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Research Article

Utilization of jojoba oil and salicylic acid as postharvest treatment on storability and fruit quality of 'Late Swelling' peach cultivar

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Abstract

The 'Late-Swelling' peach is an important cultivar due to its attributes of fruit quality, such as handling ability and late harvest season. Peaches rapidly deteriorate during storage, which shortens their shelf-life. The preservation of quality traits of 'Late-Swelling' peach during handling and storage investigated. Fruits harvested in the early ripe stage (last week of June) were either dipped in jojoba oil (JO) 500, 1000, and 1500 ppm and salicylic acid (SA) 100, 200, and 300 ppm, then stored at 5+1 °C and 85% RH for 35 days besides 7 days as shelf-life the fruits were examined every 7 days until the end of the experiment. Positive influences were observed for JO and SA on the different chemical and physical characteristics of the peach fruits under study especially those related to storability and fruit quality. All fruits treated with JO 1500 and 1000 ppm, and SA 300 ppm maintained the fruit firmness, h°, total acidity, and ascorbic acid over the whole storage period, in addition to the lowest decay and weight loss, as well as maintaining the fruit sensory quality and decreased peroxidase [PPO] activity while increasing polyphenol oxidase [POD], catalase [CAT], and ascorbate peroxidase [APX] activities compared with the control at the end of shelf-life period. In conclusion, our results suggest using JO and SA to enhance and prolong the storability of peach fruits at 5+1 °C and 85% RH.

Keywords: antioxidant activity; coating; *Prunus persica*; shelf-life

Introduction

Peach is one of the most popular fruits in the world because of its high nutrient value and pleasant flavour, the fruits are good sources of antioxidants like ascorbic acid, carotenoids, and phenolics (FAO, 2011; Mihaylova *et al.,* 2021) peach is considered one of the most important deciduous fruits that shows great success and is widespread in the newly reclaimed areas in Egypt (Khalifa and Hamdy, 2018).

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Peach fruit is approximately 87% water next to carbohydrates, organic acids, pigments, volatiles, nutritive minerals, and trace amounts of proteins and lipids so it is liable to deteriorate rapidly during handling and storage owing to being a climacteric fruit that undergoes rapid ripening, the peach fruits suffer from high susceptibility to flesh softening, weight and flavour loss, pathogens attack, and higher respiration rates (Saeed *et al*., 2019). Reduction of postharvest losses is an irreplaceable challenge in the world, so, to increase the availability of fruits and vegetables, several synthetic fungicides are used for rot control but many countries do not allow the use of those fungicides, or they have a restricted approved list of authorized ingredients (Baibakova *et al.*, 2019).

An increased concern among consumers about food safety and the potentially harmful health effects of chemical residues has encouraged research to find safe alternative chemicals which can maintain the marketable quality throughout prolonged storage period of fruits, including peach (Saeed *et al*., 2019).

Edible coatings have been extensively studied in recent years for the preservation of fruits and vegetables, postharvest application of plant oils as alternatives to synthetic fungicides and reduced weight loss and decay incidence have been reported (Taheri *et al*., 2020). Moreover, the application of essential oils as food additives is a recently growing interest because of their high antimicrobial, antifungal, antidiabetic, physicochemical, and antioxidant activities (Antunes and Cavaco, 2010). Each of these essential oils has a different biological activity, physicochemical properties, and aroma. It is thus important to select the most appropriate one or combination for each specific application (Chen *et al*., 2020).

In this sense, using jojoba oil as the safety postharvest coating is effective in controlling postharvest decay and compositional changes by delaying physical and chemical changes, slowing down the respiration rate, and extending postharvest life for Murcott Tangor mandarin fruits (Elnaggar *et al*., 2021). Jojoba oil (JO) is taken out from the seed of the jojoba (*Simmondsia chinensis* (Link) C. K. Schneid) plant and has been widely used by the cosmetic and pharmaceutical industries for several years (El-Emam *et al*., 2019; Sturtevant *et al*., 2020). JO is not a triglyceride like other plant oils but a mixture of long-chain esters (97-98%) of fatty acids and fatty alcohols, and therefore it is referred to as wax or oil-wax (Sturtevant *et al*., 2020).

Salicylic acid (SA) or ortho-hydroxyl benzoic acid is an endogenous plant growth regulator of phenolic nature classified as a growth promoter, inhibitor of ethylene biosynthesis, and delaying fruit senescence (Raskin, 1992). SA has been widely applied either at the preharvest or postharvest stages it is a safe chemical used to control the postharvest quantity or quality losses of perishable crops (Hayat *et al*., 2013). Using salicylic acid as the postharvest application on peach improve fruit quality and fruit firmness, and lowered weight loss and fruit decay besides increasing the antioxidant activity in fruits treated with 2- and 4-mM concentrations of SA (Khademi and Ershadi, 2013). Moreover, (Saif, 2022) found that the peach fruits treated by SA significantly preserved fruit quality by reducing weight loss, saving firmness, delaying the decline of acidity and vitamin C, and the increase of soluble solids content (SSC), SSC/ Acid ratio, and antioxidant enzymes activity during the cold storage period. Abd El-Gawad and El-Moghazy (2018) reported that using the essential oils as edible coatings for Florida Prince peach fruits significantly decreased weight loss, and decay percentage. In addition to their positive effect on quality properties including TSS, TA, vitamin C, total phenolic content (TPC), and fruit anthocyanin contents of Florida Prince peach fruits during cold storage and shelf-life periods. Moreover, El-Motty and El-Faham (2013) found that JO 20% treatment reduced weight loss, and decay percentage proved to induce the antioxidant capacity, and also sustain the total phenolic content, and lower total sugars and soluble solids content of Florida Prince peach fruits compared to the control during the cold storage period.

Therefore, the aim of this study is to find a safe alternative to postharvest treatments for late swelling peach fruits such as safe edible coatings "jojoba oil and salicylic acid" during cold storage at 5+1 °C and 85% RH on storability, and quality attributes.

