The effect of different coatings on peach (*Prunus persica* L.) storage

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Abstract

It is necessary to provide solutions to reduce agricultural waste. One of the environmentally friendly solutions to reduce fruit waste and increase their shelf life after harvesting is covering fruits with plant extracts. An experiment was conducted to investigate the effect of vegetation cover on peach (*Prunus persica* L.) shelf life in a factorial study based on a completely randomized design with four replications. Research treatments included salicylic acid at three levels: control (no consumption), 1 mM, and 2 mM, aloe vera gel at three levels control (non-application), 20%, and 30%, and clove extract (*Syzygium aromaticum*) at three levels of no consumption (control), 150 ppm, and 300 ppm. Results showed that the use of coating fruits with plant extracts and salicylic acid increased the shelf life and quality of peaches after harvesting compared to the control (no consumption), so that the maximum strength of the flesh of the fruit or tissue stiffness (kg.cm-^{2}) 4.18 was related to the mutual effects of salicylic acid 2 mM + aloe vera gel 30% + clove extract 300 ppm, which was not statistically different from the combined treatments with salicylic acid 1 mM + aloe vera gel 30% + extract 300 ppm cloves and also 2 mM salicylic acid + 20% aloe vera gel + 300 ppm clove extract. The lowest value of the tissue stiffness index (2.83 kg.cm^{-2}) was related to the control treatment.

Keywords: aloe vera gel, clove extract, salicylic acid, shelf life, total phenol

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Introduction

Peach (*Prunus persica* L.), which belongs to the Rosaceae family, is one of the most popular fruits in the world due to its nutritional value and special taste. In addition, this fruit contains significant amounts of bioactive pigments such as anthocyanins, carotenoids, lutein, and beta cryptoxanthin (Awad, 2013). As the fruits progress in the ripening cycle, they lose their water content and wither quickly. Therefore, the short storage life after harvesting of peach, makes it unsellable due to severe decomposition of internal tissues along with microbial infections (Gayed et al., 2017). Decomposition of the internal tissue of peach, which is characterized by the browning of the flesh, is characterized by an increase in neutral sugar and low amounts of cellulose and pectin, as well as a decrease in the activity of pectin hydrolyzing enzymes and the binding of cations, mainly calcium, in the cell wall. Storage in fruit freezer is suggested as a suitable solution to slow down the rotting process and maintain the quality of the fruit. However, peach is sensitive to low

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Storage temperature, which limits their storage period. Therefore, coating the peach fruit is one of the appropriate strategies to increase the storage life of this fruit (Silva et al., 2017; Hong et al., 2012).

Edible coatings of fruits can act as a suitable substitute for synthetic chemicals in delaying physiological processes and biochemical degradation in fruits and thus maintaining the quality of fruits (Silva et al., 2017). Aloe vera gel is a polysaccharide plant cover and a protective layer that has features such as reducing the loss of juice and reducing the amount of gas in relation to the skin of the fruit and reducing the production of ethylene in the raw fruit. Aloe vera gel has approximately 99.5% water and 0.5% solid matter, which includes compounds such as polysaccharides, vitamins, minerals, phenolic compounds and organic acids (Guillen et al., 2013). The decay process was reported to slow down in grapes treated with chitosan and aloe vera gel, and the lowest rate of decay was observed in the 2% chitosan treatment with aloe vera gel (Nia et al 2021). Application of chitosan before harvesting and aloe vera gel after harvesting increased the life after harvesting of Asgari grapes (*Vitis vinifera*) and improved its quality characteristics (Ehtesham Nia et al., 2022). The amount of total phenol and antioxidant capacity were higher in kiwi (*Actinidia deliciosa*) samples with a more concentrated coating and in modified atmosphere packaging. In the samples with higher concentration of aloe vera, the destruction of ascorbic acid was less. Also, according to sensory evaluators, the coated samples under modified atmosphere had a higher score. In general, modified atmosphere and aloe vera gel coating improved the quality of stored kiwi (Mansour Gorgani et al., 2018).

