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Effect of Ascorbic acid, Hydrogen peroxide, Jasmonic Oil, Potassium Silicate and Salicylic acid Treatments on Preventing of Chilling Injury Sweet Pepper During Storage

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Abstract: Sweet pepper Testy hybrid were grown under plastic house condition during 2018 and 2019 seasons to study the effect of Jasmonic oil (MeJA) at 0.1 mM, Salicylic acid (SA) at 2 mM, Hydrogen peroxide (H_20_2) at 200 ppm, ascorbic acid (ASA) at 0.5%, potassium silicate at 100 mg/L and distilled water (control) as postharvest dipping in reducing chilling injury and maintaining fruit quality during storage at 5°C in addition to 2 days at 15°C (shelf life conditions). Sweet pepper fruits treated with ASA and SA did not show any decay and had higher value (indicating lighter fruit) until the end of storage period plus shelf life. Fruits dipped in ASA, potassium silicate and SA were the most effective treatments for reducing the loss of b value (indicated that fruits retained more green color) and reduce the loss of firmness during storage plus shelf life. Sweet pepper fruits treated with ASA and SA did not develop any symptoms of chilling injury (CI) during all storage period plus shelf life. The onset of CI symptoms in fruits was delayed by potassium silicate, MeJA and H_2O_2 treatments and these treatments reduced the rate of CI development. The lowest accumulation of carotenoids content was found in potassium silicate and SA treatments. Sweet pepper fruits dipped in solution of ASA or SA treatments were the most effective treatments in maintaining quality (firmness, TSS% and Vit C) and give fruits with good appearance without decay and chilling injury symptoms till 35 days at 5°C plus 2 day at 15°C.

Key words: Chilling injury · Sweet pepper · Salicylic Acid · Ascorbic acid · Methyl Jasmonate

INTRODUCTION

Sweet pepper (*Capsicum annuum* L.) is an important vegetable crop worldwide and may be green (unripe), red, yellow, orange, or brown when rips. Peppers are rich in vitamins, especially A and C and are low in calories [1]. Sweet pepper is a very perishable vegetable with a short shelf life and high susceptibly to fungal diseases [2]. Common inherent postharvest problems of pepper fruits after harvesting include significant metabolic and physiological activities, quality degradation and shriveling, as well as fast physical decay and rapid senescence [3]. Sweet pepper fruits, being of tropical origin, are susceptible to chilling injury, if held at temperature lower than 7°C for more than 3 days [4]. The main chilling injury symptoms in sweet pepper fruits include poor ripening, surface discoloration, sheet pitting, collapse of structural integrity, development of off-flavors, the formation of sunken, calyx darkening, seed browning and darkening and increased susceptibility to decay and fungal growth [5, 6]. The symptoms of CI usually become more pronounced after transfer of the fruit from a chilling temperature to a warmer temperature.

Several methods have been applied to reduce chilling injury in order to extend fruit shelf life and impressive responses have been reported. Among this techniques applied to many horticulture crops, including sweet pepper, MeJA, salicylic acid, H_2O_2, ASA and potassium silicate [7-15].

Salicylic acid, as natural and safe phenolic molecule, at non-toxic concentrations may be commercially used in alleviating CI in fruit and vegetables such as tomato, pomegranate, sweet pepper and plum [16-19, 7, 20]. Thus SA has high commercial potential for use at low

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concentrations in alleviating CI in fruits and vegetables. Moreover, postharvest application with SA at 2mM concentration was highly effective in reducing chilling injury incidence and decay of cold storage pomegranate fruits at 2°C for three months [17-19]. In addition, immersing cucumber fruits in SA solution reduced chilling injury symptoms in fruit during cold storage at 5°C [21].

Jasmonic acid and MeJA are also regulators of stress responses [22, 23]. MeJA treatment alleviates CI and reduces ethylene production in peppers and enhances CI tolerance by inducing the expression of the AOX gene, thereby maintaining the balance between ROS production and general antioxidant system activity [24]. In cucumbers, MeJA induces chilling tolerance by inhibiting H_2O_2 generation and enhancing both CAT activity and CAT gene expression [25].

Carotenoids enhance the value of pepper from a nutritional standpoint, despite being commonly prized for the pharmacologically active pungent capsaicinoids. Carotenoids are important antioxidants [26]. Antioxidants play an important role in protecting fruits from the oxidative damage inflicted by ROS, thus assuring quality and extending produce shelf life [27]. They are considering protecting tissue against ROS [27]. ASA is a major water-soluble antioxidant in plants and it is one of the most abundant plant antioxidants. Moreover, ASA is one of the most powerful antioxidants [28]. ASA maintained the cell plasma membranes structure, less oxidative reactions accumulations and effectively controlled the enzymatic browning and cell death of fruits [29]. Postharvest soaking in ASA controlled the chilling injury symptoms in mango fruits and 'Eureka' lemon fruits during cold storage [12, 30-32].

Recently, silicate has been shown to induce resistance to both biotic and abiotic stress. There is ample experimental evidence suggesting that Si affects the activity of major antioxidant enzyme involved in plant stress defense systems [33-37]. Moreover, recent postharvest studies on avocado have proved silicate to be a safe and effective antioxidant source [38]. Also Mditshwa *et al*. [14, 15] found that lemon fruits dipped in potassium silicate reduced chilling injury symptoms in fruits during cold storage.

Therefore, this study was undertaken the effectiveness of Jasmonic oil, Salicylic acid, H_2O_2, ASA, potassium silicate and distilled water (control) treatments in maintaining the quality and reducing chilling injury of sweet pepper fruits during cold storage at 5°C (chilling temperature).

MATERIAL AND METHODS

Sweet pepper (*Capsicum annuum* L.) Testy hybrid plants were grown under plastic house conditions at private farm in Ismailia Governorate during winter seasons 2017/2018 and 2018/2019. Normal cultural practices were carried out wherever it was needed according to the recommendation of Ministry of Agriculture. Sweet pepper fruits were harvested at 3/4 yellow color stage then transferred to laboratory of Postharvest and Handling of Vegetable Crops Department Hort. Res. Inst. at Giza. Only uniform fruits in size, weight and color with short calyx (1 cm) that were sound, healthy and free from any visible defects were selected for the follow treatments:

- Dipping in solution of ascorbic acid (ASA) at 0.5 % for 5 min.
- Dipping in solution of salicylic acid (SA) at 2 mM for 5 min.
- Dipping in hydrogen peroxide (H_2O_2) 200 ppm (1 ml/L) for 5 min.
- Dipping in solution of methyl jasmonate (MeJA) at 0.1 mM for 5 min.
- Dipping in solution of potassium silicate at 100 mg / L for 5 min.
- Untreated fruits dipped (in distilled water) control.

