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Research Article

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Effect of Preharvest Chitosan and/or Salicylic Acid Spray on Quality and Shelf Life of Tomato Fruits

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Abstract The present study was conducted to study the effect of chitosan and salicylic acid on physico-chemical quality attributes, ripening time and shelf life of the tomato variety Faridah. Fruits were treated with chitosan (Chi) and/or salicylic acid (SA) in different concentrations: 0.0, 4.0 and 6.0 g l^{-1} for Chi and 0.0, 1.0 and 2.0 g l^{-1}, for SA either alone or in combinations. Treating tomato fruits with 4.0 and 6.0 g l^{-1} Chi combined with 2.0 g l^{-1} SA increased fruit firmness, weight, length, diameter, juice volume, colour intensity, carotenoids, chlorophyll, total and reducing sugars, SSC, acidity, ascorbic acid content. Also, an extended fruit shelf life and delayed ripening were obtained. In the mean time, the treatments decreased fruit decay incidence, electrolyte leakage and pH as well as, unmarketable fruits.

Keywords Tomato Fruits; Chitosan; Salicylic Acid; Preharvest Spray; Quality; Shelf Life

1. Introduction

A remarkable worldwide increase in producing, marketing and consuming fresh fruits and vegetables is monitored [1]. This increase is not only linked to the growth of the world population and to the consequent demand of fruits and vegetables, but also to the continuous improving of the produce quality in the emerging countries [2]. A big quantity of fresh horticultural commodities that are objective of both international and internal markets should be characterized by high quality and nutritional properties that could be maintained until reaching the final consumer [3].

Never the less, there is increasing evidence that diet can play an important role in human health by providing important substances which activate the body defense system against several diseases. For example, tomatoes (*Solanum lycopersicon* L.) is a major contributor of carotenoids (especially lycopene), phenols, vitamin C and small amounts of vitamin E in daily diets [4] and results of several epidemiological studies showed that tomatoes and tomato products may have a protective effect against various forms of cancer and cardiovascular diseases [5]. Thus, tomatoes are an important and widely cultivated vegetable in Saudi Arabia. According to FAO [6], the annual tomato production in Saudi Arabia reached 525,588 tons from a total area of 6700 hectares.

Even though efforts are being made to help increase tomatoes production, maximum profit is only obtained if the increased production is accompanied with high quality attributes and minimum postharvest losses [7]. Tomatoes are fruits with high metabolism that makes them very perishable, impairing their storage and shelf life. Therefore, treatments that extend fruit life by delaying ripening and reducing diseases infection are essential if tomato fruits are to be stored or shipped to distant markets or even introduced to the local ones.

In most cases, synthetic pesticides application is the primary means of controlling many diseases of fruits and vegetables, where also emergence of new races of pathogens diversity is reported [8]. Additionally, due to the

concern of the public about food safety on human health and environment, restrictions are made for pesticide usage on the fresh product [9]. Therefore, many international markets in the recent years are highly demanding produce that are not /or treated with the least amount of pesticides in particular those preharvest applied. [10].
Accordingly, interests are made to find effective alternatives to pesticides in order to control fruit diseases, as well as marinating fruit quality. Fruits and vegetables may be able to develop enhanced resistance to pathogens infection by pre-or postharvest treatments with a variety of organic chemical elicitors such as salicylic acid, jasmonic acid and chitosan [11]. Thus, chitosan pre-or postharvest application has been considered as an alternative to the use of synthetic fungicides in order to prevent postharvest decay and extend storage life as well as retain the overall quality of different fresh fruit and vegetable commodities [12]. Also, the use of chitosan and salicylic acid to defense and to improve resistant of tomato fruits against pathogens attacks in the field or during storage is previously reported by Liu et al. [13]. Moreover, the aspect that chitosan treated fruits may retain their nutritional value could be explained by the fact that chitosan retains ascorbic and phenolic compounds contents, which are positively correlated with antioxidant capability.
In accordance to the above discussed, the purpose of this work was to study the effect of different pre-harvest applications of chitosan (Chi) and salicylic acid (SA) sprayed either alone or in combinations on the retention of fruit quality attributes and nutritional value of fresh tomatoes variety Faridah at harvest and during shelf life.