The use of plant extracts, including clove extract (*Syzygium aromaticum*), is a useful and environmentally friendly method that increases the storage life of fruits. Plant extracts increase the plant's defense system and significantly reduce fungal contamination. It has been reported that coating with clove extract increased the shelf life of oranges compared to the control (without coating) (Baran Zehi et al., 2019).

Acid salicylic, aminohydroxybenzoic acid, belongs to the phenolic group of compounds with strong antioxidant properties that activate the systemic acquired resistance and synthesis of metabolites and antioxidant enzymes. Also, salicylic acid as a natural compound has a high potential in preventing the production and effect of ethylene (Haider et al., 2020; Kumari et al., 2015). It was reported that coating pistachios (*Pistacia vera*) with salicylic acid increased their shelf life in storage (Molamohammadi et al., 2020). Salicylic acid has also been reported to increase the quality and shelf life of pear (*pyrus communis*) (Sinha et al., 2021). The present study was conducted with the aim of investigating the effects of vegetation and salicylic acid on increasing shelf life and preserving the quality of peach fruit after harvest.

Materials and Methods

This research was carried out as a factorial study in the form of a completely randomized design with four replications on peach (*Persica pronus* L.) Zafarani cultivar. Treatments included salicylic acid at three levels of control (no consumption), 1 mM, and 2 mM, aloe vera gel at three levels of control (no consumption), 20% and 30%, and clove extract (*Syzygium aromaticum*) at three levels of control (no consumption), 150 ppm, and 300 ppm.

The peach fruits were harvested from one of the orchards located in Arak, Markazi Province Iran. Efforts were made to ensure that the selected fruits were uniform and with the same size, completely healthy, and free from scratches, wounds, and diseases. Aloe vera gel was obtained from leaves in a commercial farm located in Arak. To prepare clove extract, first the samples were powdered and then extracted. Aloe vera gel coatings of different concentrations were prepared from the gel diluted with distilled water (20-30% w/w) (Boudreau and Beland, 2006).

The coating was carried out by spray method where the samples were thoroughly sprayed with each treatment and air-dried. The control sample did not have any coating. Each sample contained 5 peaches. To determine some physiological characteristics, first, a gas control chamber was constructed with different sensors to measure variations in the levels of gases emitted from fruits. The sensors detect and check the level of gases in the fruit storage environment, storing the data in a RAM. The respiration rate and metabolic activities of the fruits were detected using the obtained data. Also, carbon dioxide, ethylene, and oxygen were measured and monitored in the fruit storage compartment. The samples were placed inside the machine twice a day for 3 hours in the day and 3 hours at night.

The duration of fruit storage was one week. Traits such as firmness of fruit flesh or texture, total acidity, total phenol, fruit weight (grams), vitamin C, alcohol gas, NH4, toluene, octene, and carbon dioxide were measured. A tissue analyzer (Topals, England) was used to measure tissue. A flat cylindrical probe with a diameter of 2 mm was used. The jaw of the device was set at a speed of 1 mm/s with a penetration depth of 20 mm. The maximum force required to sink the probe into the product was reported as hardness (in Newtons) (González-Aguilar et al., 2004).

For measuring vitamin C contents, a spectrophotometer (2601 UV, Double Beam, China) with visible light and a 1 cm tube was used. The extraction solution of 0.4% oxalic acid contained 20% acetone. Four (4) grams of oxalic acid was dissolved in 500 ml of water, to which 200 ml of acetone was added, and the mixture was diluted to 1 liter with distilled water. Then the pH was adjusted to 1.1 with the help of concentrated H_2SO_4. The stock solution of 2,6-dichloroindophenol (DCIP) was prepared by dissolving 100 mg of dye in 100 ml of hot water and adding 84 mg of $NAHCO_3$ to 500 ml solution, diluted with water and then filtered. The stock solution of DCIP diluted with water was mixed with 9 ml of DCIP in the ratio of 1 ml of the extraction solution and its absorbance at 520 nm was read between 0.35-0.3. The standard ascorbic acid stock solution was 100 mg of ascorbic acid in 100 ml of extraction solution. The mashed peach sample was immediately placed in a bed of powdered dry ice to prevent the oxidation of ascorbic acid. After 30 to 60 minutes, a part of this frozen mass was placed in glass molds (at a pressure of less than 100 microns); after 3 days, the samples were ground, passed through a sieve, and kept in a freezer at -16 °C for analysis. The moisture content was determined by drying the samples to a constant weight in an oven under vacuum at 70 °C for 16 to 18 hours (Egoville et al., 1988).