All treatments of fruits were dipped in various solutions under ambient condition (20±5°C) and air dried and then packed in polypropylene bags (25×30 cm) and 30 microns thicknesses. Each bag contains 3 fruits represented as experimental unit (EU). Twelve EU were prepared for each treatment and stored at 5°C and 95% relative humidity (RH). Samples were taken randomly in three replicates EU and were arranged in complete randomized design. Measurement, were examined immediately after harvest and at 7 days intervals (0, 7, 14, 21, 28 and 35 days) of storage at 5° C in addition to 2 days at 15° C (shelf life conditions) for the following characteristics.

Weight Loss (%): It was calculated according to the equation: = [(initial weight of fruits - weight of fruits at sampling data)/ (initial weight of fruits)] x100 [39].

General Appearance: General appearance was evaluated using a scale from (1-9) with 9= excellent, 7= good, 5= fair, 3= poor, 1= unsalable and fruits rating (5) or below were considered unmarketable (the panel tests for general appearance, decay and chilling injury, evaluated by seven researchers at postharvest vegetable lab).

Decay Score: Decay was determined using the following score 1=no decay, 2=slight, 3=moderate, 4=sever and 5=extreme [40].

Color: Color was measured on two sides of each fruit by using Minolta CR-400 Chroma Meter (Minolta Co. ltd. Osaka, Japan). The measurements of skin color and gloss were expressed in chromaticity values of lightness (L) and b value respectively. Three readings were taken at different locations of each fruit during each data observation [41, 42].

Chilling Injury: The degree of chilling injury, as judged by the extent of surface pitting was evaluated two days after transfer of sweet pepper fruits from 5°C to 15°C by rating scale of 1 to 5, where 1= no pitting, 2= 10% of the surface area pitted, 3= 11-25% of the surface area pitted, 4= 26-50% of the area pitted 5= = 50% of the surface area pitted [40].

Fruit Firmness: Fruit firmness was measured in Lp/in^2 by Magness and Ballouf pressure tester equipped with 3/16 inch plunger and adjusted in Newton (as recommended by ASHS postharvest working Group).

Ascorbic Acid Content (Vit. C): (mg/100g fruit fresh weight) was determined by titration method using 2, 6 dichloro-phenol-indo-phenol the dye as described in A.O.A.C. [39].

Total Carotenoids Content (mg/100g fresh weight): Was determined according to A.O.A.C. [39].

Total Soluble Solids Percentage (TSS) % it was measured from the fresh materials using PR-101 digital refractometer.

Statistical Analysis: Data were subjected to statistical analysis for calculation of means, variance and stander error according to MSTATC software. The method of Duncan multiple range tests were applied for the comparison between means according to Waller and Duncan [43].

RESULTS AND DISCUSSION

Weight Loss Percentage: Data in Table (1) revealed that weight loss (%) of sweet pepper fruits was increased considered and consistently with the prolongation of storage period plus shelf life in the two seasons. These results are in agreement with Huang *et al.* [44] and Sheren *et al.* [45]. The loss in weight may be due to transpiration, respiration and other senescence related metabolic processes during storage [46].

All postharvest treatments reduced weight loss % as compared with untreated control during storage and shelf life. Moreover, sweet pepper fruits treated with SA and potassium silicate were the most effective treatments in reducing the weight loss percentage with no significant difference between them in the two seasons followed by

Table 1: Effect of some postharvest treatments on weight loss percentage of sweet pepper fruits during cold storage plus shelf life in 2018 and 2019 seasons.

	Storage period (days)						
	2018						
Treatments	0+2	2+7	2+14	2+21	2+28	2+35	Mean
Potassium Silicate	0.06 O-Q	0.07 OP	0.14 MN	0.17 M	0.25 JK	0.27 H-J	0.16 E
Salicylic acid	0.02 Q	0.07 O-Q	0.16 M	0.26 I-K	0.28 G-J	0.30 F-J	0.18 DE
Ascorbic acid	0.05 O-Q	0.06 O-Q	0.16 M	0.28 G-J	0.31 F-I	0.33 E-G	0.20 CD
Hydrogen Peroxide	0.04 PQ	0.02 Q	0.22 KL	0.31 F-I	0.41 D	0.32 F-H	0.22 BC
Methyl Jasmonate	0.06 O-Q	0.09 NO	0.17 LM	0.27 H-K	0.38 DE	0.46 C	0.24 B
Distilled water (Control)	0.03 PQ	0.17 LM	0.33 E-G	0.34 EF	0.54 B	0.83 A	0.37 A
Mean	0.04 F	0.08 E	0.20 D	0.27 C	0.36 B	0.42 A	
	2019						
Potassium Silicate	0.06 O-Q	0.07 OP	0.14 MN	0.17 M	0.25 JK	0.28 H-J	0.16 E
Salicylic acid	0.02 Q	0.07 O-Q	0.16 M	0.26 I-K	0.28 G-J	0.30 F-J	0.18 DE
Ascorbic acid	0.06 O-Q	0.06 O-Q	0.16 M	0.28 G-J	0.31 F-I	0.33 FG	0.20 D
Hydrogen Peroxide	0.04 PQ	0.02 Q	0.22 KL	0.31 F-H	0.41 D	0.32 F-H	0.22 C
Methyl Jasmonate	0.07 O-Q	0.10 NO	0.18 LM	0.28 H-K	0.39 DE	0.47 C	0.24 B
Distilled water (Control)	0.04 PQ	0.18 LM	0.34 EF	0.35 EF	0.55 B	0.84 A	0.38 A
Mean	0.05 F	0.08 E	0.20 D	0.27 C	0.36 B	0.42 A	

Means in the same column having the same letter are not significantly different at 0.05 level by Duncan's multiple rang test.