2. Materials and Methods

2.1. Plant material and cultivation

A greenhouse experiment was conducted on tomato plants (*Solanum lycopersicon L.*) cultivar Faridah throughout the growing season of 2013. The experiment was carried out at the Research and Agricultural Experiment Station at Dirab, King Saud University, Riyadh. Tomato plants were planted at a spacing of 100 cm between rows and 40 cm between plants. The greenhouse conditions were 27 ± 2°C at day time and 18 ± 2°C at night with a relative humidity (R.H.) of 70 ± 10%. Tomato plants were irrigated and supplemented with mineral fertilizers according to the regular program followed for tomato plants.

2.2. Prehrvest treatments and statistical design

Organic chemical elicitors including chitosan and salicylic acid were used at different concentrations: 0.0, 4.0 and 6.0 g l^{-1} for chitosan (Chi_0, Chi_1, and Chi_2, respectively) and 0.0, 1.0 and 2.0 g l^{-1}, for salicylic acid (SA_0, SA_1 and SA_2, respectively) either alone or in combinations. Nine foliage preharvest treatments were laid out in a randomized complete block design (RCBD) with three replications for each treatment and eight plants for each replicate. The zero control treatment was sprayed with sterile distilled water only. Tomato plants were sprayed with the chemical elicitors solutions for 15-20 days starting when fruits were at the mature green stage (fruit surface is completely green in colour) until before harvesting with a hand pressure sprayer (20 litre in volume). The leaves and the fruits of each plant were completely drenched to a slightly run off by spraying in clockwise and then in anti-clockwise direction. The wetting agent Tween-20 was added to all treatments including the control at the rate of 40 cm^3/100 L water.

2.3. Fruit samples and processing

Thirty tagged tomato fruits (sorted with similar size and free from physical injuries or any disease infection) per each replicate were harvested when they reached the light red ripe stage according to Kader [3]. Fruits were then transported to the Department of Plant Production Research Laboratory for investigations. Ten fruits per replicate were taken to measure the effect of the different preharvest applications on fruit physico-chemical characteristics at harvest. Additionally, the remaining twenty fruits per replicate were surface disinfectant with 2% sodium hypochlorite for 3 min, then rinsed with water, air-dried and placed in foam trays measuring 23.0 x 17.0 cm, over wrapped with PVC film and held in room chambers at ambient temperature (25°C ± 1) and 85-90% relative humidity (R.H.) for sixteen-day shelf live where after the fruits physico-chemical characteristics were measured as well as fruit shelf life.

2.4. Measured parameters

2.4.1. Percentage of harvested fruits

The harvest date of the control treatment (first harvest date) was recorded. Also, the number of fruits of each treatment harvested at the first harvest date was recorded and the percentage of harvested fruits of each treatment was calculated as follows:

$$\text{Harvested fruits (\%)} = \frac{\text{Number of harvested fruits at first harvest date}}{\text{Total number of harvested fruits}} \times 100$$

2.4.2. Fruit physical characteristics

Fruit weight (g), length (cm), diameter (cm), shape index and juice volume (cm^3) were measured. Also, fruit firmness (puncture force) was measured using a hand penetrometer (Fruit Pressure Tester, Make: Effegi, Model: PT 327) and the pressure required to penetrate the fruit was recorded in kg/cm^2. In addition, fruit ground fruit colour was estimated using a gradient of colour intensity as follow: (1) = 100 % green, (2) = 20 % red, (3) = 30 % red, (4) = 40 % red, (5) = 50 % red, (6) = 60 % red, (7) = 70 % red, (8) = 80 % red, (9) = 90 % red and (10) = 100 % red.

