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PRE-STORAGE APPLICATION OF AQUEOUS OZONE, *ALOE VERA* GEL AND PACKAGING ON THE QUALITY AND STORABILITY OF ORANGE FRUITS

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ABSTRACT

This study aimed to determine the quality and storability of the orange fruit cv. Diyala after 60 days of storage at 6±1°C and 90% RH under aqueous ozone at 4 mg L-1 or 15% Aloe vera gel. The fruit packaging was applied in three types: without packing, perforated plastic bags, and paper wrapping bags. The experiment was performed in a complete randomized design with three replicates. These parameters were studied: weight loss, respiration rate, moisture content, firmness, pH, juice, total soluble solids, total titratable acidity, TSS/TA, total sugar, ascorbic acid, and total carotenoids. Results indicated that the lowest weight loss in orange fruits was recorded for the 15% Aloe vera + Perforated plastic bag (7.17%), the minimum respiration rate was recorded for the 15% Aloe vera + Perforated plastic bag (8.96 mg CO2 kg-1 h-1), the same treatment had the most significant effect on the moisture content (80.55%), all treatments significantly affected on the firmness of orange fruits. The aqueous ozone + Perforated plastic bag treatments were significantly superior to the control treatment on the pH value. On the other hand, the highest juice percentage was recorded from the control treatment—the total titratable acidity obtained in aqueous ozone + 15% Aloe vera (0.72%). Furthermore, 15% Aloe vera + without packaging significantly affected the ascorbic acid content of oranges. The aqueous ozone + 15% Aloe vera + fruit wrapping paper bag treatment greatly affected the total sugar and carotenoid contents.

INTRODUCTION

Orange (*Citrus sinensis* L. Osbeck) is one of the most important evergreen fruit trees in the Rutaceae family and belongs to the genus Citrus. It is the most traded horticultural product in the world, with production and consumption increasing every year in Iraq (Inglese and Sortino, 2019). According to world data atlas statistics, citrus fruit production in Iraq was 167,880 tons in 2021. According to FAO statistics, oranges are the most important citrus fruit, accounting for 79 million tons (46.7% of citrus fruit production) (FAOSTAT, 2023). Because postharvest losses account for approximately 30-40% of total fruit and vegetable production, storage is regarded as one of the most important practices for increasing shelf life and improving the quantity and quality of fruits. Consumers demand high quality food without any chemical preservatives and have a longer shelf life. Packaging is thus an important stage of the storage process to protect the product from spoilage (Al-Mahmood, 2022). Many packaging materials are designed to aid in the cooling process, and perforated packaging materials are recommended for removing excess heat and moisture from products during storage (Azene *et al*., 2014). The quality and shelf-life of fruits are impacted by contamination by several microbial agents, and when the fruits are stored in a cold room without treatments, significant losses occur (Rocha-Pimienta *et al*., 2020). In 1997, the US Food and Drug Administration approved ozone as a prospective alternative treatment for fresh produce, notably fruits and vegetables, as well as a potential substitute for a sanitizing agent for postharvest treatment.

Ozone is a gas with a high oxidant capability that kills most microorganisms (Karaca, 2010). When ozone is used in postharvest treatment, it can be administered in a gaseous or aqueous manner, and the critical advantage is that it does not leave any chemical residues in treated products, which is why many organic producer groups support it (Horvitz and Cantalejo, 2014). Ozone is not only antimicrobial but can also destroy pesticide residues and chemical substances (Ozen *et al*., 2021). It is thus a non-contaminant substitute for reducing the use of fungicides during fruit preservation. Additionally, the use of ozone at a proper level in the storage atmosphere might increase shelf life, possibly protect against disease with no physiological effect, and reduce the respiration rate indirectly, indicating that ozone considerably slows the aging process and weight loss in oranges in comparison to untreated oranges and is approved by many organic producer organizations (Karaca, 2010; García-Martín *et al*., 2018). Aqueous ozone is also used for the sanitation of fruit surfaces and packaging equipment and is an alternative to chlorine (Carletti *et al*., 2013). (Kassem *et al*., 2022) who found that after 40 days of cold storage at five °C and 0.6 ppm ozonated water, grapefruits showed physiologically desirable traits such as delayed loss of weight, deterioration, and preservation of juice content. Compared to all the treatments or the control, this treatment conserved the TSS/TA ratio, total phenolic, lycopene, vitamin C, and antioxidant activity. Consequently, the efficacy of aqueous ozone as a novel approach was used to prolong the freshness of grapefruits after cold storage and was confirmed as long as possible.

Aloe vera (AV) is a succulent plant with short stems that belongs to the Asphodeleceae family. The plant contains many complex substances, including hormones, amino acids, vitamins, saponins, phenolic compounds, polysaccharides, glycoproteins, salicylic acid, and lignin. This contributes to its numerous therapeutic benefits as an antibacterial, antifungal, anti-inflammatory gel, and edible coating to prevent moisture loss and softening (Kumar and Bhatnagar, 2014). Additionally, Aloe vera coatings reduced carbon dioxide production and oxygen consumption, preventing anaerobic conditions (Benítez *et al*., 2013). AV gel is a polysaccharide that acts as a barrier to moisture and oxygen, slowing respiration and preserving fruit quality (Maan *et al*., 2018). Several researchers have recently shown that internal gases are transformed by A. vera, which also increases antioxidant activity and decreases moisture loss, respiration rate, oxidative browning, tissue softening, and microbial growth in fruits (Rehman *et al*., 2020). 10% Aloe vera gel coating delayed yellowing and extended the shelf life of lime fruits during ambient storage without affecting physicochemical traits (Pimsorn *et al*., 2022).

Fruits must be packaged carefully to ensure freshness until they are served to customers. The different types of packaging significantly affected weight loss, firmness, pH, TA%, and total sugars and maintained the quality of the tomato fruits (Dladla *et al*., 2023). Therefore, this investigation aimed to study the impact of aqueous ozone and Aloe vera gel as edible coatings with different types of packaging on the quality and storability of orange fruits during cold storage.