The samples were centrifuged at 6000 rpm for 15 minutes at 4 °C and then filtered. Afterwards, 0.5 ml of the extract was mixed with 0.5 ml of Folin Ciocalteu reagent and 10 ml of saturated sodium carbonate solution and kept at room temperature for one hour. Then, the absorbance of the samples was calculated at 725 nm. The results were expressed as milligrams gallic acid per kilogram fresh weight (Singleton et al., 1999).

The volumes of gases emitted from fruits including alcohol, nitrate, toluene, octane, and carbon dioxide were measured using a gas control chamber.

Statistical Analysis

The data obtained from different stages of the research were analyzed using SAS software version 4.9 and the averages were compared using Duncan's multi-range test with a probability of 5% error. Excel software was used to draw graphs.

Results

Fruit texture firmness

The results of analysis of variance indicated that the effects of salicylic acid, aloe vera gel, clove extract, and also their interaction were significant (p<0.01) on fruit texture firmness (Table 1). The results of the mean comparison showed that with increasing concentration of salicylic acid, aloe vera gel, and clove extract, the firmness of fruit flesh or tissue firmness increased. The highest value of tissue hardness was recorded as 4.18 $kg.cm^{-2}$, which was related to the mutual effects of 2 mM salicylic acid + 30% aloe vera gel + 300 ppm clove extract, albeit in the same statistical group as 1 mM salicylic acid + 30% aloe vera gel + 300 ppm clove extract and also 2 mM salicylic acid + 20% aloe vera gel + 300 ppm clove extract. The lowest value of this index was 2.83 $kg.cm^{-2}$ corresponding to the control treatment (Fig. I).

Table 1
Variance analysis of the studied traits

S.O.V		Mean Squares				
	df	Fruit Texture Firmness	Total Acidity	Total Phenols	Fruit Weight	Vitamin C
salicylic acid (S)	2	7.13**	28.46*	51298.63**	7432.58**	3265.73**
aloe vera gel (A)	2	5.18**	32.97*	43676.59**	6948.21**	2986.51**
clove extract (D)	2	3.34**	20.85*	27652.78**	3455.90**	3186.93**
S×A	4	0.01 ns	2.53 ns	2012.35**	41.75ns	2374.64**
S×D	4	2.17**	1.98 ns	15686.70**	31.82ns	1826.53**
A×D	4	0.003ns	3.63 ns	75369.34**	26.44ns	7911.41**
S×A×D	8	4.85**	5.23 ns	18123.95**	19.71ns	1845.38**
Error	81	0.0059	10.34	146.32	49.46	17.24
C.V (%)		8.24	7.33	9.49	12.65	13.54

