	0.45
2nd	11.03	c	16.87	b	19.83	a	17.03	b	20.03	a	0.65
3rd	8.17	d	9.67	c	13.00	b	9.67	c	13.63	a	0.52
Storage at 1º C											
1st	9.33	b	10.33	b	12.67	a	9.83	b	11.00	ab	1.69
2nd	10.50	c	14.17	b	16.50	a	15.00	b	16.50	a	1.38
3rd	14.00	b	14.50	b	17.50	a	14.67	b	17.83	a	1.13
4th	14.67	c	17.00	b	20.83	a	17.00	b	20.83	a	1.41
5th	17.50	c	19.17	b	22.83	a	19.83	b	22.67	a	1.17
6th	20.00	c	22.00	b	25.00	a	23.00	b	25.83	a	1.37
7th	14.83	c	17.83	b	20.83	a	17.67	b	21.00	a	1.49
8th	8.83	c	15.00	b	20.00	a	14.83	b	19.83	a	1.68
9th	8.50	c	10.50	b	13.83	a	10.83	b	13.50	a	1.13
2nd season (2021)											
0 Time	9.94										
Storage at 22-24º C											
1st	20.10	c	23.87	b	26.00	a	23.97	b	26.37	a	0.50
2nd	10.30	c	15.80	b	19.50	a	16.30	b	19.30	a	0.68
3rd	7.83	d	9.00	c	12.33	b	9.00	c	13.03	a	0.41
Storage at 1º C											
1st	8.00	d	9.00	cd	12.67	a	9.50	bc	10.33	b	1.27
2nd	12.00	c	13.17	b	15.50	a	13.00	bc	16.17	a	1.14
3rd	13.33	c	16.33	b	17.17	ab	14.00	c	17.50	a	1.14
4th	16.33	b	16.33	b	20.50	a	16.33	b	20.50	a	1.31
5th	17.83	c	18.83	b	22.50	a	19.50	b	22.67	a	0.78
6th	16.43	c	21.33	b	24.33	a	22.33	b	25.50	a	1.63
7th	14.50	c	17.50	b	20.50	a	17.00	b	20.33	a	0.84
8th	8.50	c	14.33	b	19.33	a	14.50	b	18.83	a	0.76
9th	8.17	c	10.17	b	13.50	a	10.50	b	13.17	a	0.66

Means in the same row with the same letters aren't significantly different at P<0.05 according to Duncan's multiple range tests.

TABLE 9. Effect of salicylic acid (SA 0.5, 1 mM) and aspirin (AS 0.5, 1 mM) on superoxide dismutase enzyme activity (U) of peach fruit (cv. Tropical snow) during storage period at room temperature on 22 - 24 °C (RT) or under cold storage on 1 °C (CS)

Week	Control		AS0.5		AS1		SA0.5		SA1		LSD 0.05
1st season (2020)											
0 Time	26.48										
Storage at 22-24º C											
1st	33.62	D	38.73	c	40.52	b	38.61	c	41.66	a	0.40
2nd	23.58	D	28.59	c	30.38	b	28.63	c	31.80	a	0.47
3rd	16.69	D	18.78	c	21.76	b	18.62	c	22.46	a	0.48
Storage at 1º C											
1st	19.87	D	24.00	c	28.53	b	24.40	c	29.87	a	1.21
2nd	24.40	D	28.53	c	32.60	b	27.80	c	34.87	a	0.96
3rd	28.00	C	31.27	b	37.27	a	30.80	b	37.53	a	1.22
4th	30.67	C	34.93	b	38.80	a	34.13	b	38.40	a	0.98
5th	32.67	C	38.80	b	40.10	a	39.07	b	40.93	a	0.88
6th	38.07	C	41.33	b	44.67	a	41.80	b	45.60	a	1.16
7th	34.20	C	43.27	b	45.80	a	43.53	b	46.67	a	1.07
8th	31.33	D	36.80	bc	36.27	c	37.73	ab	38.80	a	1.42
9th	29.40	C	33.13	b	32.60	b	33.33	b	36.80	a	1.66
2nd season (2021)											
0 Time	26.05										
Storage at 22-24º C											
1st	33.05	C	38.61	b	40.14	a	38.05	b	41.01	a	0.89
2nd	23.09	D	28.08	c	30.29	b	28.04	c	31.53	a	0.61
3rd	15.97	D	18.55	c	20.91	b	18.04	c	22.21	a	0.65
Storage at 1º C											
1st	25.83	B	25.80	b	28.80	a	26.07	b	28.80	a	1.41
2nd	25.80	D	28.13	c	32.40	b	27.53	c	33.90	a	0.72
3rd	28.00	D	30.73	c	33.73	b	33.87	b	37.13	a	0.97
4th	30.67	D	34.40	c	38.53	a	35.87	b	38.27	a	1.34
5th	32.00	D	38.53	c	39.93	ab	38.93	bc	40.40	a	1.25
6th	34.43	C	40.67	b	44.67	a	41.53	b	45.07	a	0.96
7th	35.43	E	42.07	d	45.20	b	43.13	c	46.67	a	0.90
8th	30.67	C	36.07	ab	35.77	b	36.27	ab	37.20	a	1.32
9th	28.60	C	32.20	b	32.07	b	32.67	b	36.53	a	0.83