Table 2: Effect of some postharvest treatments on general appearance (score) of sweet pepper fruits during cold storage plus shelf life in 2018 and 2019 seasons

	Storage period (days)						
	2018						
Treatments	0+2	2+7	2+14	2+21	2+28	2+35	Mean
Potassium Silicate	9.00 A	9.00 A	9.00 A	7.67 AB	7.00 BC	5.00 D	7.78 BC
Salicylic acid	9.00 A	9.00 A	9.00 A	8.33 AB	7.67 AB	7.00 BC	8.33 AB
Ascorbic acid	9.00 A	9.00 A	9.00 A	9.00 A	8.33 AB	7.67 AB	8.67 A
Hydrogen Peroxide	9.00 A	9.00 A	7.67 AB	7.00 BC	5.00 D	3.00 EF	6.78 D
Methyl Jasmonate	9.00 A	9.00 A	7.67 AB	7.67 AB	5.67 CD	4.33 DE	7.22 CD
Distilled water (Control)	9.00 A	7.00 BC	4.33 DE	3.00 EF	2.33 FG	1.00 G	4.44 E
Mean	9.00 A	8.67 A	7.78 B	7.11 B	6.00 C	4.67 D	
	2019						
Potassium Silicate	9.00 A	9.00 A	9.00 A	7.00 BC	7.00 BC	5.00 DE	7.67 B
Salicylic acid	9.00 A	9.00 A	9.00 A	7.67 AB	7.67 AB	7.00 BC	8.22 AB
Ascorbic acid	9.00 A	9.00 A	9.00 A	9.00 A	8.33 AB	7.67 AB	8.67 A
Hydrogen Peroxide	9.00 A	9.00 A	7.67 AB	7.00 BC	5.00 DE	3.00 F	6.78 C
Methyl Jasmonate	9.00 A	9.00 A	7.67 AB	7.00 BC	5.67 CD	3.67 EF	7.00 C
Distilled water (Control)	9.00 A	7.00 BC	3.67 EF	2.33 FG	2.33 FG	1.00 G	4.22 D
Mean	9.00 A	8.67 A	7.67 B	6.67 C	6.00 D	4.56 E	

Means in the same column having the same letter are not significantly different at 0.05 level by Duncan's multiple rang test.

ASA and H_2O_2 with no significant difference between them in the first season. MeJA treatment was less effective in this concern.

These results are in agreement with those reported by Rageh and Abou-Elwafa [47] for MeJA, Liang *et al*. [33] for potassium silicate and Yanthan *et al*. [8] and Díaz-Pérez *et al*. [9] for SA.

The application of exogenous organic acids such as SA and ASA has been found to affect fruit quality and induce stress tolerance [48]. These organic acids mainly function in maintaining the ability to inhibit O_2 accumulation, delaying H_2O_2 decrease and enhancing antioxidant enzyme activities with an increase in the expression of senescence related proteins or defense proteins to keeps the fruit in good quality during storage [49-51].

Salicylic acid maintained higher fruit firmness by maintaining cell membrane integrity which ultimately leads to less water loss and less shriveling [8].

The favorable effect of potassium silicate in reduction of weight loss was probably due to the modification of cell membranes after Si application that led to reduction of water loss and subsequently reduced fruit weight loss [36]. Silicon application also reduced electrolyte leakage in rice leaves. This may be attributed to the improved strength and rigidity of tissue following Si application [52].

The reducing weight loss % by using MeJA treatments may be attributed to reducing the respiration process during storage which slows down the metabolic processes and diminished the weight loss during storage [53, 54].

In general, the interaction between postharvest treatments and storage period plus shelf life was significant in the two seasons. Sweet pepper fruits treated with ASA or SA reduced weight loss percentage of fruits during all storage period with no significant differences between them, followed by potassium silicate treatment. On the other hand, the highest values of weight loss percentage are recorded from untreated control. These results were achieved in the two seasons.

General Appearance (Score): Data in Table (2) indicated that general appearance (GA) of sweet pepper fruits deceased with the prolongation of storage period plus shelf life. The decrease of general appearance of sweet pepper fruits during storage might be due to shriveling, pitting, color change of fruits and decay [46].

Concerning the effect of postharvest treatments, data revealed that sweet pepper fruits treated with all postharvest treatments had significantly the highest score of appearance as compared with untreated control. However, sweet pepper fruits dipped in ASA, SA and potassium silicate were the most effective treatments for maintaining GA followed by H_2O_2 or MeJA treatments with no significant differences between them, while untreated control recorded the lowest ones in this concern.

Table 3: Effect of some postharvest treatments on decay percentage of sweet pepper fruits during cold storage plus shelf life in 2018 and 2019 seasons.

	Storage period (days)						
	2018						
Treatments	0+2	2+7	2+14	2+21	2+28	2+35	Mean
Potassium Silicate	1.00 E	1.00 E	1.00 E	1.00 E	1.00 E	2.33 CD	1.22 BC
Salicylic acid	1.00 E	1.00 E	1.00 E	1.00 E	1.00 E	1.00 E	1.00 C
Ascorbic acid	1.00 E	1.00 E	1.00 E	1.00 E	1.00 E	1.00 E	1.00 C
Hydrogen Peroxide	1.00 E	1.00 E	1.00 E	1.00 E	2.00 D	2.67 C	1.44 B
Methyl Jasmonate	1.00 E	1.00 E	1.00 E	1.00 E	2.00 D	2.67 C	1.44 B
Distilled water (Control)	1.00 E	1.00 E	2.00 D	2.67 C	3.33 B	4.00 A	2.33 A
Mean	1.00 D	1.00 D	1.17 CD	1.28 C	1.72 B	2.28 A	
	2019						
Potassium Silicate	1.00 C	1.00 C	1.00 C	1.00 C	2.00 B	2.33 B	1.39 B
Salicylic acid	1.00 C	1.00 C	1.00 C	1.00 C	1.00 C	1.00 C	1.00 C
Ascorbic acid	1.00 C	1.00 C	1.00 C	1.00 C	1.00 C	1.00 C	1.00 C
Hydrogen Peroxide	1.00 C	1.00 C	1.00 C	1.00 C	2.00 B	2.67 B	1.44 B
Methyl Jasmonate	1.00 C	1.00 C	1.00 C	1.00 C	2.00 B	2.67 B	1.44 B
Distilled water (Control)	1.00 C	1.00 C	2.33 B	2.67 B	3.67 A	4.33 A	2.50 A
Mean	1.00 C	1.00 C	1.22 C	1.28 C	1.94 B	2.33 A	

Means in the same column having the same letter are not significantly different at 0.05 level by Duncan's multiple rang test.

These results were achieved in the two seasons and were in agreement with González-Aguilar *et al*. [13] for ASA; Rageh and Abou-Elwafa [47] for MeJA; Liang *et al.* [33] for potassium silicate; Promyou *et al*. [55] for SA and Mohamed *et al*. [56] for H_2O_2.

The application of ASA and SA are proposed that the increase in the activity of POX enzyme and decrease in activity of PPO enzyme with lowest chilling injury were generally a consequence of the system ability to delay senescence during cold storage and increase marketable fruits. These result compatible with [56, 57].

Mshraky *et al*. [58] found that the main effect of silicon application lies in suppression of respiration and ethylene production. Therefore, improving Si infiltration techniques could enhance shelf life of fruits. They add that Si increases antioxidant and total phenolics accumulation in the fruit, thereby, increasing the stress relieving ability of the fruit, producing fruit with a higher ability to withstand long-term storage.