MATERIALS AND METHODS

This study was carried out on the orange fruit Diyala cv., which was picked in the morning at the ripe stage (when the rind turns green to light yellow). The orange trees belong to a private orchard in the Kalar-Kurdistan region of Iraq. The fruits were transported to the College of Agricultural Engineering Sciences-Scientific Laboratory, University of Sulaimani. The fruits were selected for uniform size, color, and shape without damage or visual defects, and they were subsequently cleaned to remove dirt and other undesirable particles from the surface. Table (1) summarizes the study's treatments. The experiment was performed in a complete randomized design (CRD) with three replicates, and every replicate (experimental unit) consisted of 2 Kg of fruits. The fruits were dipped in Aqueous Ozone (AO) at 4 mg L-1 or 15% Aloe vera gel for 5 min. The fruit packaging was applied at three levels: without packing, perforated plastic bags, and paper wrapping bags. The treated fruits were stored for 60 days at 6±1°C with 90% relative humidity in the cold room storage (Misa Branded-Italy) of the Horticulture Department. The data were subjected to and analyzed of variance (ANOVA) using the XLSTAT program (Addinsoft, 2021). The means were compared using Duncan multiple range comparison tests at a probability of 0.05 (Al-Rawi and Khalaf Allah, 1980).

After the storage period (15/11/2022 to 15/1/2023), the samples were evaluated for analysis. These parameters were determined as follows: Fresh weight loss (%) was calculated, the difference between the initial weight of the fruits and their final weight was translated as weight loss percentage, The respiration rate (mg CO2 kg h-1) was calculated by the Carbon Dioxide Detector Model JD-112 Dongguan Jinlide Electronic Technology Co., Ltd, China (González-Buesa and Salvador, 2019). Moisture content (%) has been determined using the method described by (Sultana *et al*., 2012). Fruit firmness (lb. cm-2) was determined by a Fruit Texture Analyzer with 10 mm depth and 0.2 mm /second speed as described by (Omar *et al*., 2022) for orange fruits. The pH of the orange juice was determined using a microprocessor pH meter (model-pH 211-HNA Com. Italy) (Kasnazany *et al*., 2023), and Juice (%) was determined with the method described by (Akusu *et al*., 2016). A portable hand refractometer measured total soluble solids (TSS%) (Erma Japan) (Cao *et al*., 2010), total titratable acidity (TTA%) was measured by titration with sodium hydroxide (NaOH) and phenolphthalein (Ranganna, 2011), total sugars were determined by using 1mL of phenol 5%, and H2SO4 (97%) by spectrophotometer at 490 nm as mentioned (Joslyn, 1970). Ascorbic acid (mg.100g-1 fresh weight) orange pulp of 5g was randomly collected from 5 fruits and blended with (5 ml) 1.0% (w/v) HCl and centrifuged at 10000 x g for 10 min. The supernatant's absorbance (243 nm) (ascorbic acid extract) was recorded using a spectrophotometer.

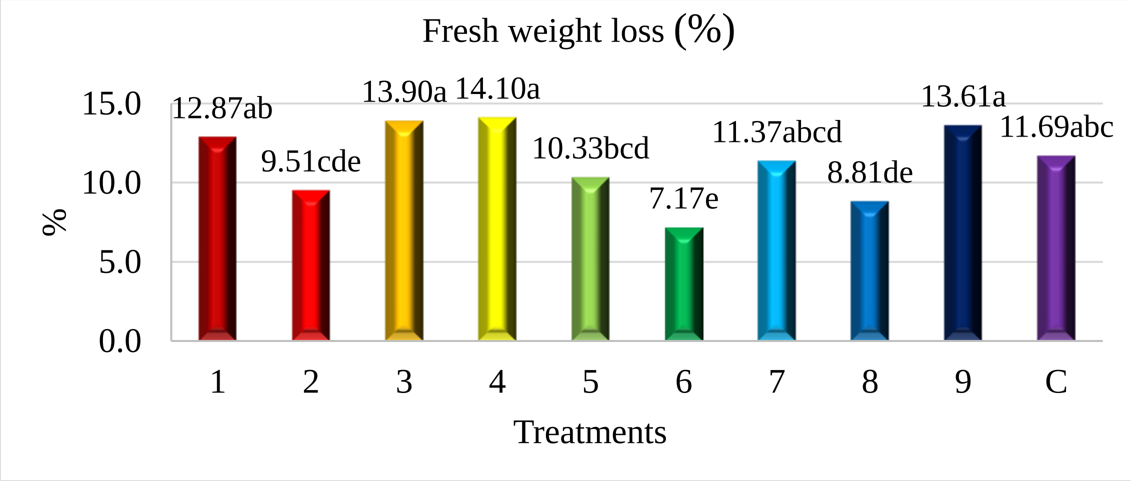
The spectrophotometer was calibrated by making standard solutions of ascorbic acid in the same way before the measurements were recorded (Tareen *et al*., 2012), and total carotenoids (mg. 100 ml-1) were measured in orange juice by using 80% acetone. Then, the sample concentration was read by a spectrophotometer at 480 nm, as mentioned by (Aljabary *et al*., 2021). Finally, a scanning spectrophotometric colorimeter determined colorimetric parameters for three fresh orange fruits per treatment (Agrosta Roxanne, France). The half-maximum detection enabled the sensor to cover the visible region of the electromagnetic spectrum with a total width of 40 nm. A specific area of the spectrum was sensitive to 6 phototransistors in this sensor: (380 nm) violet; (450 nm) blue; (500 nm) green; (570 nm) yellow; (600 nm) orange; (670 nm) red. The whole visible area was lit by a white LED (Coelho *et al*., 2020).

Table (1): The treatments used in the experiment

No.	Symbol	Treatment combinations
1	T1	Aqueous ozone + Without packaging
2	T2	Aqueous ozone + Perforated plastic bag
3	T3	Aqueous ozone + Fruit wrapping paper bag
4	T4	Aqueous ozone +15% *Aloe vera*
5	T5	15% *Aloe vera*+ Without packaging
6	T6	15% *Aloe vera*+ Perforated plastic bag
7	T7	15% *Aloe vera*+ Fruit wrapping paper bag
8	T8	Aqueous ozone+ 15% *Aloe vera*+ Perforated plastic bag
9	T9	Aqueous ozone+ 15% *Aloe vera*+ Fruit wrapping paper bag
10	C	Control (Dipped in distilled water without packaging)

RESULTS AND DISCUSSION

Physiological water loss is a significant cause of postharvest deterioration. It results in shriveling and accelerates senescence, which decreases fruit weight, quality, and marketable value. The impacts of some treatments on weight loss in orange fruits are shown in Figure (1). According to the data analysis, the 15% AV + perforated plastic bag (T6) caused the most minor weight loss (7.17%), followed by the AO + 15% AV + perforated plastic bag (T8) and AO + perforated plastic bag (T2) treatments, with values of 8.81% and 9.51% respectively. However, there was increased fresh weight loss in the AO + 15% AV treatment (T4), while no significant difference was detected among the T1, T3, T4, T7, T9, and control treatments. The respiration rate is another factor that affects the postharvest life of fruits. The results shown in Figure (2) also indicate that the maximum respiration rate of 11.45 mg CO2 kg h-1 was obtained from the AO + without packaging treatment (T1). In contrast, the minimum respiration rates of 8.96 and 9.09 mg CO2 kg h-1 were obtained from T6 and T2, respectively. Therefore, a decrease in the respiration rate extends the life of fruits.