2.4.3. Fruit chemical characteristics

The percentage of soluble solids content **(**SSC) was determined by hand refractometer (Atago Co., Tokyo, Japan). Fruit juice pH was determined according to the method described by AOAC [14]. Acidity percent (expressed as citric acid) was determined. The vitamin C (ascorbic acid) content as mg/100ml juice was determined using 2, 6- dichlorophenol indophenol dye according to the modified procedure of AOAC [14]. Moreover, fruit moisture content was estimated by putting about 15 g of fresh fruit samples in petri dish, dried in an oven at 70°C until the weight of the petri dish with its content was constant and the percentage of fruit moisture was calculated.

In addition**,** reducing sugars were determined according to the dinitro-salicylic acid method [15]. Total reducing sugars were determined by the same method after inversion of the non-reducing sugars using diluted hydrochloric acid [14]. The percentage of non-reducing sugars was obtained by subtracting the values of reducing sugars from that of total reducing sugars and all values obtained were expressed as percentage on fresh weight basis. Never the less, fruit total chlorophyll and carotenoids content were determined by the method of Hendry and Price [16] by using a spectrophotometer (UV755B, Shanghai, China).

2.4.4. Shelf life

Fruits behaviour during shelf life was monitored according to the obtained percentages of weight loss, electrolyte leakage, decay and commercially unmarketable fruits during a period from the beginning of holding at ambient temperature until the percentage of unmarketable tomato fruits reached 20-25 % and the rest of the fruits are still acceptable for marketing. Fruit weight loss, decay and unmarketable percent fruits were estimated:

$$\text{Weight loss \%} = \frac{\text{Initial fruit weight} - \text{Fruit weight on the time observation}}{\text{Initial fruit weight}} \times 100$$

The percentage of electrolyte leakage was measured as follows: electrolyte leakage before killing was measured with digital electrical conductivity meter (Orion- model 150- USA). The fruit samples were killed by autoclaving (JKA-J.39 Autoclave, Japan) at 121^{o}C for 20 min to release all electrolytes, cooled to 25±2^{O}C after which they were left on the shaker for 1 hour, vortexed for a few seconds. Total electrolyte leakage was measured by using the same digital conductivity meter. Percentage of electrolyte leakage was calculated for each sample using the ratio of the initial (before killing) to the final (after killing) multiplied by 100 according to Zheng and Zhang [17].

Decay (rotting) percent was calculated at harvest date and after sixteen days at 25°C ± 1 and 85- 90% relative humidity. The percent of commercially unmarketable fruits was calculated as follows:

$$\text{Unmarketable fruits \%} = \frac{\text{Weight of rotted and shrivel ed fruits}}{\text{Initial fruit weight}} \times 100.$$

2.5. Statistical analysis

All data were tested for treatments effects on analyzed parameters by the general linear model (GLM) and one-way analysis of variance (ANOVA) technique. Treatments means were separated and compared using the honest significant differences (HSD) at 0.05 level of significance according to Snedecor and Cochran [18].

3. Results

3.1. Percentage of harvested fruits

A significant decrease in the percentage of harvested fruits was obtained by spraying chitosan alone at 6 g/l (Chi_2) or salicylic acid alone at 2 g/l (SA_2) as compared with Chi_1, SA_1 and the untreated control (SA_0+Chi_0). Spraying chitosan at 6 g/l combined with SA_1 or SA_2 (1 or 2 g/l SA) resulted in lower percentage of harvested fruits than all other treatments (Table1).

3.2. Fruit physical characteristics

The data of Table (1) also showed that spraying either chitosan alone at 6.0 g/l (Chi_2) or salicylic acid alone at 2.0 g/l (SA_2) increased tomato fruit weight, length, diameter, juice volume, firmness and colour intensity at harvest as compared with Chi_1, SA_1 and the untreated control (SA_0+Chi_0). Furthermore, spraying SA at 2.0 g/l (SA_2) combined with Chi_1 or Chi_2 caused a significant increase in fruit weight, length, diameter, juice volume, firmness and colour intensity at harvest as compared with the untreated control (SA_0+Chi_0). In most cases almost all measured characteristic was better when combining Chi_2 with SA_2.