In general, the interaction between postharvest treatments and storage periods plus shelf life was significant in the two seasons. Results indicated that sweet pepper fruits dipped in ASA and SA showed the best appearance which gave good appearance at the end of storage period plus shelf life (35 days at 5°C + 2 days at 15°C), while potassium silicate treatment gave good appearance after 28 days at 5°C + 2 days at 15°C. H_2O_2 and MeJA treatments rated good appearances after 21 days at 5°C + 2 days at 15°C. On the other hand, untreated control had the unsalable appearance at the end of storage period plus shelf life.

Decay Percentage: Data in Table (3) showed that there were significant increases in decay percentage with the prolongation of storage period plus shelf life in the two seasons. Some reactions may be due to the continuous chemical and biochemical changes happened in fruits such as transformation of complex compounds to simple forms of a more liability to fungal infection [46].

There were significant differences among postharvest treatments on decay percentage during storage plus shelf life. All postharvest treatments were much better in reducing decay percentage and so longer storage period compared with untreated control. However sweet pepper fruits treated with ASA and SA did not show any decay until the end of storage period plus shelf life in the two seasons.

Fruits treated with potassium silicate, H_2O_2 and MeJA reduced the incidence of decay % with no significant differences between them in the two seasons, while untreated control gave the highest decay %. These results were true in the two seasons and are in agreement with Saad [21] and Afifi [59] for potassium silicate; Rageh and Abou-Elwafa [47] for MeJA; Huang *et al*. [44]; Díaz-Pérez *et al*. [9] and Miura and Yasuomi [10] for SA; Lo'ay [30] and Samaan *et al*. [31] for ASA and Mohamed *et al*. [56] for H_2O_2.

Ghasemnezhad and Javaherdashti [60] demonstrated that MeJA increases the resistance of tissues against decay by enhancing their antioxidant system and their free radical scavenging capability. Also, Ding *et al*. [49] reported that treatment of tomato fruits with MeJA induced the expression of pathogenesis related-proteins

Table 4: Effect of some postharvest treatments on color change (L value) of sweet pepper fruits during cold storage plus shelf life in 2018 and 2019 seasons.

	Storage period (days)						
	2018						
Treatments	0+2	2+7	2+14	2+21	2+28	2+35	Mean
Potassium Silicate	51.72 A-C	50.74 B-D	48.73 E-K	47.98 I-M	47.54 J-O	45.65 PQ	48.73 B
Salicylic acid	52.73 A	52.28 AB	49.56 D-H	48.72 E-K	47.66 I-N	46.65 M-P	49.60 A
Ascorbic acid	51.92 AB	51.79 AB	52.26 AB	48.08 G-M	47.65 I-N	46.06 O-Q	49.63 A
Hydrogen Peroxide	50.19 C-E	49.79 D-F	49.02 E-J	48.01 H-M	46.02 O-Q	45.00 Q	48.01 C
Methyl Jasmonate	50.14 DE	49.64 D-G	48.27 F-L	47.01 L-P	46.00 O-Q	43.02 R	47.35 D
Distilled water (Control)	50.02 DE	49.18 D-I	47.21 K-P	46.22 N-Q	45.05 Q	41.59 R	46.54 E
Mean	51.12 A	50.57 A	49.18 B	47.67 C	46.65 D	44.66 E	
	2019						
Potassium Silicate	51.50 A-C	50.52 B-D	48.51 E-J	47.76 H-L	47.32 I-N	45.43 OP	48.51 B
Salicylic acid	52.53 A	52.08 AB	49.36 D-G	48.52 E-I	47.46 H-M	46.45 L-O	49.40 A
Ascorbic acid	51.74 AB	51.61 AB	52.08 A	47.90 G-L	47.47 H-M	45.88 N-P	49.45 A
Hydrogen Peroxide	49.95 C-E	49.55 D-F	48.78 E-I	47.77 H-L	45.78 N-P	44.76 P	47.76 C
Methyl Jasmonate	49.89 DE	49.39 D-G	48.02 F-K	46.76 K-O	45.75 OP	42.77 Q	47.10 D
Distilled water (Control)	49.76 DE	48.92 E-H	46.95 J-O	45.96 M-P	44.79 P	41.33 Q	46.28 E
Mean	50.90 A	50.35 A	48.95 B	47.44 C	46.43 D	44.44 E	

Means in the same column having the same letter are not significantly different at 0.05 level by Duncan's multiple rang test.

including B-1,3glucanase and chitinass leading to increased chilling tolerance and resistance to pathogens, thereby reducing the incidence of fruit decay during storage.

Also there are many reports indicating that SA is an endogenous signal for the activation of certain plant defense responses and is able to enhance disease resistance [53]. The reduce in decayed fruits treated with SA may be due to an increase in activity of POX enzyme and decrease activities in PPO and PE enzyme of Valencia oranges during cold storage.

As for the effect of potassium silicate, Tarabih *et al*. [61] found that potassium silicate increase the concentration of antifungal compounds and or the enzyme PAL to be able to increase the concentration of phenolic compounds present at later ripening stages in order to decrease decay incidence in apple fruit.

The favorable effect of ASA is a major water-soluble antioxidant in plants and it is one of the most abundant plant antioxidants. Moreover, ASA is one of the most powerful antioxidants [28]. ASA maintained the cell plasma membranes structure, less oxidative reactions accumulations and effectively controlled the enzymatic browning and cell death of fruits [29].

H_2O_2 is one of ROS and used as alternative to chemical materials for disinfecting fruits and vegetables to reduce microbial populations and prolong the shelf life without leaving significant residues or causing loss of postharvest quality [62, 63]. Postharvest treatment with H_2O_2 controlled postharvest green mold of lemons [64]. In addition, postharvest applications of H_2O_2 of pepper fruits reduced weight loss and rot rate as well as enhanced antioxidants content and improved general appearance during cold storage at 10°C for four weeks or during shelf life at 20°C for two weeks as compared to untreated fruits [3].

The reduction of rot rate by using H_2O_2 attributed to H_2O_2 as a reactive oxygen species (ROS), which play an important role in resistance of plant diseases to infection with pathogens [3].

Color (L value): Data in Table (4) showed that there was a significant decrease in L value with increasing storage period for all postharvest treatments or control, showing darker fruits. Hamdy *et al*. [54] found that jasmine oil vapor effectively maintained squash fruit brightness for 9 days during cold storage period, as jasmine vapor exposed fruits displayed more shiny and bright appearance than control fruits.

However, all postharvest treatments significantly reduced the loss of L value compared with untreated control. Sweet pepper fruits treated with ASA or SA had significant higher L value indicating lighter fruits with no significant difference between them in the two seasons, followed by potassium silicate treatment during cold storage plus shelf life, H_2O_2 and MeJA treatments were less effective in this concern, while untreated control had darker color (low L value).