Means with the same letters are not different significantly by Duncan's multiple ranges test (p≤ 0.05). †**Treatments**: T1= AO + without packaging, T2= AO + Perforated plastic bag, T3= AO + Wrapping paper bag, T4= AO +15% AV, T5= 15% AV+ Without packaging, T6= 15% AV+ Perforated plastic bag, T7= 15% AV+ Wrapping paper bag, T8= AO + 15% AV+ Perforated plastic bag, T9= AO + 15% AV+ Wrapping paper bag and T10= Control.

Figure (1): The effect of some treatments on the fresh weight loss% of the orange fruits of Diyala cv. stored at 6±1°C and 90% RH for 60 days.

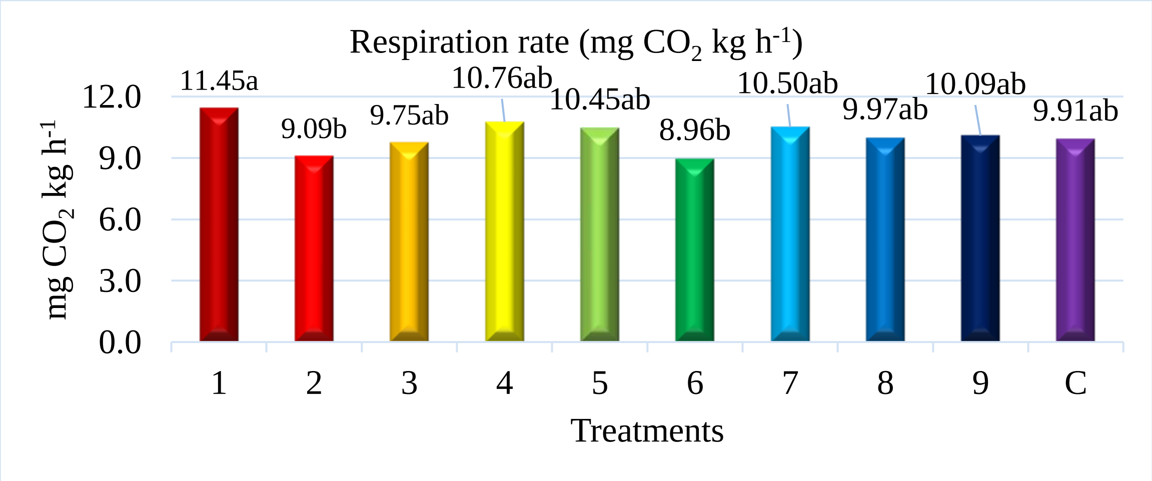


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Figure (2): The effect of some treatments on the respiration rate (mg CO_2 kg h^{-1}) of Diyala cv. orange fruits stored at 6±1°C and 90% RH for 60 days.

Figure (3) shows that the moisture content of the orange fruits of Diyala cv. was affected by various treatments with aqueous ozone, *Aloe vera* gel, and packaging type. The data showed that the moisture content decreased significantly in the (T1, T3, T4, T9 and control) treatments when compared with T6 treatment fruits were stored for 60 days when the moisture content was between 80.55% in T6 and 77.13% in the control treatment (C). The result indicates that T6 is the best treatment because it has the lowest weight loss percentage and the highest moisture content.

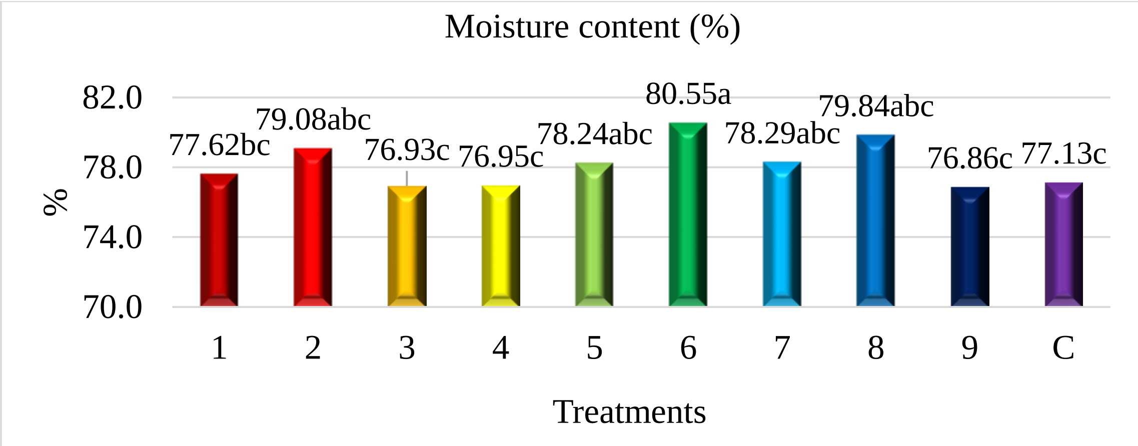

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Figure (3): The effect of some treatments on the moisture content (%) of Diyala cv. orange fruits stored at 6±1°C and 90% RH for 60 days.

Firmness plays a crucial role in determining the quality of fruits. Fresh fruits are more firm than stored and damaged fruits. Customers choose them based on their freshness and juiciness. Therefore, figure (4) illustrates the impact of the AO and AV gel coatings and different types of packaging on the firmness of the orange fruit after 60 days of storage. According to the findings, there were considerable differences in firmness when compared to the untreated treatment (control). However, all treatments contributed to maintaining the firmness in the experiment except for the control treatment. At the end of storage, the highest firmness (13.95 lb.) was observed for T8, while the lowest value (9.06 lb.) was obtained for fruits in the control treatment.