**: Significant at $p<0.01$, *: significant at $p<0.05$, and ns: not significant.

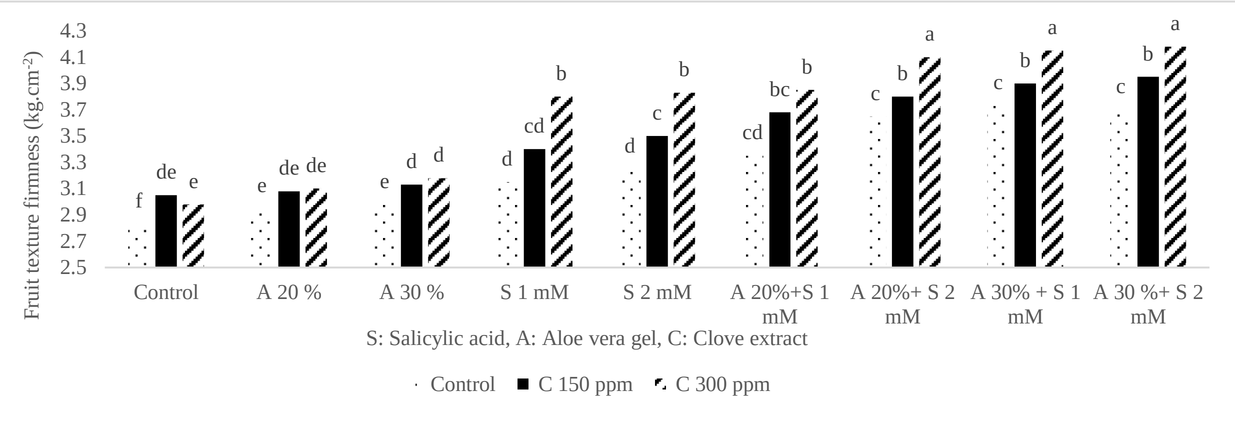

Fig. I. Mutual effects of salicylic acid, aloe vera gel, and clove extract treatments on peach fruit texture firmness

Table 2
Variance analysis of gases emitted from the fruits under study

S.O.V		Mean of squares				
	df	Alcoholic Gases in the Storage	Nitrate (NH_4)	Toluene	Octane	Carbon Dioxide
salicylic acid (S)	2	0.542**	9.21**	16.46**	11.73**	11.37**
aloe vera gel (A)	2	0.161**	6.52**	12.53**	10.97**	10.48**
clove extract (D)	2	0.563**	4.73*	10.16**	8.64**	8.94**
S×A	4	0.649 **	0.46ns	1.46 ns	1.28ns	1.83ns
S×D	4	0.721**	0.98 ns	2.13ns	1.59ns	1.35ns
A×D	4	0.568**	0.63 ns	0.91ns	1.54ns	1.79 ns
S×A×D	8	0.385**	0.076 ns	1.64ns	1.28 ns	1.62ns
Error	81	0.005	1.59	3.38	2.76	4.54
C.V (%)		7.54	9.32	10.64	8.51	8.69

**: Significant at $p<0.01$, *: significant at $p<0.05$, and ns: not significant.

Total acidity

The effect of salicylic acid, aloe vera gel, and clove extract on total acidity was significant ($p<0.05$) on total acidity of the fruits under study (Table 1). With increases in the concentration of salicylic acid, aloe vera gel, and clove extract, total acidity decreased. The highest total acidity 4.64 was for salicylic acid control, and also 4.56 for aloe vera gel control, and 4.67 for clove extract control. The lowest value of this index was related to salicylic acid, aloe vera gel, and clove extract (Table 3).