Table 1: The effect of Chi and/or SA preharvest sprays on the percentage of harvested fruits and physical characteristics of Faridah tomatoes at harvest day

Treatments	Harvested Fruits (%)	Weight (g)	Length (cm)	Diameter (cm)	Shape Index	Juice volume (cm^3)	Firmness (kg/cm^2)	colour intensity	Unmarketable (%)	Decay (%)
Chi_0 SA_0	37^{a}	100.7^{d}	4.90^{c}	6.07^{f}	0.73^{a}	61.8^{c}	2.25^{g}	7.3^{b}	8.2^{a}	4.9^{a}
Chi_1	35^{a}	103.2^{d}	5.20^{bc}	6.27^{f}	0.83^{a}	65.8^{bc}	2.39^{efg}	7.9^{b}	7.3^{abc}	3.7^{b}
Chi_2	23^{bcd}	118.3^{c}	5.28^{b}	6.61^{d}	0.80^{a}	68.2^{ab}	2.58^{def}	9.1^{a}	5.1^{d}	2.6^{cd}
SA_1	36^{a}	105.5^{d}	5.05^{bc}	6.14^{f}	0.82^{a}	66.3^{b}	2.32^{fg}	8.0^{b}	7.9^{ab}	2.9^{bc}
SA_2	21^{cd}	120.4^{bc}	5.09^{bc}	6.42^{e}	0.79^{a}	67.2^{b}	2.67^{cde}	9.2^{a}	6.0^{bcd}	1.5^{ef}
Chi_1+SA_1	26^{b}	122.8^{abc}	5.26^{b}	6.78^{bc}	0.78^{a}	68.2^{ab}	2.79^{bcd}	8.1^{b}	5.6^{cd}	1.7^{de}
Chi_1+SA_2	24^{bc}	126.3^{abc}	5.21^{b}	6.64^{cd}	0.79^{a}	68.6^{ab}	3.02^{ab}	9.0^{a}	2.4^{e}	1.2^{ef}
Chi_2+SA_1	20^{de}	129.8^{a}	$5.^{33ab}$	6.82^{b}	0.78^{a}	71.7^{a}	2.92^{abc}	9.4^{a}	2.1^{e}	1.5^{ef}
Chi_2+SA_2	17^{e}	127.9^{ab}	5.62^{a}	6.99^{a}	0.80^{a}	72.1^{a}	3.12^{a}	9.7^{a}	2.7^{e}	1.5^{f}
H.S.D	4.0	9.4	0.31	0.15	N. S	4.3	0.31	1.1	2.2	1.2

Means within each column with the same letter are not significant at 5% level

3.3. Fruit chemical characteristics

The treatments Chi_2 and SA_2 significantly increased fruit carotenoids, reducing, non-reducing and total sugars, SSC, acidity and ascorbic acid contents at harvest, while, decreased fruit pH and electrolyte leakage. However, no significant differences among the Chi_1, SA_1 and control treatments were found. The combined sprays of 4 or 6 g/l Chi with 1 or 2 g/l SA caused a significant increase in the carotenoids, chlorophyll, reducing, non-reducing and total sugars, SSC, acidity and ascorbic acid contents, and a significant decrease in the fruit pH and electrolyte leakage compared to the untreated control, with no significant differences between them were found (Table 2).

3.4. Fruit shelf life

Results presented in Table (3) showed that tomato fruits treated with salicylic acid and/or chitosan had longer shelf life than the unsprayed control fruits. Tomatoes treated with Chi_2 in combination with SA_1 or SA_2 were found to extend their shelf life to the maximum duration as compared with other treatments**.** Also, obtained data showed that chitosan and/or salicylic acid preharvest sprays tended to sustain fruit weight loss during holding the fruits for 16 days at ambient temperature as compared with unsprayed control fruits (Chi_0 + SA_0). The fruits treated with 6.0 g/l chitosan alone (Chi_2) or in combination with 1 or 2 g/l salicylic acid (SA_1 or SA_2), and 2g/l chitosan (Chi_1) in combination with 1or 2 g/l salicylic acid decreased significantly fruit weight loss percentage compared to Chi_1, SA_1 and SA_2 treatments.