Means in the same row with the same letters aren't significantly different at P<0.05 according to Duncan's multiple range tests.

TABLE 10. Interaction of room temperature on 22 - 24 °C (RT), cold storage on 1 °C (CS) and treatments of salicylic acid (SA 0.5, 1 mM) and aspirin (AS 0.5, 1 mM) at the 3rd week of storage on peach fruit quality (cv. Tropical snow).

Treatment	Weight loss (%)		Firmness (N)		Acidity (%)		SSC (%)		SSC/Acid ratio		Vitamin C (g kg^{-1})		CAT U		POD U		SOD U	
1st season (2020)																		
Interaction (AS, SA treatments and storage temperature)																		
Cont. RT	31.11	a	0.20	e	0.88	e	16.70	a	19.07	a	10.0	d	22.33	f	8.17	f	16.69	f
AS0.5 RT	30.09	a	0.20	e	1.05	abc	16.43	bc	15.69	cd	11.0	d	25.67	d	9.67	e	18.78	e
AS1 RT	19.98	b	0.20	e	0.96	d	16.50	b	17.26	b	15.0	c	27.00	c	13.00	d	21.76	d
SA0.5 RT	29.45	a	0.20	e	1.02	bcd	16.47	bc	16.24	bc	12.3	cd	25.00	d	9.67	e	18.62	e
SA1 RT	26.97	a	0.20	e	0.98	cd	16.30	c	16.60	bc	14.3	c	28.33	ab	13.63	cd	22.46	d
Cont. CS	1.97	c	27.93	d	0.85	e	12.47	d	14.61	d	49.0	b	21.33	g	14.00	bc	28.00	c
AS0.5 CS	1.76	c	28.33	cd	1.05	abc	12.13	e	11.59	e	49.3	ab	24.00	e	14.50	b	31.27	b
AS1 1 CS	1.47	c	30.87	b	1.07	ab	12.13	e	11.34	e	51.7	ab	27.67	bc	17.50	a	37.27	a
SA0.5 CS	2.43	c	30.53	bc	1.13	a	11.87	f	10.53	e	51.7	ab	25.67	d	14.67	b	30.80	b
SA1 1 CS	1.45	c	35.00	a	1.11	a	11.87	f	10.72	e	52.0	a	28.67	a	17.83	a	37.53	a
LSD	6.295		2.245		0.081		0.181		1.312		02.93		0.983		0.822		0.866	
Storage temperature																		
RT	27.52	a	0.20	b	0.98	b	16.48	a	16.97	A	12.5	B	25.67	a	10.83	b	19.66	b
CS	1.82	b	30.53	a	1.04	a	12.09	b	11.76	B	50.7	A	25.47	a	15.70	a	32.97	a
LSD	2.815		1.004		0.036		0.081		0.587		01.31		0.440		0.368		0.387	
AS and SA treatments																		
Cont.	16.54	a	14.07	b	0.86	c	14.58	a	16.84	a	29.5	a	21.83	d	11.08	c	22.35	c
AS0.5	15.93	a	14.27	b	1.05	ab	14.28	bc	13.64	b	30.2	bc	24.83	c	12.08	b	25.03	b
AS1	10.73	b	15.53	b	1.02	b	14.32	b	14.30	b	33.3	a	27.33	b	15.25	a	29.51	a
SA0.5	15.94	a	15.37	b	1.07	a	14.17	cd	13.39	b	32.0	ab	25.33	c	12.17	b	24.71	b