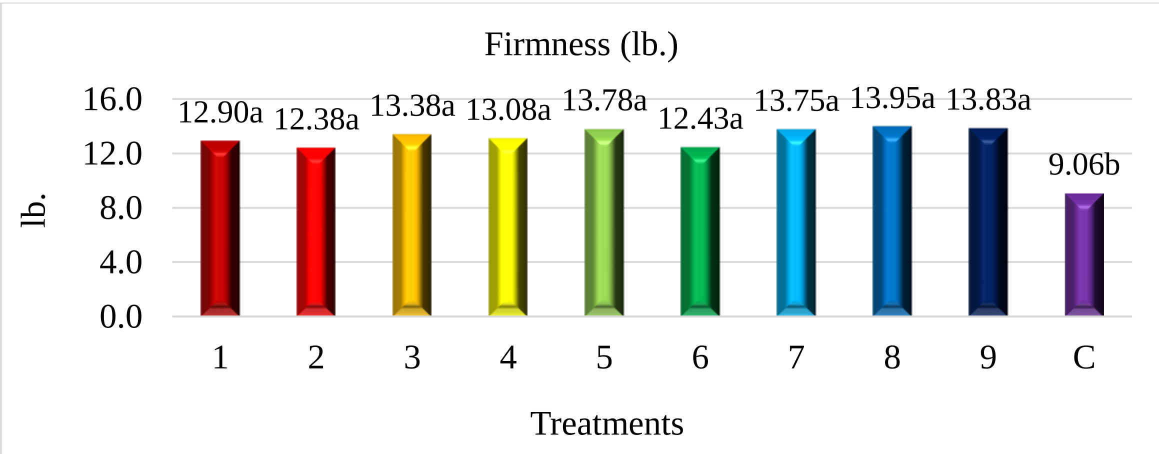

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Figure (4): The effect of some treatments on the firmness (lb.) of Diyala cv. orange fruits stored at 6±1°C and 90% RH for 60 days.

pH is an important characteristic and a critical factor affecting microbial spoilage, including the loss of clouds, the development of off-flavors, carbon dioxide production, and sensory changes that lead to deterioration. PH values must be determined to assess the quality of juice. According to the data presented in Figure (5), the highest pH of the orange fruit resulted from T1 and T2, which had the highest values of 3.70 and 3.78, respectively. Moreover, the orange fruits in the untreated control treatment had the lowest value (3.48).

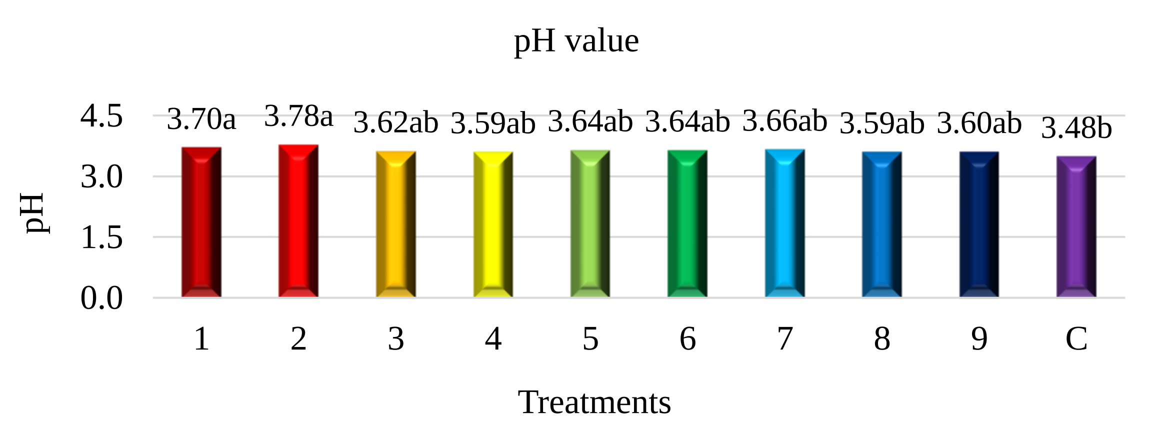

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Figure (5): The effect of some treatments on the pH of Diyala cv. orange fruits stored at 6±1°C and 90% RH for 60 days.

The Juice content is a significant indicator of internal quality. Eating quality is directly affected by the lack of juice in either under or overripe fruits. Furthermore, the data in Figure (6) shows that the highest juice content (%) recorded in the control, T6, and T4 treatments were (47.88, 46.72 and 46.35%), respectively, while the lowest mean value recorded in the T9 treatment was 39.13%.