The percentage of electrolyte leakage was significantly higher in unsprayed control fruits (Chi_0+SA_0) than those sprayed with chitosan and salicylic either alone or in combinations. In addition, all salicylic acid and/or chitosan preharvest sprays significantly reduced the percentage of decayed and unmarketable fruits as compared with the

unsprayed control (Chi_0 + SA_0). The lowest percentages were obtained by spraying SA1 or SA_2 in combination with Chi_1 or Chi_2.

Table 2: The effect of Chi and/or SA preharvest sprays on the chemical characteristics of Faridah tomatoes at harvest day

Treatments	Sugars (%)			Total chlorophyll (mg/100g)	Carotenoids (mg/100g)	SSC (%)	VC (%)	Acidity (%)	pH	Electrolyte leakage (%)
	Reducing	Non-reducing	Total							
Chi_0 SA_0	4.09^{c}	0.45^{d}	4.54^{d}	0.36^{c}	19.75^{d}	5.18^{c}	17.02^{f}	0.47^{de}	4.44^{a}	49.1^{a}
Chi_1	4.56^{bc}	0.48^{cd}	5.04^{cd}	0.36^{c}	25.82^{bcd}	5.20^{c}	18.15^{ef}	0.47^{de}	4.24^{b}	37.7^{b}
Chi_2	4.88^{ab}	0.^{64ab}	5.52^{abc}	0.35^{c}	27.14^{bc}	5.80^{ab}	19.92^{cd}	0.50^{bc}	4.16^{cde}	35.2^{bc}
SA_1	4.72^{abc}	0.42^{d}	5.14^{bc}	0.38^{bc}	24.20^{cd}	5.80^{ab}	19.28^{de}	0.45^{e}	4.22^{bc}	35.8^{bc}
SA_2	4.95^{ab}	0.70^{a}	5.65^{ab}	0.37^{bc}	28.78^{abc}	5.73^{b}	19.59^{d}	0.52^{b}	4.09^{e}	32.3^{cd}
Chi_1+SA_1	5.06^{ab}	0.58^{bc}	5.64^{ab}	0.^{41ab}	31.44^{ab}	5.80^{ab}	21.84^{b}	0.52^{b}	4.13^{de}	30.1^{de}
Chi_1+SA_2	4.89^{ab}	0.59^{b}	5.48^{abc}	0.41^{ab}	35.67^{a}	5.86^{ab}	21.84^{b}	0.55^{a}	4.18^{bcd}	30.2^{de}
	5.11^{ab}	0.68^{ab}	5.79^{a}	0.46^{a}	35.76^{a}	6.13^{a}	21.12^{bc}	0.52^{b}	4.12^{de}	29.3^{de}
Chi_2+SA_2	5.27^{a}	0.71^{a}	5.98^{a}	0.43^{a}	35.41^{a}	6.06^{ab}	23.21^{a}	0.50^{bc}	4.10^{e}	27.6^{e}
H.S.D	0.67	0.11	0.55	0.05	7.18	0.36	1.29	0.03	0.076	4.1

Means within each column with the same letter are not significant at 5% level

Table 3: The effect of Chi and/or SA preharvest spray on tomato behaviour during 16 days at ambient temperature.

Treatments	Electrolyte leakage (%)	Weight loss (%)	Decay (%)	Shelf life (day)
Chi_0 SA_0	51.9^{a}	2.7^{a}	38.5^{a}	7^{f}
Chi_1	49.3^{a}	1.9^{c}	27.2^{b}	11^{d}
Chi_2	45.9^{bc}	1.6^{d}	13.5^{cd}	16^{b}
SA_1	50.0^{a}	2.3^{b}	29.2^{b}	10^{d}
SA_2	46.8^{b}	2.1^{b}	15.8^{c}	12^{d}
Chi_1+SA_1	43.5^{cd}	1.4^{d}	11.4^{de}	14^{c}
Chi_1+SA_2	40.9^{de}	1.5^{d}	11.1^{de}	16^{b}
Chi_2+SA_1	38.9^{e}	1.5^{d}	8.4^{e}	19^{a}
Chi_2+SA_2	35.5^{f}	1.4^{d}	8.7^{e}	20^{a}
H.S. D	2.9	0.24	3.2	1.8