Materials and Methods

Plant material

This investigation was carried out in the 2022 season on peach (*Prunus persica* L. Batsch) fruits cv. 'Late Swelling'. Fruits were harvested at the early ripe stage during the last week of June according to (Saeed *et al*., 2019), from six years old trees planted 4 × 5 meters apart and grown in sandy soil under a drip irrigation system in a private orchard El Khatatba City, El Menoufia Governorate, Egypt, with coordinates of 30°21'N 30°49'E.

Chemical and reagents

Jojoba oil, salicylic acid and other chemicals received from El-Nasr Chemicals Company, Cairo, Egypt.

Preparation of postharvest treatments

Only fruits unified in size, colour, and free from any visible blemishes were selected. Fresh peaches were cooled for 2 hours at 5 °C to remove the heat of the orchard. It is dipped for one minute in a sodium hypochlorite solution (250 mg L^{-1}) then left to dry at room temperature (22-25 °C). Then fruits were exposed to the following treatments: Control fruit dipped in tap water for 5 min.; jojoba oil 500 ppm; jojoba oil 1000 ppm; jojoba oil 1500 ppm; salicylic acid 100 ppm; salicylic acid 200 ppm; salicylic acid 300 ppm.

To prepare the coating solutions, Tween-20 (0.1 %) as a surfactant was added to all solutions. After the fruits were immersed in the solutions for 5 min, all fruits treated and untreated, were air-dried (2 h to ensure surface dryness). All treatments were stored at cold storage conditions at 5±1 °C, with relative humidity (RH) of 85±5 %. Three replicates for every treatment, each replicate contains 4 boxes of low-density polyethylene thickness 0.050 mm, each box was one layer of fruits and contained 6 fruits to determine the changes in physical, and chemical properties and shelf-life.

Measurements

Fruits quality attributes were examined every 7 days throughout all the storage period to evaluate the following characteristics:

<u>Decay percentage</u>

It was recorded for all the injured or spoiled fruits resulting from fungus or bacterial as the following equation:

Decayed fruits % = (Number of decayed fruits at time of sampling / Number of the initial fruits) × 100

<u>Weight loss</u>

It was expressed as percentage of weight loss relative to the initial weight as the following equation:

Weight loss % = [(initial weight – weight at inspect date) / initial weight] × 100

<u>Colour assessment</u>

Skin color was evaluated on two opposite sides in the middle of fruit it was determined in terms of hue angle (h^o) value by using a Minolta colorimeter (CR-400/410) Osaka, Japan. Hue angle (0 = red-purple, 90 = yellow, 180 = bluish-green, 270 = blue), as described by (Tietel *et al*., 2012).

<u>Fruit firmness</u>

Firmness was measured in the two opposite sides of fruit samples by using a digital pressure tester (N/cm^2).

Fruit chemical characteristics

Total soluble solids (TSS)

Total soluble solids (TSS) were estimated by a'bbe digital refractometer, and expressed as percentage according to (A.O.A.C, 2005).

Titratable acidity

Titratable acidity (TA) was determined as malic acid by titration with NaOH, 0.1 N up to pH 8.1 (A.O.A.C, 2005). The results were calculated as gm. per 100 ml of juice.

Ascorbic acid

The amounts of ascorbic acid in juice samples were determine by the use of 2, 6-dichlorophenol indophenol dye and 0.2% oxalic acid as a substrate and 5 ml. of filtered aliquot. It was calculated as mg/ 100 g Fw (A.O.A.C, 2005).

Enzyme activity

The enzyme activity of the 'Late Swelling' peach fruits on the 3_{rd} day of shelf-life after the end of the storage period was executed.

Catalase (CAT) action was precise according to (Aebi, 1984) the absorbance recorded in decrease at 240 nm for 60 s. The enzyme action was accounted for by calculating the quantity of decomposed H_2O_2.

Polyphenol oxidase (POD) activity was measured by the method of (Chance and Maehly, 1955) the absorbance was recorded at 420 nm.

The determination of peroxidase (PPO) activity was done according to Duckworth and Coleman (1970) at 420 nm at 25 °C.

Ascorbate peroxidase (APX) activity was estimated by the method of (Nakano and Asada, 1981). APX was assayed by recording the decrease in optical density due to ascorbic acid at 290 nm.

The antioxidant enzymes activity was assayed as follow:

Enzyme activity $(U(\mu mol)/ml) = (\Delta A \times Vt \times 106)/(\Delta t \times l \times \varepsilon \times Vs \times 1000)$

Enzyme activity $(U(\mu mol)/g\ FW) = [(\Delta A \times Vt \times 106)/(\Delta t \times l \times \varepsilon \times Vs \times 1000)] \times$ dilution factor

Where: ΔA is the change in absorbance, Δt is the time of incubation (min), ε is the extinction coefficient ($M^{-1}\ cm^{-1}$), l is the cuvette diameter (1 cm), Vt is the total assay volume, and Vs is the enzyme sample volume (ml).

E 420 nm of pyrogallol is 12 $M^{-1}.cm^{-1}$

ε 420 nm of catechol is 2450 $M^{-1}.cm^{-1}$

ε 240 nm of hydrogen peroxide is 43.6 $M^{-1}.cm^{-1}$

ε 290 nm of ascorbic acid is 2.8 $mM^{-1}.cm^{-1}$

Total phenolic compounds

It was determined by the Folin-Ciocalteau spectrophotometric method described by (Singleton *et al.,* 1999) using gallic acid as a standard. Absorbance was measured in a spectrophotometer at 740 nm. A blank sample was conducted under the same conditions. Results were expressed in mg GAE g^{-1} dry weight.

Hydrogen peroxide (H_2O_2)

(H_2O_2) levels were determined according to the method described by Chakraborty *et al*. (2014). The biomass was homogenized in an ice bath with 5 mL 0.1% (w/v) trichloroacetic acid (TCA). The absorbance was read at 390 nm, and the concentration of H_2O_2 was given by a standard curve.