Table 5: Effect of some postharvest treatments on color change (b value) of sweet pepper fruits during cold storage plus shelf life in 2018 and 2019 seasons.

Treatments	Storage period (days) 0+2	2+7	2+14	2+21	2+28	2+35	Mean
2018							
Potassium Silicate	33.20 N-Q	33.94 M-P	34.26 L-O	35.83 I-L	38.93 D-F	39.73 CD	35.98 D
Salicylic acid	32.02 QR	34.40 K-N	36.55 G-J	37.74 E-G	38.73 D-F	39.84 CD	36.55 CD
Ascorbic acid	32.53 PQ	32.75 O-Q	33.12 N-Q	35.08 J-M	45.09 A	39.24 C-E	36.30 CD
Hydrogen Peroxide	30.56 R	36.27 G-J	36.71 G-I	37.53 F-H	39.71 CD	39.82 CD	36.77 C
Methyl Jasmonate	35.63 I-L	36.52 G-J	38.51 D-F	38.63 D-F	41.99 B	43.97 A	39.21 A
Distilled water (Control)	35.85 I-K	36.10 H-J	36.14 H-J	37.48 F-H	38.68 D-F	40.53 BC	37.46 B
Mean	33.30 E	35.00 D	35.88 C	37.05 B	40.52 A	40.52 A	
2019							
Potassium Silicate	32.68 L-O	33.42 K-N	33.74 J-M	35.31 IJ	38.41 C-F	39.21 CD	35.46 D
Salicylic acid	31.52 OP	33.90 J-L	36.05 G-I	37.24 E-G	38.23 D-F	39.34 CD	36.05 CD
Ascorbic acid	32.08 NO	32.30 M-O	32.67 L-O	34.63 I-K	44.64 A	38.79 C-E	35.85 CD
Hydrogen Peroxide	30.02 P	35.73 G-I	36.17 G-I	36.99 F-H	39.17 CD	39.28 CD	36.23 C
Methyl Jasmonate	35.05 IJ	35.94 G-I	37.93 D-F	38.05 D-F	41.41 B	43.39 A	38.63 A
Distilled water (Control)	35.29 IJ	35.54 HI	35.58 HI	36.92 F-H	38.12 D-F	39.97 BC	36.90 B
Mean	32.77 E	34.47 D	35.36 C	36.52 B	40.00 A	40.00 A	

Means in the same column having the same letter are not significantly different at 0.05 level by Duncan's multiple rang test.

These results may be attributed to ASA and potassium silicate which delayed fruit senescence in which the external and internal color was lighter than of untreated control. Tareen *et al*. [51] found that peach fruits illustrated that immersing in SA solution reduced the changes in fruits color and maintains fruits lightness during cold storage.

Color (b value): Changes in b values of sweet pepper fruits are indicator of senescence data in Table (5) showed that the b values of sweet pepper fruits gradually increased as the storage turned to full yellow as the storage period prolonged.

With the increasing of storage periods sweet pepper fruits color was changed from green yellow to full yellow in all treatments, all the ASA, SA and potassium silicate treatments significantly reduced the change rate of yellow color compared with untreated fruits during the two seasons, this if mean delayed fruit ripening and senescence.

Fruits dipped in ASA, potassium silicate and SA were the more effective treatments in reducing the loss of b value indicated that fruits retained more green color during storage plus shelf life, followed MeJA or H_2O_2 with significant differences between them. While lower b value were detected in the untreated control indicated that fruits had less yellow color, MeJA treatments were less effective in this concern. These results were in the two seasons and in agreement with Mohamed *et al*. [56] for H_2O_2 and Díaz-Pérez *et al*. [9] and Miura and Yasuomi [10] for SA.

The reduction of color development in sweet pepper fruits treated with ASA, SA or potassium silicate could be attributed to the low rate of respiration rate and reduced ethylene production resulted in lower activity of chlorophylls and chlorophyll degradation, so maintained green color of sweet pepper fruits. These results were true in the two seasons and are in agreement with [65] for MeJA; Fung *et al*. [7]; Mandal *et al*. [66] and Kumar *et al*. [67] for SA and Mditshwa *et al*. [14 and15] for potassium silicate.

Chilling Injury (CI): Sweet pepper fruits in this study were evaluated for the severity of appearance of CI two days following transfer from 5°C to 15°C. Results in Table (6) indicated that sweet pepper fruits in all treatments appeared without any symptoms of pitting after 14 days at 5° C + 2 days at 15° C.

The differences in the severity of CI among different treatments became more appearance as time progressed. This results were in agreement with Fung *et al*. [7] and may be due to CI (surface pitting) may be due to the increase of ethylene evolution and level of amino cyclopropanecarboxlic acid (ACC), putrescine and ASA. The high concentration of these chemicals in the preicarp tissue induced chilled fruits with pitting appearance [68].

Slight of chilling injury were found on the skin of sweet pepper fruits in the untreated control on the 21 days at 5°C + 2 day at 15°C and the symptoms of chilling injury became more apparent in these fruits after 28 days of storage at 5°C + 2 day at 15°C, reached the severe stage by 35th days at 5°C + 2 day at 15°C (severity of CI at 5°C).

Table 6: Effect of some postharvest treatments on chilling injury (score) of sweet pepper fruits during cold storage plus shelf life in 2018 and 2019 seasons

	Storage period (days)						
	2018						
Treatments	0+2	2+7	2+14	2+21	2+28	2+35	Mean
Potassium Silicate	1.00 E	1.00 E	1.00 E	1.00 E	1.00 E	2.00 CD	1.17 C
Salicylic acid	1.00 E	1.00 E	1.00 E	1.00 E	1.00 E	1.00 E	1.00 C
Ascorbic acid	1.00 E	1.00 E	1.00 E	1.00 E	1.00 E	1.00 E	1.00 C
Hydrogen Peroxide	1.00 E	1.00 E	1.00 E	1.33 DE	2.33 BC	3.00 B	1.61 B
Methyl Jasmonate	1.00 E	1.00 E	1.00 E	1.00 E	2.33 BC	2.67 BC	1.50 B
Distilled water (Control)	1.00 E	1.00 E	1.00 E	2.00 CD	3.00 B	4.00 A	2.00 A
Mean	1.00 C	1.00 C	1.00 C	1.22 C	1.78 B	2.28 A	
				2019			
Potassium Silicate	1.00 F	1.00 F	1.00 F	1.00 F	1.00 F	2.67 CD	1.28 CD
Salicylic acid	1.00 F	1.00 F	1.00 F	1.00 F	1.00 F	1.00 F	1.00 D
Ascorbic acid	1.00 F	1.00 F	1.00 F	1.00 F	1.00 F	1.00 F	1.00 D
Hydrogen Peroxide	1.00 F	1.00 F	1.00 F	1.33 EF	2.33 D	3.67 B	1.72 B
Methyl Jasmonate	1.00 F	1.00 F	1.00 F	1.00 F	2.33 D	3.33 BC	1.61 BC
Distilled water (Control)	1.00 F	1.00 F	1.00 F	2.00 DE	3.67 B	5.00 A	2.28 A
Mean	1.00 C	1.00 C	1.00 C	1.22 C	1.89 B	2.78 A	

Means in the same column having the same letter are not significantly different at 0.05 level by Duncan's multiple rang test.