SA1	14.21	ab	17.60	a	1.04	ab	14.08	d	13.66	b	33.2	a	28.50	a	15.73	a	30.00	a
LSD	4.451		1.587		0.057		0.128		0.928		02.07		0.695		0.581		0.612	
2nd season (2021)																		
Interaction (AS, SA treatments and storage temperature)																		
Cont. RT	30.99	ab	0.20	c	0.82	f	16.63	a	20.21	a	08.3	d	24.33	d	7.83	g	15.97	h
AS0.5 RT	27.49	bc	0.20	c	0.87	ef	16.37	bc	18.88	b	12.4	cd	27.67	bc	9.00	f	18.55	g
AS1 RT	24.26	c	0.20	c	0.83	ef	16.43	b	19.88	ab	19.5	b	28.33	b	12.33	e	20.91	f
SA0.5 RT	32.07	a	0.20	c	0.95	c	16.47	b	17.41	c	15.7	bc	28.33	b	9.00	f	18.04	g
SA1 RT	23.30	c	0.20	c	0.94	cd	16.23	c	17.37	c	17.3	b	29.67	a	13.03	de	22.21	e
Cont. CS	2.72	d	24.73	b	0.88	de	13.47	d	15.24	d	45.9	a	20.67	e	13.33	cd	28.00	d
AS0.5 CS	2.41	d	25.93	b	1.05	b	12.14	e	11.58	e	48.5	a	24.67	d	16.33	b	30.73	c
AS1 1 CS	1.26	d	29.13	a	1.12	a	12.13	e	10.80	e	46.7	a	27.00	c	17.17	a	33.73	b
SA0.5 CS	2.67	d	26.60	ab	1.10	ab	11.89	f	10.78	e	47.2	a	25.00	d	14.00	c	33.87	b
SA1 1 CS	1.31	d	27.07	ab	1.12	a	11.86	f	10.59	e	45.0	a	28.00	bc	17.50	a	37.13	a
LSD	4.391		2.996		0.060		0.144		1.022		04.13		1.121		0.802		0.771	
Storage temperature																		
RT	27.62	a	0.20	b	0.88	b	16.43	a	18.75	A	14.6	B	27.67	a	10.24	b	19.14	b
CS	2.08	b	26.69	a	1.06	a	12.30	b	11.80	B	46.7	A	25.07	b	15.67	a	32.69	a
LSD	1.964		1.340		0.027		0.064		0.457		01.85		0.501		0.359		0.345	
AS and SA treatments																		
Cont.	16.85	a	12.47	b	0.85	c	15.05	a	17.73	a	2.71	b	22.50	d	10.58	d	21.99	e
AS0.5	14.95	ab	13.07	ab	0.96	b	14.25	bc	15.23	b	3.05	a	26.17	c	12.67	b	24.64	d
AS1	12.76	b	14.67	a	0.98	b	14.28	b	15.34	b	3.31	a	27.67	b	14.75	a	27.32	b
SA0.5	17.37	a	13.40	ab	1.03	a	14.18	c	14.09	c	3.14	a	26.67	c	11.50	c	25.96	c
SA1	12.31	b	13.63	ab	1.03	a	14.05	d	13.98	c	3.11	a	28.83	a	15.27	a	29.67	a
LSD	3.105		2.118		0.043		0.102		0.723		02.92		0.793		0.567		0.545	

Means in the same column with the same letters aren't significantly different at P<0.05 according to Duncan's multiple range tests.