Evaluation of sensory quality

The sensory evaluation of the Swelling peach fruits on the 7th day of shelf-life after the end of the storage period was executed. The triangle discrimination test (Lawless and Heymann, 2010) was used to determine whether there were any detectable differences in the external and internal quality of the treated swelling peach fruits compared to the control fruits, the participants in the sensory evaluation experiment were 9 people aged between 30 to 40 years who were workers at the faculty of agriculture, at Al-Azhar university, and voluntarily agreed to participate in the evaluation session. All samples (two fruit for each treatment) were coded and then randomly presented to for each participant in the test to avoid any positional bias to evaluate external and internal quality "appearance, firmness, smell, and quality of taste". Samples were served at room temperature and consumers were provided with a glass of water for palate cleansing, which they used between samples. Then, they were asked to evaluate selected attributes "appearance, firmness, smell, and quality of taste" separately on a numerical scale from 1 (lowest quality) to 10 (highest quality) points.

Decay percentage at shelf life

After end of cold storage, fruit samples of each treatment were placed at ambient temperature, and shelf-life was determined as a number of days of which fruits maintained acceptable eating quality and appearance.

Statistical analysis

All data parameters studied were analysed as a completely randomized block design in factorial arrangement with three replications. All data were subjected to statistical analysis as described by (Snedecor and Cochran, 1989). The differences between means were differentiated using LSD test at $p \leq 0.05$.

Results and Discussion

Decay percentage

The decay is caused by physiological injuries of the fruits during storage or the progress of the fruits in maturity or due to pathogens such as bacteria, fungi, or yeast (El-Dengawy *et al*., 2018). The results in Figure 1 showed that there were continuous significant increases in decay percentage with a prolonged storage period in all treatments. All treatments significantly reduced the decay of peach fruits, while the treatments of JO 1500, 1000 ppm, and SA 300 ppm recorded the lowest significantly decay percentage of fruits respectively compared with control and other treatments during the storage period. These results were agreed with (Hassan *et al.,* 2014) who recorded that the application of edible coating will partially restrict gas exchange through the fruit peel and inhibit the action of ethylene; this inhibitory action can provide better protection against postharvest decay in fruits. Postharvest application of plant oils on bell pepper as alternatives to synthetic fungicides has been reported (Taheri *et al.,* 2020). Moreover, El-Abbasy *et al.* (2018), reported that treating apricots fruit with SA decreased weight loss and decay percentage at 0 °C with a higher marketable fruit percentage by, reducing transpiration and respiration which results in minimizing weight loss and delaying the senescence of fruit and improving resistance against fungal attacks in treated and fruits its effectiveness in inducing a defense system by enhancing the activities of antioxidant enzymes (Prodhan *et al.,* 2018; Saif, 2022). As for the effect of interaction between the tested postharvest treatments and storage periods, the lowest value for decay in Swelling peach fruits at different sampling times i.e., 7 up to 35 days of storage was connected with coating the peach fruits with 1500 ppm jojoba oil compared with control and other treatments.

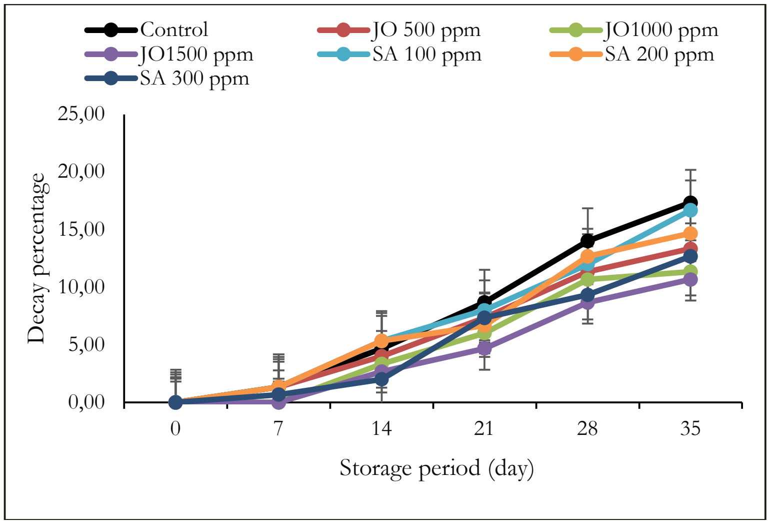

Figure 1. Effect of salicylic acid and jojoba oil on decay percentage of 'Late Swelling' peach fruits during cold storage period at 5 ±1 °C, RH 85%

Weight loss percentage

Weight loss percentage is an important factor in determining the freshness and consumption suitability of fruits and affected by different dipping treatments during cold storage at 5±1 °C while the weight loss percentage of all samples experienced was affected by storage periods under cold storage ($p < 0.05$) as shown in Figure 2. Surface coating can reduce fruit weight loss by up to 50%, depending upon coating type and concentration and maintain the freshness of the products and improve their appearance (Baldwin, 1995). The losses were lower in the fruits that have been treated with jojoba oil "1500, 1000 and 500 ppm" compared with SA "300, 200 and 100 ppm" and control respectively. All SA treatments prevented weight loss compared to the control during the storage period.

In terms of the effect of cold storage, untreated peach fruits lost the highest weight after 35 days, compared with JO 1500 ppm had the least amount ($p < 0.05$) of weight loss percentage. Also clear the sample treated with JO 1500 ppm had the least amount ($p<0.05$) of weight loss percentage, the reduction in weight loss due to the effect of the coating as a semi-permeable barrier against O_2, CO_2, moisture, and solute movement, thereby, reducing respiration, water loss, and oxidation reaction rates (Abdel-Salam, 2016). Moreover, weight loss is due to metabolic activity, respiration, and transpiration, and salicylic acid, as an electron donor, produces free radicals which prevent normal respiration (Wolucka *et al.,* 2005).