However, sweet pepper fruits treated with ASA and SA did not develop any symptoms of CI during all storage period plus shelf life. The onset of CI symptoms in fruits was delayed by potassium silicate, MeJA and H_2O_2 treatments. However these treatments reduced the rate of CI development.

These results were true in the two seasons and in agreement with Mohamed *et al*. [56] who found that Si improved the levels of flavonoids and phenolics, they had an adverse effect on fruit by increasing the occurrences of chilling injury. However, increased levels of flavonoids and phenolics in response to high concentrations of Si suggest that Si may be involved in modulating enzyme.

The impaired visual fruit quality after postharvest silicon applications should be considered as a method to reduce postharvest chilling injury.

Luo *et al*. [20] observed that SA treatment (1.5 mM for 10 min) significantly reduced CI effect in plum fruits and this event was associated with enhanced endogenous polyamines accumulation and led to reduction of MDA, associated with improved cell membrane integrity [20]. Postharvest treatment of bamboo shoot with 1.0 mM SA for 15 min effectively alleviated CI and this effect was associated with reducing electrolyte leakage, MDA and total phenol contents and shoot tissue browning [20].

Wang *et al*. [69] found that MeJA enhance the resistance of tissues to chilling injury by increasing the gene expression of heat shock proteins, pathogenesis-related proteins and alternative oxidase. Also, MeJA increased antioxidant capacities, antioxidant enzyme activities and free radical scavenging capacities in the tissues.

Sayyari *et al*. [18] found that SA can play a role in inducing PR gene transcription and protect against chilling injury most likely arises from reports that SA can inhibit catalase activity in several plant species.

Fruit Firmness: Data in Table (7) reveled that fruit firmness was gradually and consistently decreased with the prolongation of storage period and reached the lowest value at the end of storage period. The losses of fruit firmness are associated with changes in cell wall mechanical strength during storage [70]. Also, the loss of fruit firmness starts with the conversion of insoluble protopectin into water soluble pectin by breakdown of the middle lamellae, which is intimately related to hydrolytic enzyme, so rigidity of cell walls was reduced and led to fruit softening [71]. These results were true in the two seasons and are in agreement with those obtained by Ahmed *et al*. [72] and Abdullah and Srour [73].

Concerning the effect of postharvest treatments, data revealed that all postharvest treatments had a significant effect on fruit firmness as compared with untreated control during storage plus shelf life. However, sweet pepper fruits treated with ASA, potassium silicate or SA were the most effective treatment in reducing the loss of firmness during storage with no significant differences between them in the second season, followed by MeJA and H_2O_2 treatments with no

Table 7: Effect of some postharvest treatments on fruit firmness (LP/in^2) of sweet pepper fruits during cold storage plus shelf life in 2018 and 2019 seasons

Treatments	Storage period (days) 2018 0+2	2+7	2+14	2+21	2+28	2+35	Mean
Potassium Silicate	3.43 A	3.40 A	3.17 AB	3.08 A-C	3.02 A-D	2.95 A-E	3.18 A
Salicylic acid	3.42 A	3.10 A-C	3.10 A-C	3.08 A-C	2.85 A-F	2.80 A-H	3.06 A
Ascorbic acid	3.17 AB	3.02 A-D	2.83 A-G	2.57 B-K	2.50 C-L	2.01 J-L	2.68 B
Hydrogen Peroxide	2.84 A-F	2.67 B-I	2.63 B-J	2.57 B-K	2.40 D-L	2.17 H-L	2.55 B
Methyl Jasmonate	2.90 A-E	2.80 A-H	2.60 B-K	2.50 C-L	2.35 E-L	2.20 G-L	2.56 B
Distilled water (Control)	2.50 C-L	2.23 F-L	2.10 I-L	1.97 K-M	1.90 LM	1.37 M	2.01 C
Mean	3.04 A	2.87 AB	2.74 BC	2.63 BC	2.50 CD	2.25 D	
2019							
Potassium Silicate	3.13 AB	3.10 AB	2.87 A-E	2.78 A-F	2.72 A-G	2.65 A-G	2.88 A
Salicylic acid	3.22 A	2.90 A-D	2.90 A-D	2.88 A-D	2.65 A-G	2.60 A-H	2.86 A
Ascorbic acid	3.12 AB	2.97 A-C	2.78 A-F	2.52 B-I	2.45 C-J	1.96 H-O	2.63 A
Hydrogen Peroxide	2.44 C-J	2.27 D-M	2.23 E-M	2.17 F-M	2.00 H-O	1.77 K-P	2.15 B
Methyl Jasmonate	2.40 C-K	2.30 D-L	2.10 G-N	2.00 H-O	1.85 J-P	1.70 L-P	2.06 B
Distilled water (Control)	1.90 I-P	1.63 M-P	1.50 N-P	1.37 O-Q	1.30 PQ	0.77 Q	1.41 C
Mean	2.70 A	2.53 AB	2.40 BC	2.29 BC	2.16 CD	1.91 D	

Means in the same column having the same letter are not significantly different at 0.05 level by Duncan's multiple rang test.

significant difference between them in the two seasons. The lowest value of fruit firmness was obtained from untreated control. These results were in agreement with Saad [21] for SA and potassium silicate and Rageh and Abou-Elwafa [47] for MeJA.

Higher level of firmness in salicylic acid treated sweet pepper could be attributed to reduction of ethylene biosynthesis by salicylic acid which consequently lowered the activity of cell wall degrading enzymes and thereby helped in retaining the firmness [7].

MeJA are shown to induce phenylala-nine ammonia lyase, superoxide dismutase and polygalacturonase. The favorable effect of MeJA on maintained fruit firmness. Feng *et al*. [74] reveled that MeJA maintained higher pectinasterase and polyglacturonase activities, thereby preventing the development of fresh firmness of peaches. Also, MeJA induce synthesis of abscisic acid and polyamines which act as free radical scavengers and membrane stabilizer as an indicator of membrane integrity were maintained [69].

Tesfay *et al* [38] reported that silicon-treated fruit had lower electrolyte leakage compared with the control, possibly due to Si deposition between cell wall and cell membrane, maintaining a barrier against solute leakage.