Due to the temperature effect, firmness, acidity, VC, POD and SOD activities in fruit under CS storage, recorded significantly high values compared to RT conditions. In contrast, weight loss, SSC of fruit and SSC/Acid ratio under CS storage, recorded significantly lower values compared to RT conditions. Although, CAT activity did not show significant difference between RT and CS conditions in the first season, it achieved significant difference between two storage temperatures in the second season.

According to the effect of AS and SA treatments, SSC and SSC/Acid ratio recorded significantly high values with AS and SA treatments compared to control. On the other hand, acidity, VC, CAT, POD and SOD activities in the treated fruit with AS and SA treatments, recorded significantly low values compared to control. Furthermore, AS1 and SA1 treatments demonstrated significantly high weight loss values compared to control in the two seasons of investigation. Moreover, SA1 in the 1st season and AS1 in the 2nd season observed significantly high firmness values compared to control.

Collectively, data of Table 10 demonstrated that the CS treatment compared to RT storage and AS and SA treatments compared to control reduced fruit quality losses in peach fruit. Furthermore, AS and SA treatments under CS recorded the best results in preserving fruit quality in peaches.

Costs and profitability

Gross production value of peaches in Egypt according to FAOSTAT (2020) recorded 69.406998 million US$. The Export quantity recorded 9381 tons with an export value of 14.772 million US$. That means the price of one-ton peach fruit for export equals 1575 US$ and the hectare produces 12.13 tons of fruit. Fruit appearance during storage can be affected by color change, misshape, shriveling, drying, bruising, skin cuts, skin cracks, chilling injury symptoms, raise CO_2 damage, reduce O_2 damage, ethylene damage, infection by pathogens and insects, aroma changes, off-flavors and off-odors (Yahia, 2019). Therefore, fruit during storage should be inspected and rated or sorted according to the desired parameters of the fruit market into two main groups, marketable and nonmarketable fruit. Peach fruit in the current investigation under cold storage conditions stored successfully up to 9 weeks compared to fruit on RT, which stored only 3 weeks. However, the unmarketable fruit started to be shown at 2nd week on RT and at 7th week under CS conditions in control, then at the 8th week in the treated fruit with AS and SA treatments under cold storage. Therefore, the 1st week on RT and the 7th week on SC storage were considered the longest storage period under every temperature condition without unmarketable fruit. The result of the costs analysis showed that weight loss (Kg/ton) and price loss (US$/ton) was increased due to the rise of nonmarketable fruit percentage during the extension of the postharvest period in both storage temperatures.

According to that data in Table 11 for peach fruit on RT, the control did not cost money for cooling which recorded about 7 US$ every month but the cost of AS0.5 and AS1 recorded 0.5 and 1 US$ respectively while the cost of SA0.5 and SA1 recorded 0.7 and 1.3 US$, respectively.

The best treatment net income recorded 1101.5 and 944 US$/ton in the 3rd week with SA1 and AS1 treatments followed by AS0.5 and SA0.5 treatments which recorded 944 and 1101.8 U$ in the 2nd week under RT compared to control which recorded only 787.5 US$. That means, AS and SA treatments at RT raised the income with 156.5 to 314 US$/ton compared to the control. Peach fruit under CS conditions cost 15 US$ for cooling until the 7th week, 20 US$ for 8 weeks, and 25 US$ for 9 weeks. The storage of peach fruit until the 7th week resulted in a rise of net income at all treatments (AS and SA) and recorded 761.5 US$/ton in high concentration and 604.5 US$ in low concentration higher than control while the cost of AS and SA treatments did not exceed more than 26 US$/ton (cost of cooling plus cost of AS or SA treatment).

Discussion

Peach is one of the favorite fruit for Egyptians, but its fruit are very sensitive during the postharvest handling to weight loss and fruit quality through its way to the consumer. In the current study, AS and SA treatments significantly decreased the weight loss of peach from the 7th to 9th week under CS while AS and SA treatments decreased the weight loss without significant difference at RT. These results are in the agreement of Eroğul and Özsoydan (2020) who observed that SA treatment significantly reduced weight loss of peach fruit at 0 to 2 ºC with 90 % RH compared with other treatments including control.