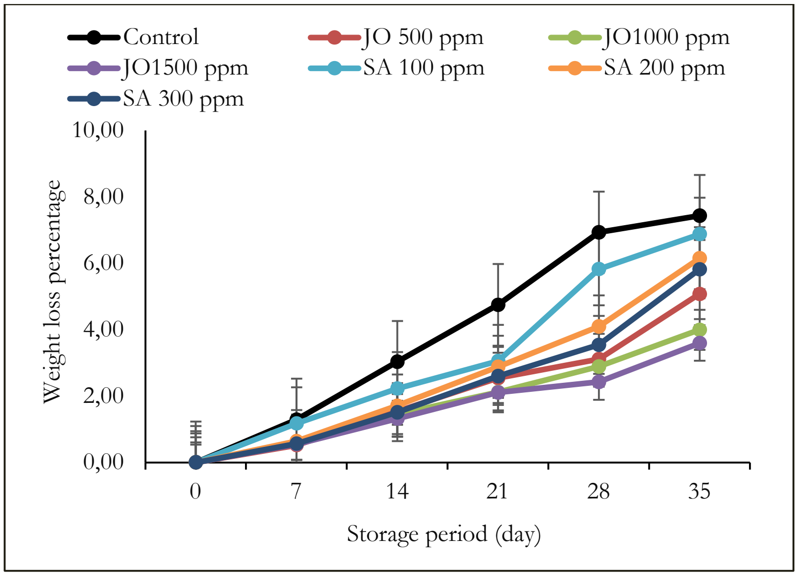

Figure 2. Effect of salicylic acid and jojoba oil on weight loss percentage of 'Late Swelling' peach fruits during cold storage period at 5 ±1 °C, RH 85%

Fruit colour (h°)

Fruit colour is one of the most influential attributes for consumer. Figure 3 showed that the fruit hue angle values decreased significantly generally with the progress of the storage period for all stored fruits at 5 °C, while the hue angle values reached the minimum values after 35 days of storage in all treatments. The increase in colour "decrease in the hue angle value" may be due to the acceleration of ripening which occurred by the age progress of fruit accompanied by decreasing of phenolic compounds content, which prevents the enzyme activity responsible for carotene content (Bill, 2012). However, all treatments reduced significantly the decrease in the hue angle value of peach fruits. The fruit hue angle values in fruit treated with jojoba oil 1500 ppm jojoba oil were lower significantly than control or other treatments respectively. During the storage, period the ethylene production and respiration rate increased which stimulate a change of colour (Nasrin *et al.,* 2020). As for the interaction between treatments and cold storage periods (0, 7, 14, 21, 28, and 35 days), the best peach fruits colour "hue angel" observed in JO 1500 ppm followed by SA at 300 ppm, during storage period.

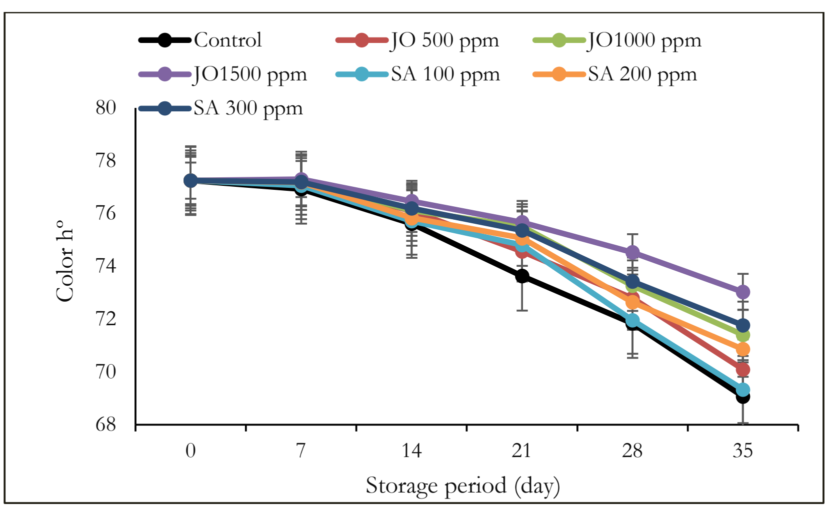

Figure 3. Effect of salicylic acid and jojoba oil on colour (h°) of 'Late Swelling' peach fruits during cold storage period at 5 ±1 °C, RH 85%

Firmness N/cm²

The firmness loss could be used as an indicator at the end of shelf-life and a key factor that determines the consumer's product acceptances. The fruit firmness showed a linear decline with an advanced storage period for all fruits (Figure 4).

The fruit firmness values were the highest significantly in fruit treated with JO 1500, and SA 300 ppm respectively after cold storage compared with control and other treatments. As for the effect of interaction between the tested postharvest treatments and storage periods, the highest value of fruit firmness at different sampling times connected with coating the peach fruits with JO 1500 ppm and SA 300 ppm compared with control. The results agreed with (Saif, 2022) who reported that the firmness of 'Tropical snow' peach fruits decreased gradually as the storage period progressed. This is due to when an excessive water loss occurs in fruits, the ethylene biosynthesis will be increasing. Therefore, polygalacturonase activity on the pectin the firmness will be decreasing during storage, so the degradation of insoluble protopectin to the more soluble pectic acid and pectin contributes to a decrease of firmness in many fruits (Bisen and Pandey, 2008; Liplap, 2013).

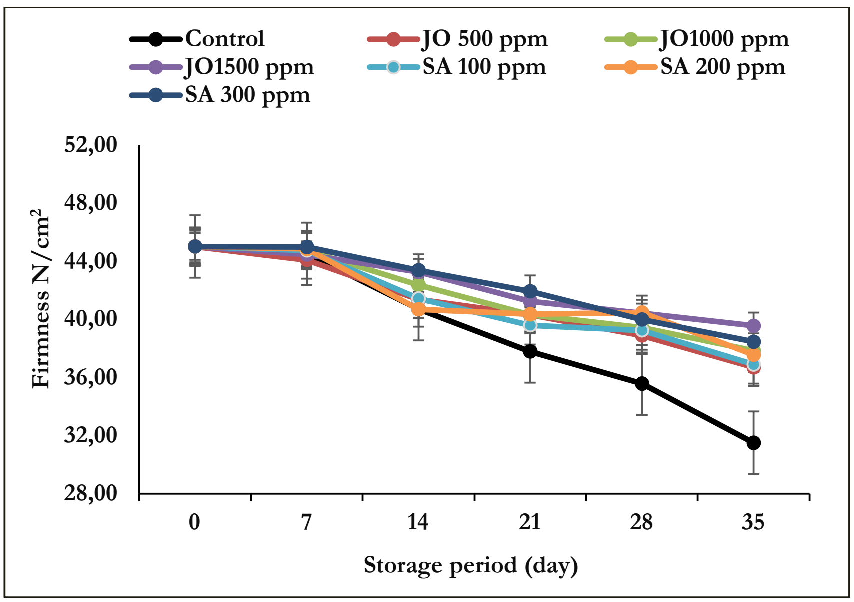

Figure 4. Effect of salicylic acid and jojoba oil on firmness N/cm² of 'Late Swelling' peach fruits during cold storage period at 5 ±1 °C, RH 85%