Also, Si may enhance activity of chitinases, peroxidase and polyphenol oxidases and increased formation deposition of callose and hydrogenperoxidesalso, silicon application improved strength and rigidity of tissue [52].

The interaction between postharvest treatments and storage period was significant in the two seasons. After 35 days at storage period at 5°C + 2 day at 15°C, data reversed that sweet pepper fruits dipped in potassium silicate and SA treatments had significantly higher fruits firmness as compared with the other treatments or untreated control in two seasons.

Total Carotenoids: Data in Table (8) showed that carotenoids accumulation was observed in all treatments and untreated control throughout storage period plus shelf life. The data show generally increasing pattern with significant variation among different treatments. During onset of ripening and sweet pepper development distraction of food pigments (chlorophyll) occurs and hence carotenoids content increase [75, 76]. Carotenoids content increase with advancement in storage conditions [77].

Concerning the effect of postharvest treatments, data showed that all postharvest treatments decreased the accumulation of carotenoids content compared with untreated control, however, the lowest accumulation of carotenoids content was found in potassium silicate and SA with significant difference between them followed by ascorbic acid and H_2O_2 with no significant difference between them in the first season, while Methyl jasmonate was less effective in reducing the accumulation of carotenoids content. These results were agreement with Díaz-Pérez *et al*. [9].

Table 8: Effect of some postharvest treatments on carotenoids content (mg/100gm f.w) of sweet pepper during cold storage plus shelf life in 2018 and 2019 seasons

	Storage period (days)						
	2018						
Treatments	0+2	2+7	2+14	2+21	2+28	2+35	Mean
Potassium Silicate	2.45 R	2.52 PQ	2.59 M-O	2.66 I-K	2.71 G-I	2.74 E-G	2.61 E
Salicylic acid	2.48 QR	2.55 N-P	2.61 K-M	2.68 H-J	2.74 E-G	2.79 C-E	2.64 D
Ascorbic acid	2.50 P-R	2.59 M-O	2.65 J-L	2.70 G-J	2.75 D-G	2.80 B-D	2.67 C
Hydrogen Peroxide	2.52 PQ	2.61 K-M	2.66 I-K	2.71 G-I	2.77 C-F	2.82 BC	2.68 BC
Methyl Jasmonate	2.54 OP	2.62 K-M	2.68 H-J	2.73 F-H	2.79 C-E	2.85 AB	2.70 B
Distilled water (Control)	2.60 L-N	2.65 J-L	2.70 G-J	2.75 D-G	2.82 BC	2.90 A	2.74 A
Mean	2.52 F	2.59 E	2.65 D	2.71 C	2.76 B	2.82 A	
	2019						
Potassium Silicate	2.00 T	2.05 ST	2.10 RS	2.15 QR	2.22 OP	2.30 LM	2.14 F
Salicylic acid	2.04 T	2.12 R	2.18 PQ	2.23 N-P	2.29 M	2.35 J-L	2.20 E
Ascorbic acid	2.12 R	2.21 OP	2.26 M-O	2.31 K-M	2.37 H-J	2.42 GH	2.28 D
Hydrogen Peroxide	2.15 QR	2.22 OP	2.29 M	2.36 I-K	2.41 G-I	2.44 FG	2.31 C
Methyl Jasmonate	2.28 MN	2.35 J-L	2.41 G-I	2.48 F	2.54 E	2.59 DE	2.44 B
Distilled water (Control)	2.45 FG	2.54 E	2.60 CD	2.65 BC	2.70 AB	2.75 A	2.62 A
Mean	2.17 F	2.25 E	2.31 D	2.36 C	2.42 B	2.48 A	

Means in the same column having the same letter are not significantly different at 0.05 level by Duncan's multiple rang test.

Mohamed *et al.* [56] for SA and Mayer [57] for potassium silicate: Silicon enhanced the antioxidant capacity such as VC and carotenoids [14]. SA is also an endogenous growth regulator with phenolic nature, which participates in the regulation of several physiological processes in plants, such as stomata closure, ion uptake, inhibition of ethylene biosynthesis and transpiration and delay accumulation of carotenoids [78].

SA increases antioxidant activity through the expression of oxidase gene, removes toxic effects of free radicals and protects plant cell tensions against all kinds of stresses [66, 67]. Pila *et al*. [79] stated that SA increased the activity of phenylalanine ammonia-lyase enzyme, a key enzyme in the phenylpropanoids metabolism, enhanced the synthesis and accumulation of important phenolic compounds with antioxidant properties and finally increased tissue resistance to living and non-living stressors.

The lowest carotenoids content form SA and potassium silicate treatments is due to the effect of this materials reduced respiration rate and which provides a decrease in metabolism activities and suppressing the enzyme activities so, reduced the accumulation of carotenoids content during storage according to Saniawski and Czapski [80] and Glick1*et al*. [81] for MeJA; Carvajal *et al*. [82] for ASA and Aghdam [16] for SA.

Interaction had significant effect of carotenoids and data showed that after 35 days at 5°C plus 2 days at 15°C, sweet pepper fruits dipped in potassium silicate and SA reduced carotenoids development with no significant difference between them followed by H_2O_2 and ASA treatments with no significant difference between them, the highest value of carotenoid was recorded from untreated control.

Ascorbic Acid Content (Vit. C): Data in Table (9) showed that the highest values of ASA contents were shown in the initial storage, however, the lowest ones were given in the last storage period (35 days). These results agree with Abdullah and Srour [73] who found that there were significant reductions in ASA content with the increase of storage period.

The reduction in ASA contents during storage may be due to the higher rate of sugar loss through respiration than the water loss through transpiration [46]. Also; losses in ASA contents were associated with senescence and quality deterioration of the fruits [83].

Regarding the effect of treatments, data showed that all postharvest treatments were effective in preventing ASA degradation during storage plus shelf life as compared with untreated control. Moreover, fruits dipped in ASA were the most effective treatment in maintaining ASA content, followed by potassium silicate and SA with no significant differences between them in the two seasons. The lowest values resulted in untreated control. These results were achieved in the two seasons and were in agreement with Liang *et al*. [33] for potassium silicate; Promyou *et al*. [55] for SA and Samaan *et al*. [31] for ASA.