TABLE 11. Costs and profitability of using salicylic acid (SA 0.5, 1 mM) and aspirin (AS 0.5, 1 mM) on Tropical snow peach fruit during storage on room temperature (22-24 °C) and under cold storage (1 °C).

Treatment	Storage		Nonmarketable fruit		Value loss	Treatment cost US$/ Ton		Net revenue income	
	Temp.	Week	%	Kg/Ton	US$/Ton	AS or SA	Cooling	US$/Ton	US$/Ha*
Control	RT	2	50	500	787.5	0	0	787.5	9552.38
		3	70	700	1102.5	0	0	472.5	5731.43
	CS	7	10	100	157.5	0	15	1402.5	17012.3
		8	20	200	315.0	0	20	1240	15041.2
		9	20	200	315.0	0	25	1235	14980.6
AS0.5	RT	2	40	400	630.0	0.50	0	944.5	11456.8
		3	50	500	787.5	0.50	0	787	9546.31
	CS	7	0	0	0	0.50	15	1559.5	18916.7
		8	10	100	157.5	0.50	20	1397	16945.6
		9	10	100	157.5	0.50	25	1392	16885.0
AS1	RT	2	30	300	472.5	1.00	0	1101.5	13361.2
		3	40	400	630.0	1.00	0	944	11450.7
	CS	7	0	0	0	1.00	15	1559	18910.7
		8	0	0	0	1.00	20	1554	18850.0
		9	0	0	0	1.00	25	1549	18789.4
SA0.5	RT	2	30	300	472.5	0.65	0	1101.8	13364.8
		3	40	400	630.0	0.65	0	944.3	11454.4
	CS	7	0	0	0	0.65	15	1559.3	18914.3
		8	0	0	0	0.65	20	1554.3	18853.7
		9	10	100	157.5	0.65	25	1391.8	16882.5
SA1	RT	2	30	300	472.5	1.30	0	1101.2	13357.6
		3	40	400	630.0	1.30	0	943.7	11447.1
	CS	7	0	0	0	1.30	15	1558.7	18907.0
		8	0	0	0	1.30	20	1553.7	18846.4
		9	0	0	0	1.30	25	1548.7	18785.7

During the investigation of El-Abbasy et al. (2018), treating apricots fruit with SA decreased weight loss and decay percentage at 0 °C with a higher marketable fruit percentage. That was in harmony with the investigation results of Arafat (2019) on guava under shelf life conditions and El-Mahdy et al. (2017) on orange at 13 °C. Transpiration, or evaporation of water from the plant tissues, is one of the major causes of deterioration and shriveling in fresh horticultural crops after harvest. Not only that, but the fruit water loss results in softening, limpness, and losses in nutritional quality (Kader and Rolle, 2004). Weight loss is regulating by transpiration, respiration and metabolic activities in fruit. Salicylic acid, reduce transpiration and respiration which results in minimizing weight loss and delaying senescence of fruit (Prodhan et al., 2018). This indicated that AS and SA could be used to reduce the weight loss of peach fruit during CS.

Firmness of fruit is one of the most important physical parameters to monitor the ripening progress. Higher firmness in treated fruit may attribute to reduce hydrolysis of soluble starch and delay ripening process. Generally, the fruit firmness of peach fruit decreased with advancing the storage period with the agreement of other studies (Nuzzi et al., 2015, Shalan, 2020). The decrease of the firmness was delayed significantly with the use of AS and SA treatments (from 6th and 7th week until 9th week) under CS conditions. Çelik et al. (2006) reported that peach softening

was increased after being removed from CS and kept at RT. In addition, Crisosto (2002) and Çelik et al. (2006) found that cold-stored nectarines left at shelf life for 2 days, the flesh firmness decreased and starting to decay. El-Abbasy et al. (2018), dipping apricots fruit in SA at 0 °C, enhanced fruit firmness. Similarly, in our research under CS, using AS and SA treatments especially with high concentration maintained firmness in peach fruit. These findings were explained by Razavi et al. (2018) who proved that treating peach fruit with SA before storing them at 1 °C for 4 weeks, showed an increase in the content of antioxidant enzymes which resulting in higher firmness.