TSS %

Admittedly the fruit taste is mainly composed of a combination of sugars and acids so the TSS content is one of the major indicators that determine the quality of all fruit cultivars. There were increases gradually in total soluble solids percentage in general with the extended storage periods, while the total soluble solids percentage reached the significant maximum value after 35 days. Figure 5 showed that all treatments decrease this increase in the TSS percentage of peach fruits while the highest values of TSS were recorded in control and salicylic acid 100 ppm respectively after 35 days of cold storage. On the other side, the significantly low values of TSS during cold storage were recorded with the treatments of Jojoba oil 1500 ppm, Jojoba oil 1000 ppm, and salicylic acid 300 ppm respectively compared with the control. In addition, Jojoba oil 1500 % and salicylic acid 300 ppm reflected the lowest TSS of peach fruits with regard to the effect of the interaction during the different periods of storage. El-Motty and El-Faham (2013) reported that the JO treatment showed stability in the SSC of Florida prince peach fruits during the storage period, which consequently affect the fruit shelf-life. On the same line (Shokri Heydari *et al.,* 2020) found that peach fruits treated with salicylic acid 4 mM recorded a reduction of ethylene production by about 50 % compared with the control fruits so SA could delay the decline in total sugar content and maintained TSS in fruits during storage. This increase in TSS is due to the cell walls containing large amounts of polysaccharides, mainly pectin and cellulose, and digested due to the activity of the cell wall degrading enzymes leading to a slight increase in TSS content during storage (Ali *et al.,* 2010; Nasrin *et al.,* 2020).

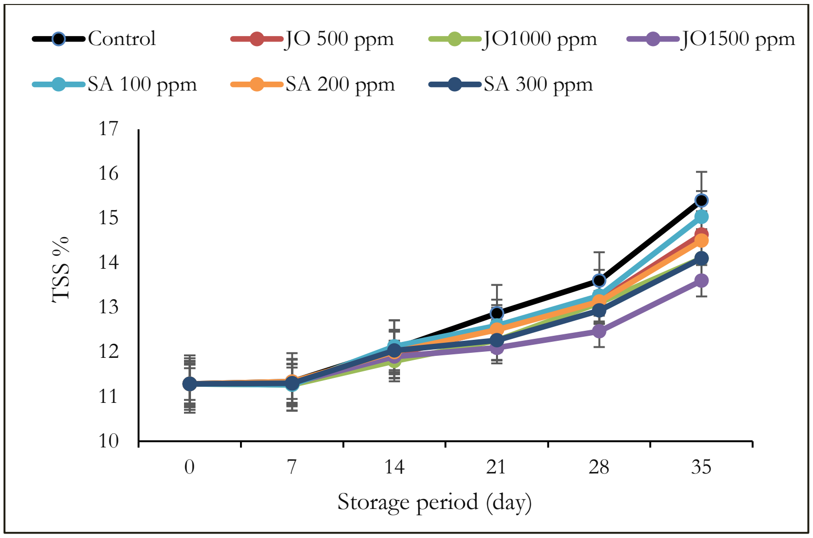

Figure 5. Effect of salicylic acid and jojoba oil on TSS % of Swelling peach fruits during cold storage period at 5 ±1 °C, RH 85%

Total acidity

Organic acids "oxalic, tartaric, malic, lactic, citric, and ascorbic" are limiting components besides sugars, but they play an important role in the organoleptic properties of fruit. The data in Figure 6 illustrates that the total acidity percentage significantly decreased during storage under a low temperature 5 °C for all fruit treatments.

The significant highest values of the total acidity percentage recorded in the fruit treated with Jojoba oil at 1500 ppm and salicylic acid at 300 ppm after 35 days of cold storage respectively. On the other hand, the significant lowest values of the total acidity percentage recorded with "Control, salicylic acid at 100 ppm Jojoba oil at 500 ppm" at the end of the storage period respectively. Moreover, the total acidity percentage of Florida Prince peach fruits gradually decreased according to the storage period in jojoba oil treatment including that of the control but the control treatment showed high reduction values than jojoba oil treatment (El-Motty and El-Faham, 2013). The decreasing trend in fruit acidity with the increasing storage period might be due to the respiratory metabolism of organic acid and its further utilization in metabolic processes accordingly, the higher the metabolic respiration, the higher would be the decline in acidity content (Obenland *et al.,* 2011; Chiabrando and Giacalone, 2016). SA leads to decreasing in the oxidation of organic acid in treated fruits by enhancing the activities of antioxidant enzymes (Xu and Tian, 2008; Khademi and Ershadi, 2013).

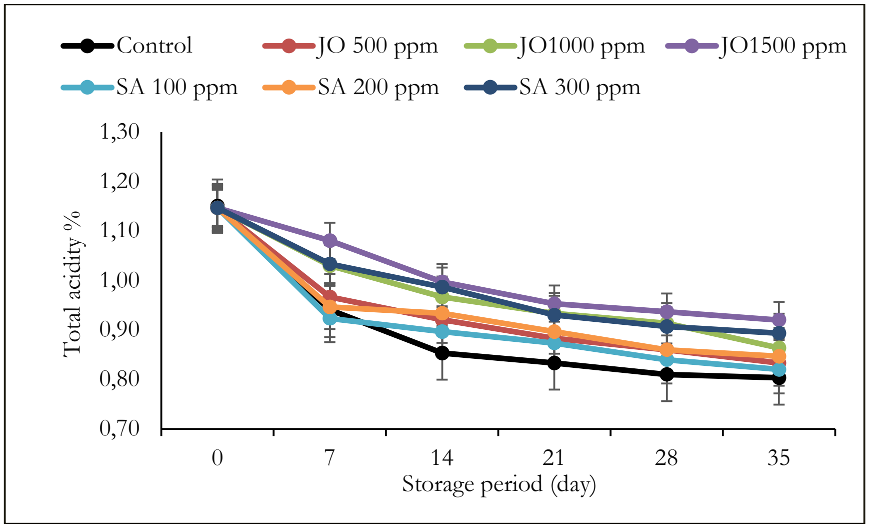

Figure 6. Effect of salicylic acid and jojoba oil on total acidity percentage of Swelling peach fruits during cold storage period at 5 ±1 °C, RH 85%