Means within each column with the same letter are not significant at 5% level

4. Discussion

The above mentioned results indicated a positive enhancement in all studied postharvest tomato fruits physico-chemical characteristics at harvest and after holding for 16 days at ambient temperature by preharvest chitosan and/or salicylic acid sprays, especially the combined treatments with the highest concentration of both substances. These results go on line with previous studies on chitosan application to tomato [19] and sweet pepper [20]. Similarly, to the obtained results, Maqbool et al. [21] reported higher firmness of banana fruits coated with chitosan than untreated ones after storing.

Moreover, in the present investigation salicylic acid sprays maintained fruit firmness and slowed fruit softening. According to Ramana Rao et al.[20] treating the fruits with different concentration of SA lowered the activity of these enzymes which might have been associated with a high integrity of the cell membrane and contributed to high levels of crispness and firmness in the fruits during storage. Similar to the obtained results, salicylic acid has been documented to enhance flesh firmness of harvested banana during fruits ripening [22].

In the same context of the obtained data in the present study, Yu-Yan et al. [23] reported that chitosan treatments maintained navel orange fruit soluble protein, total phenolic and flavonoids levels and slowed down the decrease of fruit ascorbic acid, acidity and total soluble solids contents. Further, Tezotto-Uliana et al. [24] stated the effectiveness of 1.0 or 2.0 % chitosan pre- or postharvest application in maintaining fruit firmness and retarding respiration and ethylene production of raspberries. A suppressed respiration rate slows down the

synthesis and the use of metabolites, resulting in lower SSC due to the slower hydrolysis of carbohydrates to sugars during storage [25].

In addition, similar to the present investigation, high ascorbic acid content was found subsequently to chitosan application in fruit tissues of strawberry [26]. The reduction of ascorbic acid loss in chitosan coated fruits is proposed to be due the low oxygen permeability of the chitosan coating around fruit surface, which lowered the oxygen level and reduced the activity of the ascorbic acid oxidase enzymes, preventing oxidation of ascorbic acid [27].

Results of this study found that chitosan preharvest spray decreased fruit pH and electrolyte leakage during ambient temperature. The low pH that characterizes many fruits (below pH 5) is probably an important factor in their general resistance to bacterial decay agents, but it furthers the postharvest development of various fungi. In fact, fungi cause most of the decays in harvested fruits, whereas bacteria are important mainly in vegetables [28].

In addition, the results of the present study are in agreement with those obtained by Pila et al. [29]. They reported that SA treatment indicated a significant delay in the change of acidity, total soluble solids, sugar accumulation, chlorophyll degradation and carotenoids accumulation in tomato fruits, and resulted in high amounts of ascorbic acid and phenolic compounds. Similarly, the application of SA on pepper fruits showed a significant delay in changes of total soluble solids, pH and acidity, lowered enzymatic activity of polygalacturonase, pectin methyl esterase, cellulase, *β*–galactosidase and ascorbic acid oxidase and increased activities of scavenger antioxidant enzymes, including, peroxidase and catalase. Accordingly, the salicylic acid treatments of the present study might have been associated with a high integrity of the cell membrane and few changes in the cell wall constituents which might contribute to the delay of tomato fruits ripening and softening process, that reflected on extended fruits shelf life.

Moreover, according to the obtained results of the present study, preharvest chitosan and salicylic acid sprays decreased the percentages of fruit electrolyte leakage, weight loss and decay, which is reflected on extending the tomatoes shelf life.