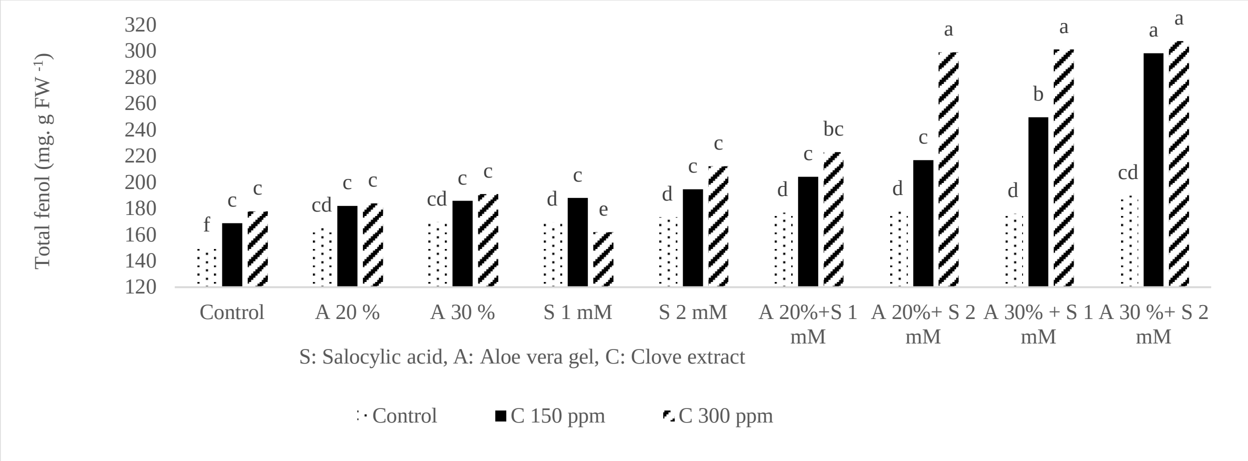

Fig. II. Mutual effects of salicylic acid, aloe vera gel, and clove extract treatments on total phenol contents of the fruits

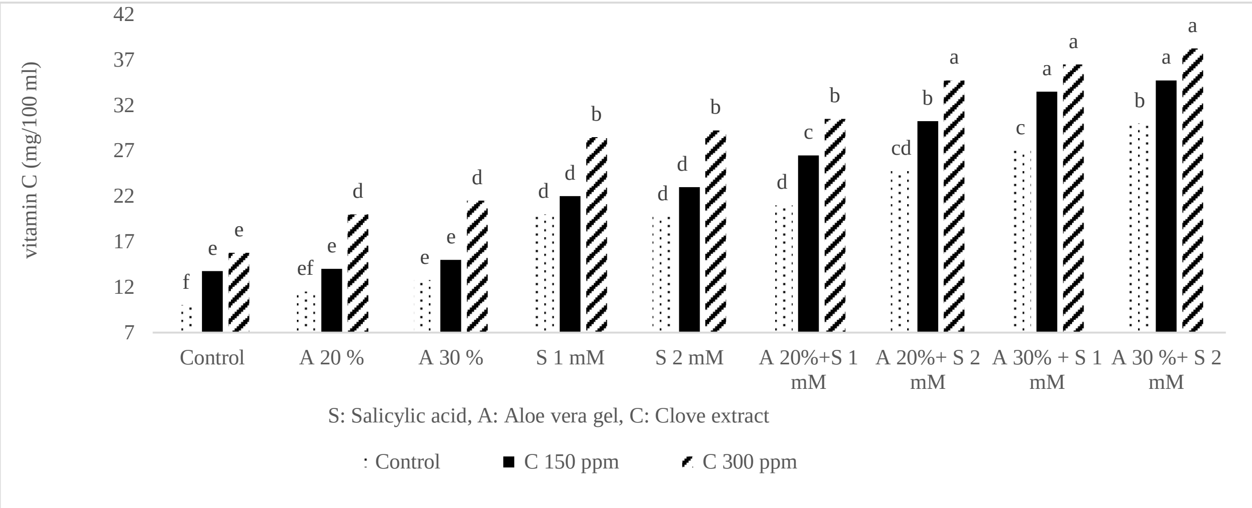

Fig. III. Mutual effects of salicylic acid, aloe vera gel, and clove extract treatments on vitamin C contents of the fruits

Total phenol

The effects of salicylic acid, aloe vera gel, clove extract and their interaction were significant on total phenol ($p<0.01$) (Table 1). Increasing the concentration of salicylic acid, aloe vera gel, and clove extract increased total phenol contents. The highest level of total phenol, 307.5 mg. g^{-1} FW was seen in interaction of 2 mM salicylic acid + 30% aloe vera gel + 300 kg cm^{-2} clove extract, and also interaction of 1 mM salicylic acid treatments + aloe vera gel 30% + clove extract 300 kg.cm^{-2}, and salicylic acid 2 mM + aloe vera gel 20% + clove extract 300 kg.cm^{-2}, and also salicylic acid 1 mM + aloe gel vera 30% + clove extract 150 kg. cm^{-2}. The lowest value of this index was 149.75 mg. g^{-1} FW related to the control (Fig. II).