Ascorbic acid content

Maintaining ascorbic acid content in fruits during postharvest ripening is crucial for human health (Hassanpour *et al*., 2011) as shown in Figure 7 the ascorbic acid content of 'Swelling' peach fruit juice decreased with increasing the storage period regardless of treatments and reached the lowest level after 35 days of cold storage. Also, the untreated fruits (control) showed inferior ascorbic acid content while all treatments of jojoba oil and salicylic acid reduced the losses of ascorbic acid content. Ascorbic acid values in fruit treated with Jojoba oil 1000 ppm and salicylic acid 300 ppm were significantly higher than control in both seasons respectively. As for the interaction during the different periods of storage in the studied, jojoba oil 1500 ppm and salicylic acid 300 ppm reflected the highest ascorbic acid of Swelling peach fruits in this respect. The results were consistent with (Razavi *et al*., 2018; El-Motty and El-Faham, 2013) who found that the ascorbic acid was reduced throughout the cold storage while the peach fruit which was treated with jojoba oil 20% and salicylic acid 1.5 mM maintained the ascorbic content fruits compared with the control during the storage period. The retention of ascorbic acid in the coated fruits could be due to the decreasing respiration rate process and reduction of oxidation of ascorbic acid (Abdel-Salam, 2016).

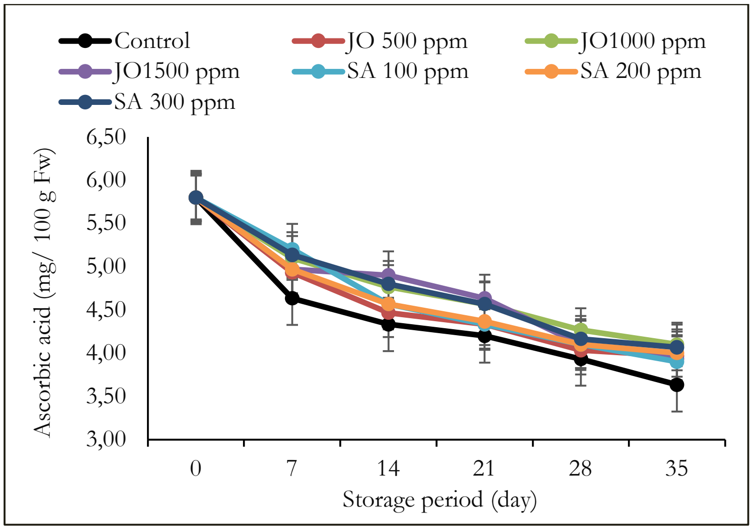

Figure 7. Effect of salicylic acid and jojoba oil on ascorbic acid content mg/100 g FW of 'Late Swelling' peach fruits during cold storage period at 5 ±1 °C, RH 85%

Decay percentage at shelf life

After shipping and storing at cold temperatures, knowing the shelf-life at the room conditions of fruits is very necessary to determine the optimal period of validity of the fruits for handling and marketing at retail traders. The application of salicylic acid and jojoba oil at different concentrations positively affected the postharvest shelf-life of 'Late Swelling' peach fruits (Figure 8). Data showed that, the decay percentage increases gradually in general at the end of shelf-life periods in both treated and untreated fruits, while the decay reached percentage the significant maximum in the control fruits followed with SA 100 ppm at the end of shelf-life. Moreover, the lowest value of decay % was observed in fruits treated with JO 1500, 1000 ppm and SA 300, and 200 ppm respectively after 7 days of shelf-life. These results agree with the findings by (El-Motty and El-Faham, 2013; Abd El-Gawad and El-Moghazy, 2018) who found that coating the Florida prince peach fruits with jojoba oil 20% significantly led to reduced decay percentage compared to control samples or wrapping treatments during the self-life period. This decay percentage decrease in the peach fruits which treated with JO was probably due to the effects of these coatings on delaying senescence and decreasing the effects of enzymes (PPO) by preventing the flow and exchange of oxygen in and out of the fruit beside inhibit the action of ethylene and the result of that decrease the decay percentage of fruits (Taheri *et al.*, 2020; Aboryia and Omar, 2020; Abd El-Gawad and El-Moghazy, 2018). At the same direction Tahereh Boshadi *et al.* (2018) revealed that postharvest application of SA 3 mM L^{-1} asignificantly increased total antioxidants and decreased chilling injury and decay of pomegranate fruit compared with untreated fruits during cold storage it is due to the salicylic acid is an endogenous plant growth regulator of phenolic nature classified inhibitor of ethylene biosynthesis and delaying fruit senescence (Raskin, 1992).

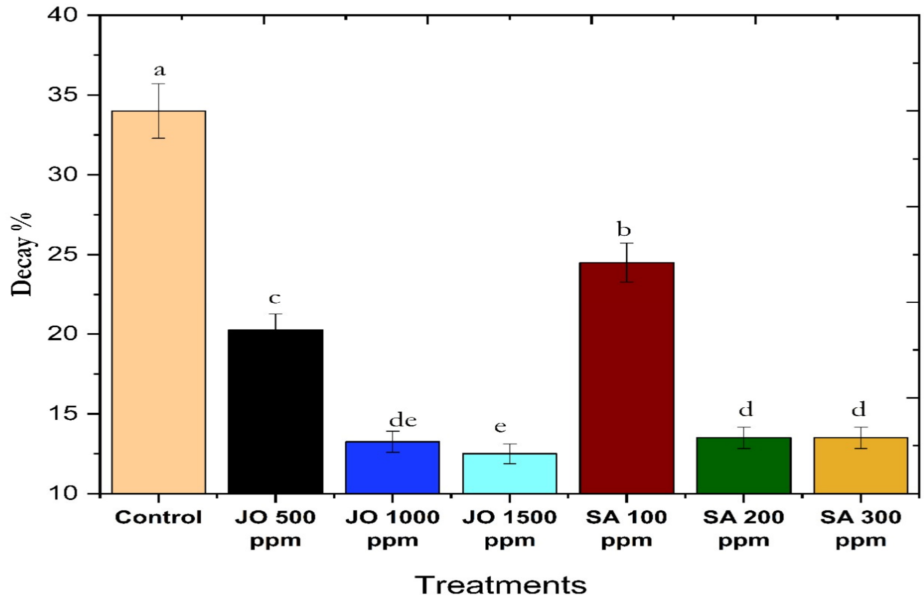

Figure 8. Effect of salicylic acid and jojoba oil on decay percentage of 'Late Swelling' peach fruits after 35 days of cold storage beside 7 days as shelf-life