Fruit titratable acidity percentage of peach fruit decreased with the progress in the storage period with the agreement of Shalan (2020) who stored peach fruit at 25 °C. In the present study, SA and AS treatments delayed the decrease in acidity starting from the 2nd week at RT and from the 3rd week under CS conditions until the 9th week. These results are in harmony with those obtained by El-Abbasy et al. (2018) who found that SA significantly increased the titratable acidity content of apricot fruit at 0 ºC. In addition, a similar conclusion was demonstrated by Çelik et al. (2006), El-Mahdy et al. (2017) and Orabi et al. (2018) who mentioned that treating fruit with SA on some fruit (nectarine, orange, and mandarin) during storage at its optimum temperature, delayed the decline of total acidity.

The fruit SSC and SSC/acid ratio of peach fruit were increased with advancing the storage period at 25 °C (Nuzzi, et al., 2015, Nakano et al., 2020, Shalan, 2020). In spite of that, Pinto et al. (2015) found that the relationship between SSC and maturity indicators of peach fruit did not observe significant differences. El-Abbasy et al. (2018), reported that SA significantly increased the SSC and SSC/acid ratio of apricot fruit, stored at 0 ºC. In our investigation, also the SSC and SSC/acid ratio of peach increased during the storage period while AS and SA delayed that increase under RT and CS.

Vitamin C of peaches decreased with advancing the storage period. Meanwhile, AS and SA protected V.C content in peach fruit during RT or CS conditions. Similarly, Razavi et al. (2018) found that SA significantly maintained the V.C content of peach fruit stored at 0 °C compared to control. In addition, El-Mahdy et al. (2017) reported that SA treatment of orange fruit improved ascorbic acid contents in fruit when stored at 13 °C. Junmatong et al. (2015) reported a similar finding on mango fruit during storage at 5 °C. The results of Kazemi et al. (2011) suggest that SA may be effective in reducing the oxidation of ascorbic acid with increasing peroxidase activity during storage periods.

Catalase enzyme is a very important enzyme in protecting the cell from oxidative damage by reactive oxygen species (ROS) (Meitha et al., 2020). The current study suggests that SA is effective in increasing the activity of POD, CAT and SOD, which are important oxyradical detoxification enzymes in the tissues of plants. The activity of these enzymes increases in plants in response to stress in order to prevent damage (Hayat et al., 2007). Results could explain the reason of enhance the peach fruit quality using AS and SA treatments, as the effect on the increase of antioxidant enzymes activities in the fruit which delayed ripening. Junmatong et al. (2015) and Boshadi et al. (2018) reported the same results.

Treating fruit with AS or SA increased antioxidant enzymes during storage and enhanced fruit characteristics due to their effects on delaying the ripening processes. Similarly, Razavi et al. (2018) concluded that treating peaches with SA during storage at 1 °C for 4 weeks delayed fruit postharvest decay due to the rising of antioxidant enzymes (APX, SOD, and CAT) content. Similar findings were reported on treating fruit (tomato, apricot, mandarin and guava) with SA during storage, resulted in delayed ripening, decreased decay percentage, extended fruit storage and enhanced fruit quality and storability (El-Abbasy et al., 2018, Orabi et al., 2018, Arafat, 2019). That could be attributed to SA inhibits the action of ethylene receptors, which enhances fruit decay (Heydari et al., 2020). Furthermore, Zhang et al. (2003) reported that treating kiwifruit with AS resulting in decreasing ACO and ACS genes, which led to a decrease in ethylene biosynthesis during ripening, higher SA accumulation associated with lower activity of superoxide and finally delayed ethylene biosynthesis. Ethylene synthesis is normally limited by the supply of the immediate precursor amino cyclopropane-1-carboxylic acid (ACC). SA may inhibit ACC oxidase activity, thus, inhibition of ethylene production has occurred (Srivastava and Dwivedi, 2000).

Due to the effect of storage temperatures and AS and SA treatments, the CS treatment compared to RT storage and AS and SA treatments compared

to control improved the peach fruit quality and this effect was more pronounced with the use of AS and SA treatments under CS.