Fruit weight

The effect of salicylic acid, aloe vera gel and clove extract on fruit weight was significant ($p<0.01$) (Table 1). Increasing the concentration of salicylic acid, aloe vera gel, and clove extract improved fruit weight. The highest fruit weights observed in salicylic acid 2 mM, aloe vera gel 30%, and clove extract 300 ppm were 65.24 g, 68.73 g, and 62.75 g, respectively. The lowest value of this index was seen in salicylic acid, aloe vera gel, and clove extract control (Table 3).

Vitamin C

The effect of salicylic acid, aloe vera gel, clove extract and their mutual effects on vitamin C were significant ($p<0.01$) (Table 1). With increasing salicylic acid, aloe vera gel, and clove extract,

Table 3
Comparison of the average characteristics of total acidity, fruit weight, fruit nitrate, and gases released from the fruit

treatments	Total acidity	Fruit weight (g)	NH4 (ppm)	Toluene (ppm)	Octane (ppm)	CO_2 (ppm)
Salicylic acid						
2 mM	4.3 b	65.24 a	51.38 a	0.35 c	0.68 a	0.26 c
1 mM	4.27 b	59.3 b	38.96 b	0.41 b	0.47 b	0.44 b
Control	4.64 a	53.29 c	26.47 c	0.48 a	0.32 c	0.67 a
Aloe vera gel						
30 %	4.29 b	68.73 a	52.27 a	0.38 c	0.77 a	0.41 c
20 %	4.32 b	61.51 b	43.34 b	0.43 b	0.64 b	0.53 b
Control	4.56 a	54.36 c	35.17 c	0.49 a	0.47 c	0.69 a
Clove extract						
300 ppm	4.45 b	62.75 a	53.28 a	0.37 c	0.67 a	0.44 c
150 ppm	4.49 b	56.42 b	45.33 b	0.44 b	0.53 b	0.57 b
Control	4.67 a	50.21 c	40.72 c	0.51 a	0.36 c	0.65 a

Dissimilar letters in columns indicate significant differences at the 5% level according to Duncan's test.

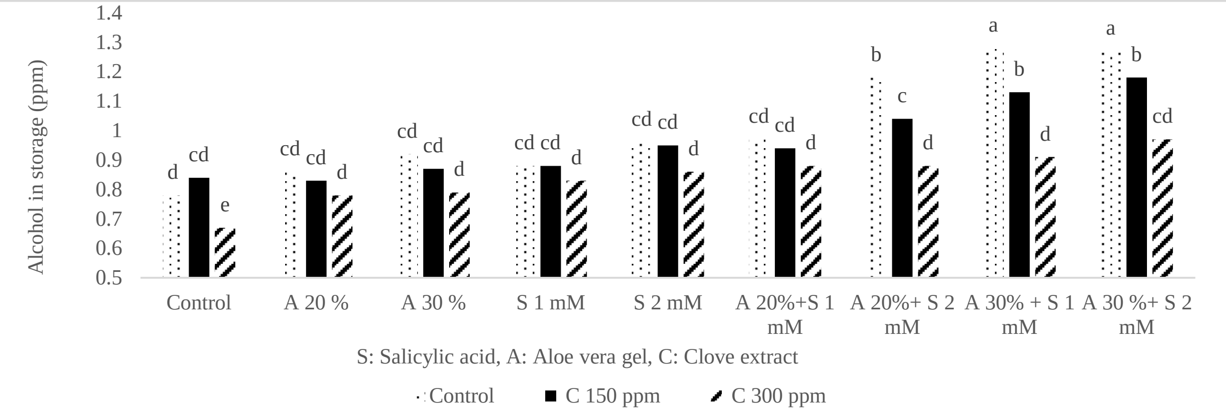

Fig. IV. Mutual effects of salicylic acid, aloe vera gel, and clove extract treatments on the alcohol contents of fruits

vitamin C contents increased. The highest vitamin C, 25.38 mg.100 ml^{-1}, was observed in the interaction of 2 mM salicylic acid + 30% aloe vera gel + 300 ppm clove extract, which was in the same statistical group with 1 mM salicylic acid + 30% aloe vera gel + 300 ppm clove extract, 2 mM salicylic acid + 20% aloe vera gel + 300 ppm clove extract, 2 mM salicylic acid +30% aloe vera gel + 150 ppm clove extract, and also 1 mM salicylic acid +30% aloe vera gel + 150 ppm clove extract. The lowest value of this index was 10 mg.100 ml^{-1} related to the control, and also 20% salicylic acid treatment (Fig. III).