H_2O_2, TPC production and activity of PPO, POD, CAT and APX enzymes

The essential oils possessing the strongest antimicrobial properties against foodborne pathogens contain a high percentage of phenolic compounds. Results revealed that the treatments of JO and SA had significantly influenced the fruits' physical and chemical properties during storage compared with the control. These treatments in Figure 9 improved TPC and decreased H_2O_2 during shelf-life. The treatment of JO at 1500 ppm recorded the highest TCP and the lowest H_2O_2 content followed by fruits treated with 300 ppm SA as compared with the control and the other treatments. In addition, the results showed that the treatments of JO and SA significantly influenced antioxidant enzymes activity (PPO, POD, CAT, and APX). All fruits treated with JO and SA decreased PPO activity as compared with the control while increasing POD, CAT, and APX activities. On the other side, the lowest PPO activity observed in fruits treated with 1500 ppm and 1000 ppm of JO followed by fruits treated with 300 ppm of SA as compared with the control and the other treatments at the end of shelf-life.

Similar findings were reported by (Badawy *et al.*, 2016) who observed that the use of essential oil as edible coating increased CAT activity and reduced PPO activity, thus promoting the prolongation of the shelf-life and preserving the quality of strawberries fruits during storage. Coating combination treatment of JO may decrease the effects of enzymes (PPO) that lower phenol content by preventing the flow of oxygen in and out of the fruit (Aboryia and Omar, 2020). Moreover, SA leads to the inhibition of enzymes responsible for cell wall degradation and activation of antioxidant metabolism through its involvement in acquiring systemic resistance (Ding and Ding, 2020). Also, Ghasemnezhad *et al.* (2010) and Ali *et al.* (2013) mentioned that the decrease of total phenolic levels might be due to the breakdown of cell structure in order to senescence phenomena during the storage period. The reduction in TPC could be due to a higher respiratory rate in fruits (Dat *et al.*, 2000). Generally, the effect of SA treatments on the maintenance of TPC may be attributing to the delay in senescence process.

The highest increase in POD activity noticed in fruits treated with JO while SA 300 higher than JO at 500 ppm fruits treated with SA compared with the control fruits, where the highest activity of POD was in fruits treated with 1500 and 1000 ppm of JO. While the highest CAT activity was shown by fruits treated with 300, 200, and 100 ppm of SA followed by fruits treated with 500 ppm of JO while the highest APX activity was observed in fruits treated with 300 ppm of SA followed by fruits treated with 1500 ppm of JO during shelf-life directly shelf-life. Other metabolic activities, such as aerobic respiration, could be responsible for the high quantities of O_2 and H_2O_2 produced during the experiment (Tang *et al.*, 2012). As a result, increasing, SOD may improve fruit tissue tolerance to O_2, and increasing CAT and APX activities could aid in the scavenging of both O_2 and H_2O_2 during storage (Yang *et al.*, 2011). It may be a correlated relationship between the total antioxidant of treated fruits and the following quality attributes including, weight loss, decay percentage, respiration rate soluble solids content, and PPO activity.