Gimenez et al. (2017) suggested that the preharvest treatment of salicylates would have a commercial role with decreasing costs and increasing profits in fruit nutritional quality. Moreover, in the present study, the costs and profitability analysis showed that it is economically important to use cooling storage and treating fruit with AS or SA to improve the income (between 1898 to 9237 US$/Ha according to that the yield productivity of peach recorded 12.13 tons/Ha) during peach fruit storage.

The present investigation was carried out as a trial to improve peach fruit quality during storage. Generally, data showed that fruit treated with AS or SA, delayed loss in fruit weight, redundancy in acidity and V.C and decreased the rise of SSC and softening during the storage period, which means delayed decay and improved fruit quality. These finding are in agreement with Islam et al. (2018) and Tabasum et al. (2019).

Conclusion

Peach is a sensitive fruit with a great loss in its quality through postharvest. The fruit quality improved during storage by dipping the fruit in SA or AS at 0.5 and 1 mM for 5 minutes. These treatments particularly under storage at 1 °C with 80 to 90 % relative humidity extend the storage period up to nine weeks and reserve the quality of fruit. These treatments decreased the weight loss, SSC, SSC/Acid ratio and antioxidant enzymes activity. Moreover, the deterioration in firmness, V.C, and acidity were delayed. Fruit treated with AS or SA resulted in improving the income by 156.5 US$/ton on the room temperature conditions and by 761.5 US$/ton on cold storage conditions during 7th to 9th week over than control treatment.

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Conflict of interest

No conflicts of interest during this research.

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تقليل فقد جودة ثمار الخوخ وزيادة الأرباح أثناء التخزين باستخدام حمض الساليسيليك والأسبرين

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يعتبر الخوخ من الفاكهة المفضلة إلا أن ثماره حساسة للتداول والتخزين ويحدث خسارة كبيرة في المحصول ونقص بجودة الثمار خلال مسارها حتي وصولها للمستهلك. تم في الدراسة الحالية استخدام حمض الساليسيليك والأسبرين بتركيزين (٠,٥ و ١ ملي مولار) علي الخوخ (صنف تروبيكال سنو) مع استخدام الماء في معاملة الكنترول و تم التخزين علي درجتي حرارة (٢٣ ± ١ درجة مئوية و ١ درجة مئوية ورطوبة ٨٥٪ ± ٥٪) في موسمين متتاليين (٢٠٢٠ و ٢٠٢١). أشارت النتائج إلى أنه لا يمكن تخزين ثمار الخوخ تحت ظروف درجة حرارة الغرفة في جميع المعاملات لأكثر من ٣ أسابيع بينما استمرت الثمار في التخزين البارد لمدة ٩ أسابيع بحالة جيدة مقبولة للاستهلاك. عند تخزين الثمار علي درجة حرارة الغرفة، لم تؤثر المعاملات بشكل كبير على فقدان الوزن أو الصلابة بينما أدى استخدام حمض الساليسيليك والأسبرين خاصةً بالتركيزات العالية لكل منهما إلى تأخير انخفاض الحموضة وفيتامين ج وتقليل زيادة نسبة المواد الصلبة الذائبة. تحت ظروف التخزين المبرد، أدي استخدام حمض الساليسيليك والأسبرين إلى الحفاظ على جودة الثمار بشكل كبير من خلال تقليل الفقد في الوزن، والحفاظ علي الصلابة وتأخير انخفاض الحموضة وفيتامين ج وتقليل زيادة المواد الصلبة الذائبة وتقليل التدهور في نشاط أنزيمات مضادات الأكسدة خاصة في الأسابيع الثلاثة الاخيرة. أشارت نتائج الدراسة الاقتصادية الي أن استخدام حمض الساليسيليك والأسبرين أدى إلى تحسين المكاسب بمقدار ١٥٦,٥ دولار أمريكي / طن ثمار عند تخزين الثمار علي درجة حرارة الغرفة وبمقدار ٧٦١,٥ دولار أمريكي / طن ثمار تحت ظروف التخزين المبرد.

الكلمات الدالة: الخوخ، حمض الساليسيليك، الأسبرين، التخزين، تكلفة التخزين، تحليل التكاليف.