Alcoholic gases in the storage

The effect of salicylic acid, aloe vera gel, clove extract and their interaction effects were significant (*p*<0.01) (Table 2). The concentration of salicylic acid, aloe vera gel and non-application of clove extract increased alcohol levels in warehouse. The highest level of alcohol gases (1.27 ppm) was related to the interaction of 2 mM salicylic acid + 30% aloe vera gel, which was not significantly different from the 1 mM salicylic acid + 30% aloe vera gel. On the other hand, the lowest value of this index (0.67 ppm) was seen in 300 ppm clove extract (Fig. IV).

Nitrate gas (NH4)

The effect of salicylic acid, aloe Vera gel and clove extract was significant (*p*<0.01) (Table 1). With increased concentration of salicylic acid, aloe vera gel, and clove extract, fruit nitrate gas increased. The highest fruit nitrate gas observed under salicylic acid 2 mM, aloe vera gel 30%, clove extract 300 ppm treatments were 51.38 ppm, 52.27 ppm, and 53.28 ppm, respectively.

On the other hand, the lowest value of this index was observed in control group (no application of salicylic acid, aloe vera gel, and clove extract) (Table 3).

Toluene gas, octane and carbon dioxide gas

The effect of salicylic acid, aloe vera gel, and clove extract on toluene, octane, and carbon dioxide emissions from the fruits under study was significant (p<0.01) (Table 1). With increased concentration of salicylic acid, aloe vera gel, and clove extract Octane gas levels increased while toluene and carbon dioxide levels decreased. In salicylic acid treatment, the highest level of octane (0.68 ppm) and the lowest level of toluene (0.35 ppm), and the lowest level of carbon dioxide (0.26 ppm) were recorded in 2 mM salicylic acid. In aloe vera gel treatments, the highest level of Octane (0.77 ppm), the lowest level of toluene (0.38 ppm), and the lowest level of carbon dioxide (0.41 ppm) were observed under aloe vera gel 30%. In clove extract treatments the highest level of Octane (0.67 ppm), the lowest level of toluene (0.37 ppm), and the lowest level of carbon dioxide (0.44 ppm) were recorded in 300 ppm clove extract (Table 3).

Discussion

The firmness of the fruit tissue is one of the most important physical parameters for fruit maturity and ripening. Increasing fruit firmness can increase its quality by preserving other related traits, such as fruit texture color and the associated nutritional quality. One of the important reasons for weight gain in the treatments with salicylic acid, aloe vera gel, and clove extract is the slowness of physiological processes such as respiration and sweating as shown by an increase in respiration rates and other metabolic processes (Gheysarbigi et al., 2020; Sinha et al., 2021). Improved firmness in the treated fruits may be attributed to hydrolysis of soluble starch. The delay in ripening stages in salicylic acid depends on the concentration of the treatment (Tarin et al., 2012).

The main reason for the increase in total acidity of the treated fruits is the breakdown and decomposition of organic acids in the process of respiration. It is very probable that the reduction of total acid is due to the biochemical changes of the organic compounds of the fruit during the respiration process. Therefore, any treatment that slows down the metabolism and aging of the product can reduce the rate of titratable acidity changes during storage. It might be that the use of salicylic acid leads to a decrease in the use of organic acids as a respiratory substrate due to the decrease in respiration rate and ethylene production. Studies show that the use of salicylic acid reduces the rate of respiration in banana and peach tissues and preserves organic acids compared to control fruits (Srivastava and Dwivedi, 2000).