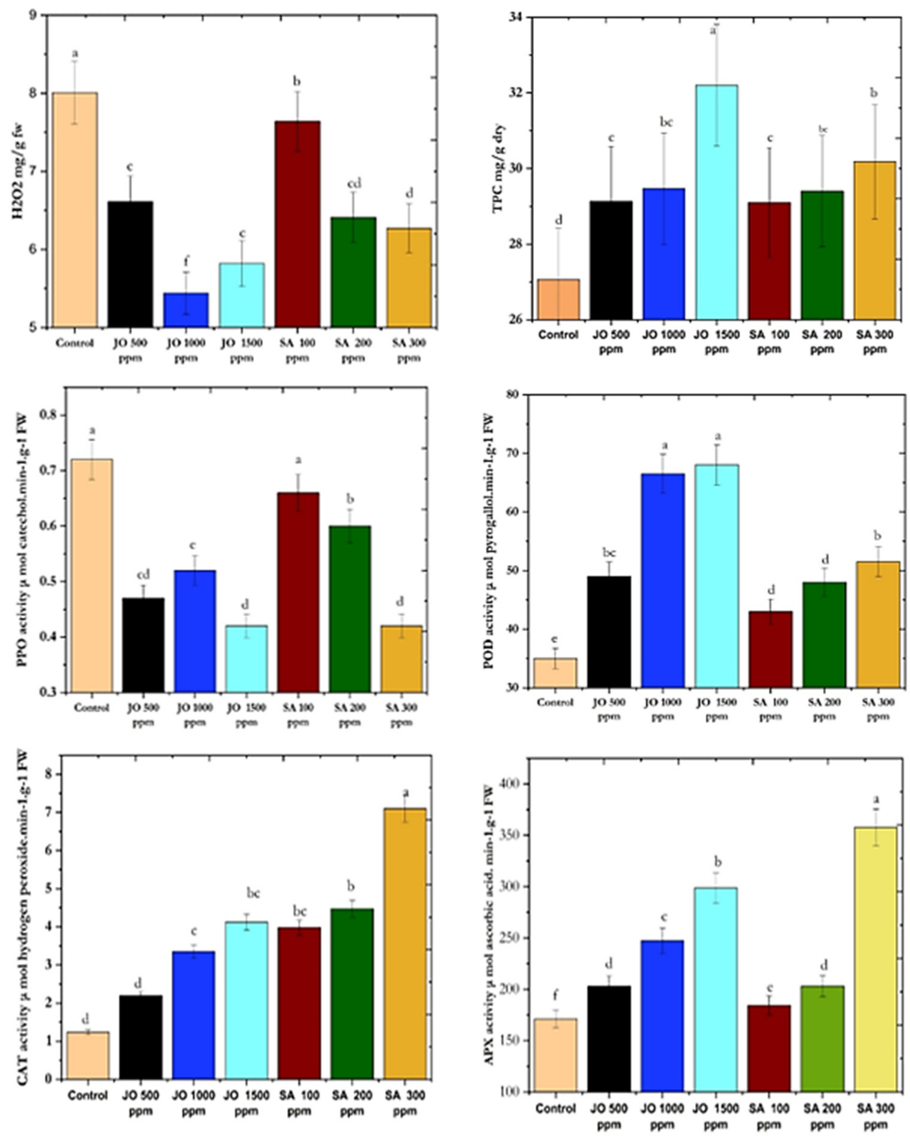

Figure 9. Effect of JO and SA on H_2O_2, TPC production and activity of PPO, POD, CAT and APX enzymes of 'Late Swelling' after storage for 35 days at 5±1 °C besides 3 days as shelf-life

Evaluation of sensory quality

As shown in Figure 10, there was a significant reduction in sensory quality "appearance, firmness, smell and, taste" of peach fruits during shelf-life.

All treatments positively affected the appearance, firmness, smell and, taste of peach fruits during shelf-life. Furthermore, treatments of JO with 1500 and 1000 ppm recorded the highest significantly sensory quality percentage peach fruits during shelf-life compared to all treatments (SA concentrations and control).

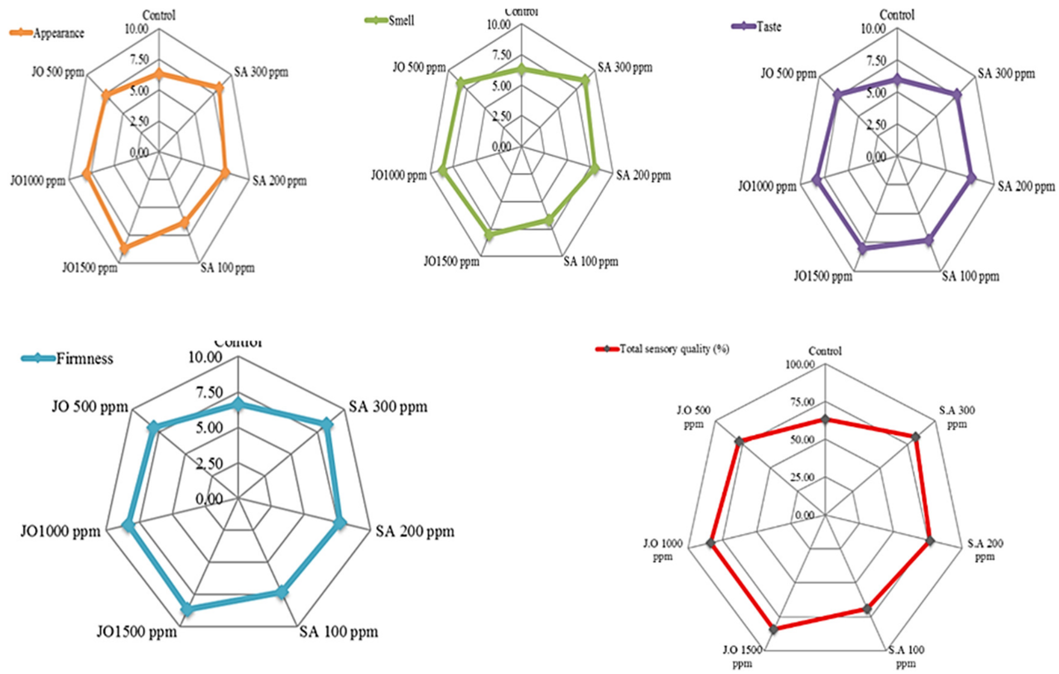

Figure 10. Effect of salicylic acid and jojoba oil on sensory quality % (appearance, firmness, smell and, taste) of peach fruits during cold storage period at 5 ±1 °C, RH 85%

Moreover, the highest values of sensory quality 'appearance and firmness' of peach fruits were observed with jojoba oil with 1500 after storage for 35 days besides 7 days as shelf-life, but the highest values of sensory quality 'smell and taste' were observed with JO 1000 ppm during shelf-life. In the same direction (El-Motty and El-Faham, 2013) jojoba and paraffin, oil improved the shelf-life of Florida prince peach fruits and led to the improved sensory quality and shelf-life, especially under cold storage. Tareen *et al.* (2012) reported that salicylic acid 2 Mm l^{-1} had a significant effect on the quality parameters of peach fruits cv. 'Flordaking' after five weeks of storage period.

Conclusions

This study investigated the effect of jojoba oil and salicylic acid as safety postharvest applications. Data indicated that treatments with SA or JO have a role to improve the preservation of peach fruits in good marketable quality for 35 days besides 7 days as shelf-life with the lowest deterioration, weight loss percentage, beside improved TPC, decrease H_2O_2 contents, and kept PPO at the lowest level, especially with those treated with 1500 ppm to keep storability of peach fruits during both cold storage and shelf-life period with sensory quality 84.16% compared with control 63.33%.

Authors' Contributions

Conceptualization, K.A, I.A.E. and A.N.; methodology, A.N. and I.A. E. and M.O.; validation, H.A. and A. H.; formal analysis, A.N., I.A. E. and M.O.; investigation, I.A.E. and A.N.; writing-original draft preparation, I.A.E.; writing-review and editing, K.A, A.H. and H.A; project administration, K.A.; funding acquisition, K.A. All authors read and approved the final manuscript.

Ethical approval (for researches involving animals or humans)

Not applicable.

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Conflict of Interests

The authors declare that there are no conflicts of interest related to this article.

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