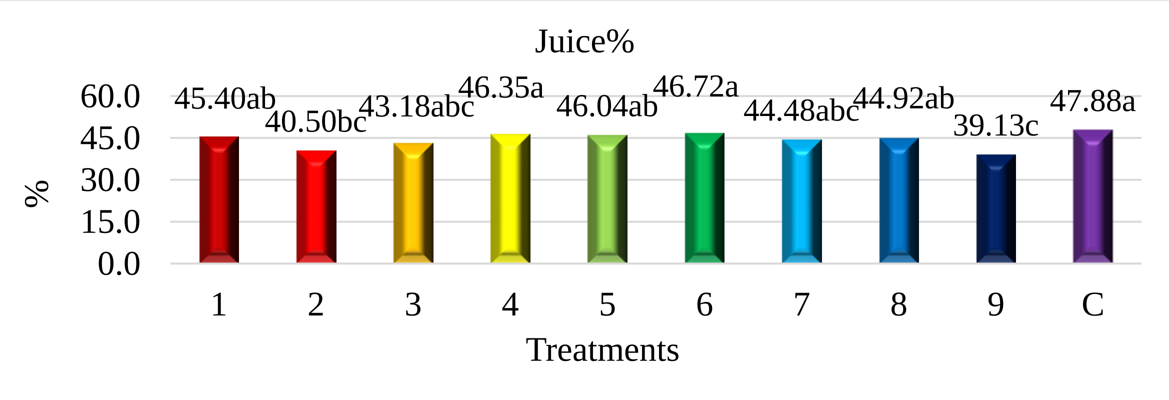

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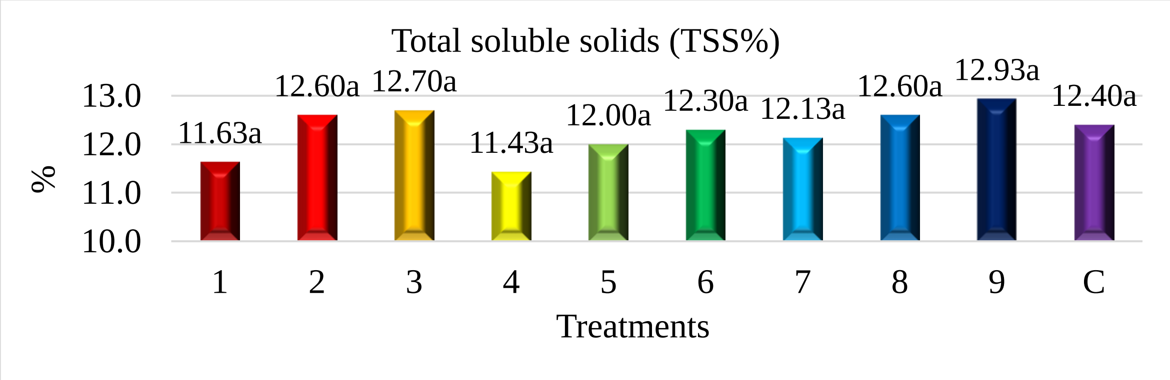
Figure (6): The effect of some treatments on the juice% of Diyala cv. orange fruits stored at 6±1°C and 90% RH for 60 days.

The TSS is another significant factor in determining the harvest date and taste of fresh or stored orange fruits. It influences quality and acceptance by consumers. Our results showed no significant variations in the TSS content amongst the orange fruit treatment combinations during storage, which ranged from 11.63 to 12.93%, as shown in Figure (7).



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†Treatments: T1= AO + without packaging, T2= AO + Perforated plastic bag, T3= AO + Wrapping paper bag, T4= AO +15% AV, T5= 15% AV+ Without packaging, T6= 15% AV+ Perforated plastic bag, T7= 15% AV+ Wrapping paper bag, T8= AO+ 15% AV+ Perforated plastic bag, T9= AO+ 15% AV+ Wrapping paper bag and T10= Control.

Figure (7): The effect of some treatments on the TSS% of Diyala cv. orange fruits stored at 6±1°C and 90% RH for 60 days**.**

Fruit taste is primarily influenced by organic acids, especially their relationship with soluble solids. TTA is an indicator of acidity, and the content of organic acids gradually decreases with maturity and ripening, as does the duration of storage. Results shown in Figure (8) indicate that the T4 and T9 treatments were (0.72% and 0.70%), respectively, maintained the acidity level of the orange fruits stored for 60 days compared to the control treatment was (0.56%), which indicates that organic acids decompose more during storage when the fruits stored without postharvest treatments.

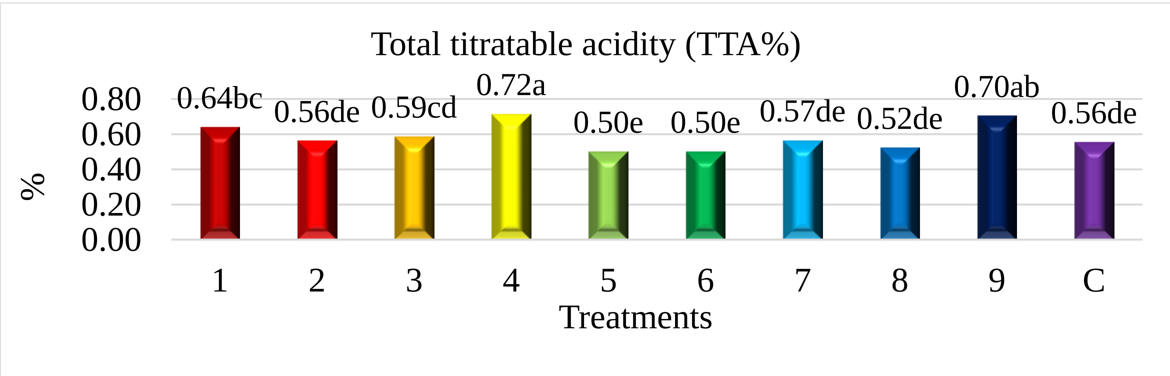

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Figure (8): The effect of some treatments on the TTA% of Diyala cv. orange fruits stored at 6±1°C and 90% RH for 60 days.

Figure (9) shows that different treatments significantly influenced the total sugar content of fruits after 60 days of storage. There was a significant influence on the total sugar content of the orange fruits by all the treatments. The highest percentage of total sugar was recorded in T9 (6.11%), while the lowest percentage (4.10%) was obtained in T8.

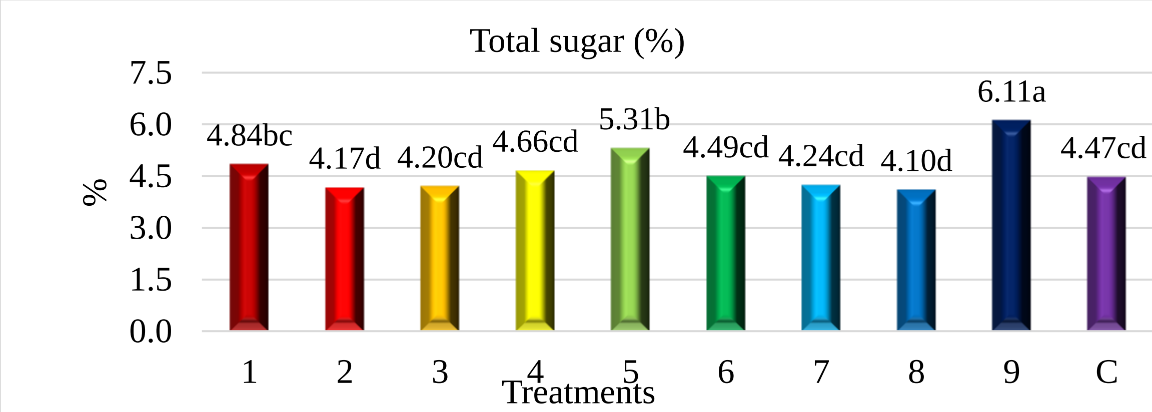

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Figure (9): The effect of some treatments on the total sugar% of Diyala cv. orange fruits stored at 6±1°C and 90% RH for 60 days.