Phenolic compounds are the main useful secondary metabolites that act as a strong antioxidant. The amount of phenol in fruits and vegetables after harvesting can decrease or increase depending on the storage conditions (Gheysarbigi et al., 2020). Aloe vera gel is a hydrocolloid coating that increases the barriers against oxygen and water. The effect of aloe vera gel concentration on total phenol content showed that the highest amount was in the coated sample with a concentration of 30% while the lowest amount was recorded in the control (without coating). Reduction of titratable acidity and organic acids through conversion to carbohydrates provides the carbon skeleton for phenol synthesis (Plaza et al., 2006). The reduction of phenolic compounds at the end of the storage period can be attributed to the failure of the cell structure due to the aging phenomenon during the storage period (Ghasemnezhad and Shiri, 2010). Phenolics synthesize the secondary metabolites of the plant. They are responsible for the flavor and color of the products. Generally, they exist as flavanols in fruit skins (Tarin et al., 2012).

Fruit weight loss can be associated with loss of quality, including loss of firmness and other undesirable changes in color, pleasantness, and loss of nutritional quality in the form of water vapor from the air spaces inside the fruit to the space around it. The reduction in weight loss in covering treatments (salicylic acid, aloe vera gel, and clove extract) is due to the slowness of physiological processes such as breathing and sweating. In control fruits without coating treatment the rate of respiration and other metabolic processes increased, causing a decrease in substrates such as sugars and proteins and leading to more weight loss (Gheysarbigi et al., 2020; Sinha et al., 2021). Similar to the results of the present study, it has been reported that salicylic acid closes the stomata and leads to suppression of respiration and minimizes the weight loss of peach fruits (Tarin et al., 2012).

Measuring vitamin C contents of the fruits in storage is an important approach to evaluate their shelf life. The amount of vitamin C decreased with the destruction of fruits, and the main reason for the destruction of ascorbic acid in the tissue of fruits is the oxidative process, which is accelerated in the presence of light, oxygen, heat, and oxidizing enzymes (Plaza et al. al., 2006; Kalt, 2005). Mansour Gorgani et al. (2018) and Sahar and Wahab (2015) reported that treatments with aloe vera gel increased vitamin C contents of kiwi fruits and apricots, respectively, which are in line with the results of the present study. In the same studies, salicylic acid was the regulator of many processes related to the growth and development of the plant and preserved vitamin C during the storage of the plant after harvesting.

The production of alcohol in fruits is controlled by ACC-synthase and ACC-oxidase enzymes, and the decrease in ethylene production after coating treatments is probably due to the decrease in the activity of these enzymes. The production of alcoholic gases was significantly controlled by the combination of aloe vera gel with rose oil in plum, nectarine and peach (Paladines et al., 2014; Saberi et al., 2018).

Fruits are still alive and breathing after harvest and will spoil if they are not stored properly. Respiration rate as well as gas emission are important physiological parameters that indicate fruit ripening and aging during storage (Lin et al., 2020). Edible coating extracted from plants reduces the respiration rate of fruits by preventing gas exchange from the cover openings. The increase in respiration rate in control fruits can be related to fruit aging. In other words, the decrease in the rate of respiration in coated fruits is the result of a decrease in gas permeability from the stomata, which leads to a decrease in O_2 and an increase in CO_2 in the internal gas atmosphere (Ncama et al., 2018; Bal, 2018). The results of the present study were consistent with those of Adhikary et al. (2020), who found that the application of salicylic acid reduced respiration in pears. Also, the results were in line with the research by (Mohammadi et al., 2021) who found that coating strawberries with aloe vera gel increased their shelf life in storage and reduced their respiration.

Conclusion

The results of the present study indicated that increasing the concentration of salicylic acid, aloe vera gel, and clove extract increased the fruit firmness texture, total phenol, fruit weight, vitamin C content, and nitrate and acetylene emissions while decreasing total acidity and toluene and the carbon dioxide gases. Coating the fruits with plant extracts and salicylic acid, increased the shelf life and quality of peaches after harvesting compared to the control (no application) and the interaction effects of the treatments had a greater effect on some investigated traits than their main effects. Therefore, in order to increase the shelf life and maintain the quality of peaches after harvesting, it is recommended to coat them with salicylic acid, aloe vera gel, and clove extract.

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