Table 9: Effect of some postharvest treatments on Ascorbic acid content (mg/100 gm f.w) of sweet pepper during cold storage plus shelf life in 2018 and 2019 seasons

	Storage period (days)						
	2018						
Treatments	0+2	2+7	2+14	2+21	2+28	2+35	Mean
Potassium Silicate	188.90 CD	179.40 D-F	158.60 HI	169.00 F-H	169.90 F-H	163.80 GH	171.60 B
Salicylic acid	184.40 C-E	175.10 E-G	190.70 CD	162.90 GH	169.90 F-H	161.00 H	174.00 B
Ascorbic acid	231.40 A	195.00 BC	234.00 A	237.50 A	206.30 B	232.30 A	222.70 A
Hydrogen Peroxide	167.40 F-H	164.70 GH	148.20 IJ	159.50 HI	158.60 HI	158.60 HI	159.50 C
Methyl Jasmonate	144.70 JK	148.20 IJ	136.10 J-L	135.20 K-M	143.90 JK	108.30 O	136.10 D
Distilled water (Control)	126.50 L-N	123.10 MN	116.10 NO	105.70 O	116.10 NO	90.13 P	113.00 E
Mean	173.90 A	164.20 B	163.90 B	161.60 B	160.80 B	152.40 C	
	2019						
Potassium Silicate	186.60 CD	177.10 D-F	156.30 HI	166.70 F-H	167.60 F-H	161.50 GH	169.30 B
Salicylic acid	182.20 C-E	172.90 E-G	188.50 CD	160.70 GH	167.70 F-H	158.80 H	171.80 B
Ascorbic acid	229.40 A	193.00 BC	232.00 A	235.50 A	204.30 B	230.30 A	220.70 A
Hydrogen Peroxide	165.00 F-H	162.30 GH	145.80 IJ	157.10 HI	156.20 HI	156.20 HI	157.10 C
Methyl Jasmonate	142.20 JK	145.70 IJ	133.60 J-L	132.70 K-M	141.40 JK	105.80 O	133.60 D
Distilled water (Control)	123.90 L-N	120.50 MN	113.50 NO	103.10 O	113.50 NO	87.53 P	110.40 E
Mean	171.60 A	161.90 B	161.60 B	159.30 B	158.40 B	150.00 C	

Means in the same column having the same letter are not significantly different at 0.05 level by Duncan's multiple rang test.

Table 10: Effect of some postharvest treatments on TSS content (%) of sweet pepper fruits during cold storage plus shelf life in 2018 and 2019 seasons

	Storage period (days)						
	2018						
Treatments	0+2	2+7	2+14	2+21	2+28	2+35	Mean
Potassium Silicate	7.10 A-C	6.97 A-E	6.33 F-J	6.47 D-I	5.87 J-M	5.27 NO	6.33 B
Salicylic acid	7.30 AB	7.25 AB	7.15 A-C	7.10 A-C	7.00 A-D	6.30 G-IJ	7.02 A
Ascorbic acid	7.40 A	7.30 AB	7.25 AB	7.20 AB	7.15 A-C	6.90 A-F	7.20 A
Hydrogen Peroxide	6.90 A-F	6.10 H-K	5.47 L-N	5.60 K-N	5.13 NO	4.40 QR	5.60 C
Methyl Jasmonate	6.80 B-G	6.40 E-IJ	6.00 I-L	5.50 L-N	5.03 N-P	4.70 O-Q	5.74 C
Distilled water (Control)	6.60 C-H	6.00 I-L	5.35 MN	4.50 P-R	3.93 RS	3.60 S	5.00 D
Mean	7.02 A	6.67 B	6.26 C	6.06 C	5.69 D	5.19 E	
	2019						
Potassium Silicate	6.80 A-D	6.67 B-E	6.03 F-J	6.17 E-H	5.57 I-M	4.97 N-P	6.03 C
Salicylic acid	7.10 AB	7.05 A-C	6.95 A-C	6.90 A-C	6.80 A-D	6.10 E-I	6.82 B
Ascorbic acid	7.35 A	7.25 A	7.20 AB	7.15 AB	7.10 AB	6.85 A-D	7.15 A
Hydrogen Peroxide	6.50 C-F	5.70 H-L	5.07 M-P	5.20 L-O	4.73 O-Q	4.00 RS	5.20 D
Methyl Jasmonate	6.30 D-G	5.90 G-K	5.50 J-N	5.00 M-P	4.53 P-R	4.20 Q-S	5.24 D
Distilled water (Control)	6.00 F-J	5.40 K-N	4.75 O-Q	3.90 ST	3.33 TU	3.00 U	4.40 E
Mean	6.68 A	6.33 B	5.92 C	5.72 C	5.34 D	4.85 E	

Means in the same column having the same letter are not significantly different at 0.05 level by Duncan's multiple rang test.

Postharvest treatment of sweet pepper with ASA and SA contribute to maintain high level of ASA via reduce of ASA oxidase (AAO) activity, the enzyme responsible for ASA oxidation and thus for the loss of this key antioxidants molecule [84]. Reduction of AAO enzyme activity by this treatment was useful for the upholding of nutrition and organoleptic quality due to maintenance of AA content, which crucially contributes to the antioxidant capacity [85].

In general, the interaction between postharvest treatments and storage periods plus shelf life was significant in the two seasons, after 35 days, at 5°C + 2 days, at 15°C, sweet pepper fruit dipped in ASA resulted in higher ASA content, followed by SA and potassium silicate with no significant difference between them in the two seasons, while untreated control gave the lowest ones.

Total Soluble Solids (TSS): Data in Table (10) initiated that TSS of sweet pepper decreased with the prolongation of storage until 35 days at 5°C + 2 day at 15°C in both seasons. Regarding the effect of treatments, data revealed that there was significant difference between treatments and untreated control in TSS% of sweet pepper during storage and shelf life. Sweet pepper dipped in ASA and SA retained more TSS percentage with no significant difference between them, followed by potassium silicate.

Untreated control gives the lowest value of TSS%. The results were achieved in the two seasons and were in agreement with their obtained by Saad [21] for Potassium silicate and SA on cucumber and Samaan *et al*. [31] for ASA. The effect of ASA, SA and potassium silicate treatments in maintaining of the TSS was probably due to the slowing down of the respiration and metabolic activity, hence delaying the ripening process [8, 21, 53, 54, 86]. With slower respiration rate, the synthesis and utilization of metabolites and conversion of carbohydrates to sugars also slowed down which in turn lower the TSS [87].

In general, the interaction between treatments and storage period plus shelf life was significant in the two seasons. After 35 days at 5° C + 2 day at 15° C., sweet pepper dipped in ASA or SA resulted in significant higher TSS% with significant difference between them, followed by potassium silicate and MeJA treatments with significant difference between them in the first season, while untreated control gave the lowest ones in the same period.

CONCLUSION

From the previous results, it could be concluded that, sweet pepper fruits dipped in solution of ASA or SA treatments were the most effective treatments in maintaining quality and give fruits with good appearance without decay and chilling injury symptoms till 35 days at 5°C + 2 day at 15°C.

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