Figure (10) shows the impact of aqueous ozone, *Aloe vera*, and packaging on the ascorbic acid content in orange fruits. The orange fruits treated with 15% AV+ without packaging (T5) had the highest ascorbic acid content (53.19 mg.100 ml^{-1}) followed by T9 and T4, compared to the lowest value (33.12 mg.100 ml^{-1}) in the control treatment.

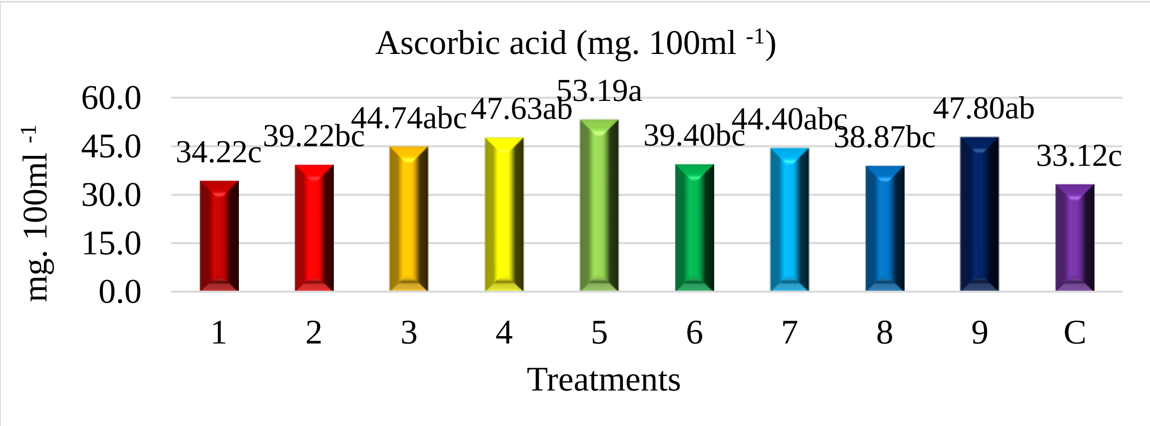

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Figure (10): The effect of some treatments on ascorbic acid (mg 100 ml^{-1}) in Diyala cv. orange fruits stored at 6±1°C and 90% RH for 60 days.

The data presented in Figure (11) show that T9 provided the highest value of total carotenoids (0.147 mg.100 ml-1), while T5 and T2 provided the lowest values of 0.104 and 0.105 mg.100 ml-1, respectively; to examine the effect of aqueous ozone, Aloe vera, and packaging on total carotenoid content (mg.100 ml-1) in the orange fruits of Diyala cv. they were stored at 6±1°C for 60 days.

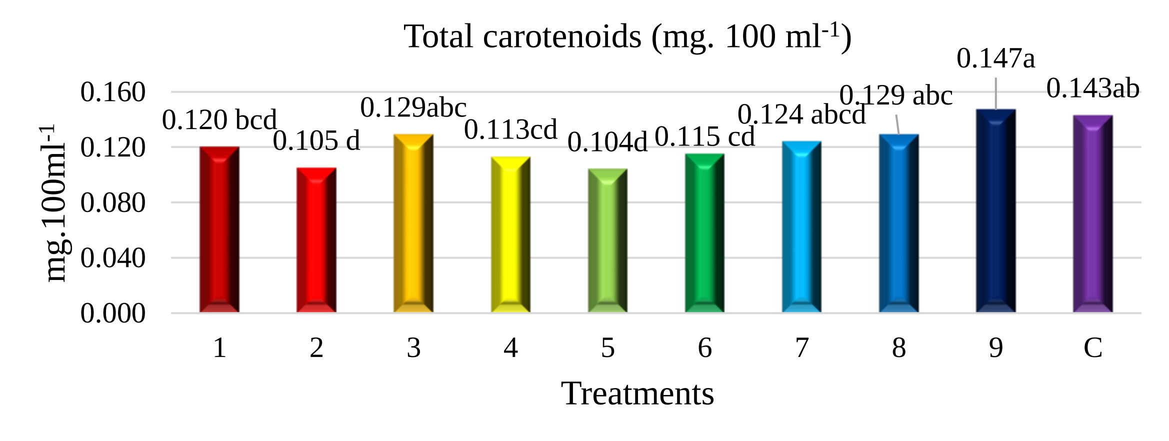

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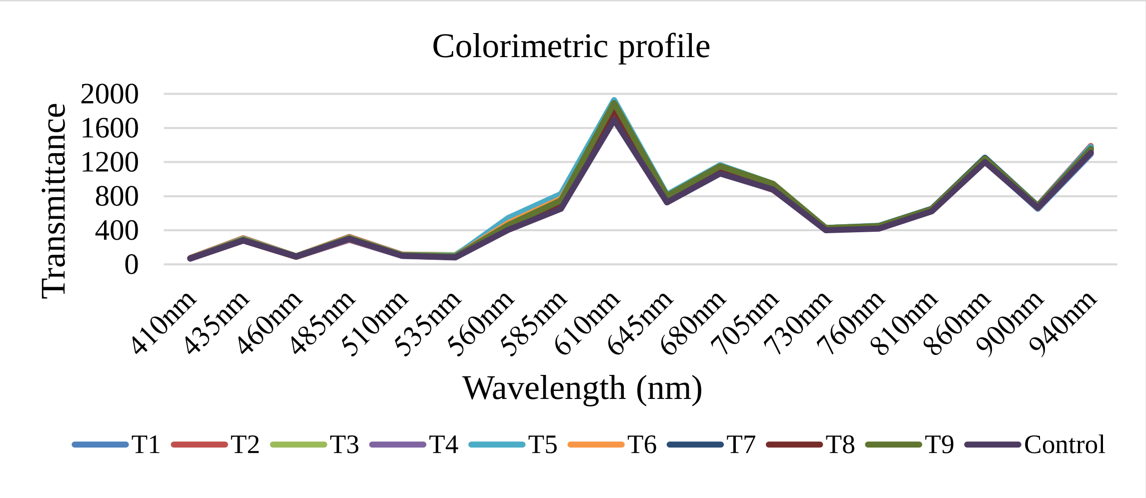
Figure (11): The effect of some treatments on the total carotenoid content (mg 100 ml^{-1}) of the orange fruits of Diyala cv. stored at 6±1°C and 90% RH for 60 days.