As it is known, injury degree of any fruit can be expressed by its electrolyte leakage, as it increases indicating that the fruit became more vulnerable to leakage [30]. In addition, the above mentioned results showed that preharvest spraying of SA decreased the fruit electrolyte leakage percent during storage. Electrolyte leakage is an index which can quantify the damage conceived by plant cell membrane [31]. Application of SA significantly decreased cucumbe leaf electrolyte leakage [32]. This result is consistent with that reported by Stevens et al. [33] for tomato, who determined that SA facilitated the maintenance membrane functions. Also, Tareen et al. [31] found that the SA treatment significantly decreased electrolyte leakage during cold storage of peach fruits. In addition, the low electrolyte leakage in SA treated fruits might be ascribed to less plasma lemma membranes damage as reported by Meng et al., [34], and the increased solidity of membranous cells [35]. SA reduces fruit electrolyte leakage, oxidase activity, the amount of ethylene production, maintains the integrity of the cell membrane, improves the effect of defense-related enzyme activity and thus reduces morbidity, Storage of Fruits. As Noor et al. [36] reported the SA lower rate of water loss during storage, delay ripening, and lower decay rate of onion. SA treatment decreased respiration rate and inhibited peroxidase activity of peach fruit during storage at room temperature, delay ethylene release peak and decreased electrolyte leakage rate, decreased polyphenol oxidase activity, reduce fruit rot [37]. Tao et al. [38] showed that SA treatments by 0.01 g/L and 0.1 g/L for tomatoes and 0.001 g/L SA for cucumber decreased membrane electrolyte leakage, MDA and free proline.

The obtained results are in agreement with previous study Dang et al. [27] working on sweet cherries. Chitosan coating is reported to provide a significant water vapour barrier on cold stored table grapes and thus reduce fruit weight losses [34].

Nevertheless, the preservation of a constant water status prior to and during postharvest handling may have an important role in maintaining crop quality [39]. Therefore, the decrease in fruit weight loss and decay obtained in the present study might be due the effect of SA on regulating the metabolic activities and physiological processes, as well as reducing fungal attack [40]. In this respect, Zheng and Zhang [17] stated that salicylic acid can also decrease respiration rate by the closure of stomata.

In the meantime, fungal infection is one of the main causes of fruits decay after harvest, Cheah et al. [41] recorded a marked reduction of decay in chitosan-treated bell peppers, cucumbers, strawberries and carrots. They added that, chitosan application stimulated the formation of structural defense barriers as it induces callose synthesis, thickening of host cell walls, formation of papillae and plugging of some intercellular spaces with fiber material, probably impregnated with antifungal phenolic-like compounds. Additionally, preharvest chitosan sprays is reported to decrease the incidence and severity of several postharvest disease infections; on strawberries and tomatoes [12].

Disease resistance and storage life extension may be according to the maintenance of the fruit total phenolic and flafvonoids levels as suggested by Yan et al. [42]. Accordingly, chitosan is cleared to be effective in the intensification of total antioxidant capacity of treated fruits by increasing the phenolic compounds in fruit tissue [43]. This effect was recorded in tomatoes [13].

Accordingly, SA treatment extend the storage life of tomato fruits and preserve its valuable attributes after harvest. This might be presumably because of its effect on inhibition of ripening and senescence processes [29]. A close relationship exist between change in SA levels in the fruit tissues and the extent of fruit ripening and softening [44]. A reduction in ethylene biosynthesis and slowing fruit ripening as a result of SA application was recorded [5]. In addition, rripening-retardation could be possibly through an anti-ethylene affect and not due to enhancement of endogenous antifungal activity in fruit skin as stated by Srivastava and Dwivedi [22]. An ethylene-suppression role of SA may extend the shelf life of the fruit, thereby delay the development of disease symptoms that normally develop as climacteric fruit ripen.

Data of Tables (3) showed that shelf life of tomato fruits has been extended significantly with preharvest SA treatment. These results support the findings of Ramana Rao *et al*. [20] showed that, SA delayed the ripening process and extended storage and shelf life of sweet pepper fruits up to 71 days without any spoilage and off-flavor.

Conclusion

It might be concluded that preharvest foliar sprays of chitosan and/or salicylic acid at concentrations of 6g/l for chitosan and 2g/l for salicylic acid could be safely applied in order to improve tomato fruit quality at harvest and for 16-day shelf life.

Accordingly, these compounds might be commercially preharvest applied to tomato fruits according to their availability in the markets and their costs, as this investigation clear their similarity in influencing the different physiological processes which play an important role in lowering the percentage of fruit weight loss and decay, and delaying fruit softening.

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