Consumer acceptance is influenced by colorimetric analysis, which is considered the most important aspect of quality. In the T9 treatment, the transmittance of the color at 610 nm was greatest, corresponding to an orange color figure (12), which indicates that a high carotene content was maintained. The quality was maintained with AO + 15% AV+ wrapping paper because carotene, a carotenoid found in orange, has strong antioxidant activity.



†Treatments: T1= AO + without packaging, T2= AO + Perforated plastic bag, T3= AO + Wrapping paper bag, T4= AO +15% AV, T5= 15% AV+ Without packaging, T6= 15% AV+ Perforated plastic bag, T7= 15% AV+ Wrapping paper bag, T8= AO+ 15% AV+ Perforated plastic bag, T9= AO+ 15% AV+ Wrapping paper bag and T10= Control.

Figure (12): Visible spectra showing the average transmittance (*n* = 3) in the orange fruits of Diyala cv. stored at 6±1°C and 90% RH for 60 days.

Water loss is the leading cause of deterioration because it results in direct quantitative losses (salable weight) and losses in appearance (wilting and shriveling), textural quality, and nutritional value. This is caused by water loss from the fruits directly and partially by respiration. Weight loss increases during storage and marketing, and these processes are considered economically and qualitatively significant (García-Martín *et al*., 2018). The FWL is linked to the physiological activity of long-term postharvest storage of orange fruits. Our findings showed that the WL rate was relatively high during storage at 6±1°C and that the exocarp was crucial for preventing water loss. Nutrients and water would be transported to the peel, while energy consumed by the peel could cope with external biotic and abiotic stresses to maintain fruit freshness (Ding *et al*., 2015).

Additionally, the type of packaging reduces weight loss and respiration and increases humidity, creating a modified atmosphere around fruits with higher carbon dioxide and low oxygen content (Kader *et al*., 1989). Furthermore, Malik *et al*. (2004) showed that green lemon and grapefruit fruits packaged in high-density or low-density polyethylene bags and stored at eight °C for three months considerably decreased weight loss. Moreover, the differences in weight loss seen during cold storage under ozone have been explained by the impact of ozone on citrus water permeability. According to Di Renzo *et al*. (2005), intermittent exposure to citrus with 0.25 ppm gaseous ozone decreased citrus aging and weight loss more than when citrus was only exposed to air. Weight loss is mainly due to the loss of water through sweat and the loss of stored carbohydrates through respiration (Nasrin *et al*., 2023). The loss rate depends on the fruits' water pressure and the atmosphere surrounding them; therefore, the AV gel coating acts as a barrier. In this way, water transfer is limited, so the decrease in moisture loss could be attributed to Aloe gel's ability to create a barrier that traps water between the fruit and its surroundings, possibly due to its hygroscopic properties. This way, external transfers are stopped, and respiratory gas exchange is controlled (Valverde *et al*., 2005).

The epidermal layer, consisting of guard cells and stomata, typically regulates the loss of moisture and exchange of gases from fruits. The coating further reduces this disorder by creating a layer on the skin that acts as an extra barrier to prevent moisture loss. This barrier also decreases oxygen uptake (Morillon *et al*., 2002) and causes a decrease in respiration rate and weight loss from the surface of the fruit. The average weight loss for the coated oranges was 29.20±0.55%, compared to 53.30±1.1% for the uncoated oranges. Similar results were obtained by Di Renzo *et al*. (2005); Ahmed *et al*. (2009); Castillo *et al*. (2010).

The respiration rate significantly influences fruit shelf life. The resistance of fruit skin to gas diffusion has been observed to increase with the application of a surface coating, possibly as a result of blockage of effective fruit pores, which also reduces the respiration rate, improves postharvest fruit quality, and its internal environment (Pérez-Gago *et al.,* 2002). According to several studies, a modified atmosphere packaging of internal gases is created by AV, which decreases the respiration rate and moisture loss in nectarines (Ahmed *et al.,* 2009) and table grapes (Valverde *et al.,* 2005); Similarly, a slower rate of respiration has been observed in delicious cherries coated with AV (Martínez-Romero *et al.,* 2006). It has been demonstrated that edible coatings made of AV can slow the process of senescence and respiration in fruits such as delicious nectarines, papaya, cherries and table grapes (Kumar and Bhatnagar, 2014).

Consumer acceptance of fresh fruit relies critically on its firmness; the key determinants of fruit quality and postharvest shelf life are the rate and extent of firmness loss during storage. Fruit softening is mostly caused by the cell wall's middle lamella breaking down. The combined activity of hydrolase enzymes, including cellulose, pectate lyase, galactosidase, pectin esterase, and polygalacturonase, mainly influences changes in cell wall composition and structure (Misir *et al*., 2014). Castillo *et al*. (2010) reported that Aloe vera is a potentially effective preharvest technique for preserving grape quality during postharvest storage because ripening parameters such as color and fruit firmness are significantly delayed. According to previous reports (Brishti *et al*., 2013), when papaya and kiwifruit fruits are treated with a coating of A. vera, which is delayed by delayed softening. These results are consistent with those reported by Martínez-Romero *et al*. (2006), who reported that the loss of firmness in cherries during cold storage dramatically decreased (more than 50%) with increasing Aloe vera gel concentration. The increase in firmness could result from the peel surface drying out due to water loss through respiration and transpiration, as mentioned by Martin-Belloso and Soliva Fortuny (2006).

The changes in pH were not significantly different among the treatments except for the control. The pH is maintained in the fruits treated with the coating than in the untreated fruits. The pH depends on the organic acid content and the respiration rate of fruits. A similar result was noted by Kaleem *et al*. (2023). TSS may arise due to the hydrolysis of starch into sugar; afterward, TSS may fall due to the conversion of sugars into organic acids and a decrease in the respiration rate (Javed *et al*., 2017). The increase in the total sugar percentage of fruits packaged with polyethylene can be explained by the fact that the respiration process consumes acids faster than sugars; thus, the rate of sugar increases (Benítez *et al*., 2013). The continuous moisture loss leads to an increase in fruit juice concentration, which increases sugar concentration.

Additionally, the degradation of pectin and hemicellulose in cell walls causes an increase in the total sugar content (Wardeh, 2009). However, there were no significant changes in the TSS content during storage after fruit coating with AV or treatment with aqueous ozone, similar to what was observed for packaging. The results of this investigation are consistent with the findings of Botondi *et al*. (2021). The increase in the total sugar percentage of fruits can be explained as the breakdown of starch into sugar. The overall sugar content of the AV-coated fruits was considerably lower than that of the uncoated control fruits, suggesting a delay in ripening. The findings in this work were similar to the results obtained by Dhall (2013) and (Salah and Fadhil, 2019).

Citrus fruits and juices are rich in bioactive compounds and exhibit antioxidant activity, such as ascorbic acid (vitamin C), an essential trait for nutritional value. Ascorbic acid has a significant role in fruit ripening, stress resistance, fruit development, and postharvest storage and can guide fruit quality improvement. The ascorbic acid concentration is a crucial component for both flavor and nutritional value and rapidly decreases with increasing storage time (Khalil, 2017); moreover, the ascorbic acid content reduces due to oxidative processes and the action of enzymes such as ascorbate oxidase or peroxidase. Our results align with those of

(Ahmed *et al*. 2009), who found that the ascorbic acid present in fruits coated with Aloe vera gel was significantly decreased during fruit ripening before and after cold storage compared to that in uncoated fruits. These results also agree with those obtained by Sogvar *et al*. (2016), who reported on A. vera gel coated on strawberries. Due to the low oxygen permeability of the coating, the deterioration of the ascorbic acid content decreased (Ayranci and Tunc, 2003).

Additionally, Maringgal *et al*. (2021) reported that coating fruits with ascorbic acid protects them and decreases fruit respiration. Therefore, limiting oxygen diffusion with packaging will have a limited positive impact. The results of Khazaei *et al*. (2012) showed that packaging with good oxygen barrier properties affects vitamin C loss. The first impression and a crucial fruit aspect is color, which is also a bioactive component, such as carotenoids (Vadiveloo *et al*., 2019).

Orange juice is a rich source of bioactive compounds and phytochemicals (carotenoids) that possess antioxidant properties. Carotenoids play a significant role in citrus fruit quality and affect the color of the peel and pulp; furthermore, these carotenoids are precursors of vitamin A, serve as human nutrients and reduce the risk of some diseases. Our results concerning Aloe vera gel application with packaging increased the carotenoid pigments. The results obtained in this study agree with the findings of Öztürk and Ağlar (2019). The green color of apple fruit skin is delayed by A. vera treatment (Ergun and Satici, 2012). The Aloe vera gel covering the fruits affected the atmosphere by slowing the ethylene production rate. This delayed the ripening process, the breakdown of chlorophyll, the synthesis of carotenoid pigments, and the eventual change in the color of the fruits (Carrillo-Lopez *et al*., 2000).

CONCLUSIONS

Orange fruits were coated with AV gel, treated with aqueous ozone packed in plastic bags, and kept under cold storage at six °C with 90% RH. The results obtained in the present study showed that applying a combined edible coating containing 15% Aloe vera and a Perforated plastic bag is more appropriate for extending storage life and maintaining the quality of the Diyala cultivar of orange fruits. These treatments delayed fruit ripening, decreased ethylene production, slowed respiration, decreased weight loss and fruit softening, and preserved ascorbic acid and other characteristics. Postharvest losses and deterioration of fruits and vegetables are a concern for all countries with economies that depend on agricultural products since our economy is partially based on horticulture commodities because fruits are suffering severe losses due to old preservation methods and a lack of knowledge about conservation tactics**.** In fact, using solution of Aloe vera gel and Perforated plastic bag as an alternative to chemical treatments after harvest due to the improved storage conditions of orange fruit. Pre-storage treatments also contribute to postharvest quality maintenance, with the added benefit of reducing costs and producing fruit more safely.

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CONFLICT OF INTEREST

The authors state that there are no conflicts of interest with the publication of this work.

المعاملة قبل التخزين بالاورزن المائي وجلي الصبار وطريقة التغليف وتأثيرها في صفات الجودة والقابلية الخزنية لثمار البرتقال

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الخلاصة

كان الغرض من هذه الدراسة هو تحديد جودة وقابلية تخزين ثمار البرتقال صنف ديالى بعد ٦٠ يومًا من التخزين عند درجة حرارة ٦±١ درجة مئوية و٩٠٪ رطوبة نسبية عند المعاملة بالأوزون المائي بتركيز ٤ ملغم لتر⁻¹ أو ١٥٪ جل الصبار وطريقة تعبئتها بثلاثة انواع: بدون تعبئة، أكياس بلاستيكية مثقبة وأكياس ورقية للتغليف. نفذت التجربة وفق التصميم العشوائي الكامل بثلاث مكررات. تمت دراسة هذه العوامل: فقدان الوزن، معدل التنفس، محتوى الرطوبة، الصلابة، الرقم الهيدروجيني، العصير، المواد الصلبة الذائبة الكلية، الحموضة الكلية القابلة للتسحيح، سكر/حامض، السكريات الكلية، حمض الأسكوربيك، والكاروتينات الكلية. أشارت النتائج إلى أن أقل نسبة الفقد بالوزن تم تسجيله في معاملة ١٥٪ صبار+ كيس بلاستيكي مثقوب (١٧,٧٪)، وأقل معدل تنفس تم تسجيله في١٥٪ جل صبار+ كيس بلاستيكي مثقوب (٩٨,٨ ملغم ثاني أكسيد الكربون كغم⁻¹ ساعة⁻¹) وكان لنفس المعاملة التأثير الأكبر في محتوى الرطوبة (٨٠,٥٥٪)، كما أثرت جميع المعاملات معنوياً في صلابة ثمار البرتقال. كانت معاملات الأوزون المائي+ الأكياس البلاستيكية المثقبة متفوقة بشكل كبير على معاملة التحكم في قيمة الرقم الهيدروجيني. ومن ناحية أخرى سجلت أعلى نسبة عصير من معاملة المقارنة. الحموضة الكلية القابلة للتسحيح تم الحصول عليها في معاملة الأوزون المائي + ١٥٪ جل الصبار (٠,٧٢٪). علاوة على ذلك، كان لنسبة ١٥٪ من جل الصبار بدون تعبئة لها تأثير كبير على محتوى حمض الأسكوربيك في البرتقال. وكان للأوزون المائي + ١٥٪ جل الصبار+ تغليف الثمار بأكياس ورقية لها تأثير الأكبر على السكريات الكلية ومحتويات الكاروتينويدات الكلية.

الكلمات المفتاحية: نبات الصبار، الأوزون المائي، ثمار البرتقال، التغليف، الجودة والقابلية الخزنية.

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