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Effect of post-harvest treatments on shelf life and physico-chemical changes of orange fruits

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Abstract

The study was carried out at Post Harvest Laboratory, Faculty of Agriculture, Sohag, during the 2021/2022 and 2022/2023 seasons, on Balady orange fruits to determine post - harvest treatment for better quality and desirable shelf life under room storage. The present study was conducted to investigate the effects of Hot water Dipping (HWD), Paraffin Oil, Sodium Bicarbonate (NaHCO3), Low-Density Polye Ethelene film (LDPE), Sodium Bicarbonate plus Low-Density Polye Ethelene (LDPE), Hot water Dipping plus Low-Density Polye Ethelene (LDPE), Hot water Dipping plus Paraffin Oil, Sodium Bicarbonate plus Paraffin Oil and distilled water (assigned as control) on post-harvest "Balady" Orange stored under room temperature conditions. The experiment results suggested that the treated orange significantly improved the shelf life of Balady orange as compared to that of untreated ones in both seasons. The results showed that wrapping orange fruits with NaHCO3+ LDPE had the longest shelf life (85, 84) days, whereas untreated orange fruits (the control) had the shortest shelf life (45, 42) days in both seasons, respectively. The highest physiological weight loss was in the untreated (the control) treatment, while the lowest was in warped orange fruits (LDPE). The highest physical and chemical fruit quality was shown in wrapping orange fruits with LDPE.

Keywords:

Citrus, post-harvest treatments, storage period, fruit quality.

Abbreviations: (LDPE: Low Density Polyethylene, HDPE: High Density Polyethylene, TSS: Total soluble solid, TA:Titrable Acidity,HWD:Hot Water Dipping,PLW:Physiological loss in weight)

INTRODUCTION

Citrus fruits are essential to a healthy diet due to their high nutritional value, antioxidant properties, and widespread consumption. These fruits contain vitamin C and various phytochemicals (Heber and Lu, 2002). It contains a large amount of ascorbic acid, a potent antioxidant and a crucial component of human nutrition. It assists in protecting people from certain dangerous diseases (Nawaz et al., 2008). Citrus is one of the most significant fruit crops worldwide, coming in third place behind grapes and apples. In Egypt, citrus species are the primary fruit crop for local consumption and exportation. Citrus fruits contain essential nutrients such as vitamins, minerals, and dietary fibers, providing numerous health benefits. Studies indicate that a fruit-rich diet can help reduce the risk of developing cancer, cardiovascular diseases, and other health issues (Kang et al., 2003; Zhao et al., 2004 and Scalbert et al., 2005). Maintaining the quality of oranges after harvest is crucial for growers due to their high market value. Factors that contribute to the quality of the fruit include environmental factors, cultural techniques, susceptibility to pests and diseases, harvest season, and post-harvest circumstances all affect the fruit's quality. The quality of the oranges significantly impacts consumers' preferences and is a critical factor in marketing fresh fruits overseas. To ensure the best value for growers, storage operators, and consumers, it is essential to maintain quality throughout the preharvest development, post-harvest storage, and distribution and marketing chains. Consumers tend to purchase fruits that have high quality based on sensory quality (texture and taste), appearance (color), and nutritional values (Sharma et al., 2008). Maintaining the quality of fruits is crucial and can be achieved by applying post-harvest treatments (Deka et al., 2006). When harvested, fruits lose water vapor, causing the peels to shrink, lose turgidity, and reduce their ability to diffuse gas. Post-harvest losses can negatively impact the fruit's taste and flavor (D'Aquino et al., 2001). Several solutions have been proposed to address this issue to improve the shelf life of fresh produce and reduce post-harvest fruit losses. Post-harvest losses can reach up to 30-40% and sometimes even more in developing countries. By decreasing these losses, we can when fruits are packed in Polyethylene films under modified atmospheric conditions; it reduces the transpiration, the rate of respiration and the other metabolic processes. Packaging fruits in Polye ethylene films leads to lower weight loss, decay incidence, and the retention of color and texture during extended shelf life. (Lange, D.L. 2000 and Sharma et al., 2007). Hot water dipping is a simpler, more cost-effective, and more practical method for applying heat than curing. Nevertheless, utilizing hot water alone to control green mold in commercially grown citrus fruit is only feasible for certain organic varieties (Ben-Yehoshua and Porat, 2005). Heat treatment (H.T.) is widely used to prevent fruit decay. It has been proven effective in reducing fly infestation, preventing chilling injury, and increasing the effectiveness of biocontrol agents like antagonistic yeasts. (Ghasemnezhad, et al.,2008 and Zhang, et al.,2008). Paraffin oil is a thin layer coating applied to fruits that are safe for consumption. It plays a crucial role in storing and marketing fruits by enhancing their appearance and safeguarding them against various forms of damage, including physical, chemical, and microbial harm. (Magashi and Bukar, 2006). Studies have found that certain essential oils can help extend the shelf life and enhance the quality of various fruits (Serrano et al., 2005). A thin layer of safe paraffin oil is applied instead of paraffin wax, which used to be used but was criticized for affecting the fruit's shine (Salman et al., 2008). Lately, there has been a growing interest in using sodium salts to reduce post-harvest damage, especially in citrus fruits. These salts can effectively control the deterioration of citrus fruits. Their powerful antibacterial properties prevent decay after harvesting and are easily accessible and inexpensive. Additionally, they do not cause significant harm to the fruit when applied (Abadias et al., 2008). The Food and Drug Administration of the United States has

approved sodium bicarbonate as safe, and it is frequently used in the food sector to improve the effectiveness of biological control agents. (Janisiewicz et al., 2008; Geng et al., 2011; Mari et al., 2007). This study explores the effects of various post-harvest treatments (such as Hot Water Dipping, Paraffin Oil, sodium bicarbonate, and Low-Density Polye Ethelene Film) on Balady Orange fruits. With the following objectives: Determining the influence of post -harvest treatments on physical and chemical characteristics of Balady orange fruits. Extending the shelf life of Balady Orange fruits. And using cheap, safe, and easy-to-apply methods (Treatments) to store Balady Orange fruits.

MATERIALS AND METHODS

Plant material:

This study was carried out on "Balady" Orange (*Citrus sinensis* L.) during two successive seasons to assess the different post- harvest treatments during (2021/2022 and 2022/2023), and to manage the post-harvest losses during storage conditions
Balady orange trees 20 years old were selected according to their bearing approximately the same vigor and health. Trees were budded on sour orange rootstocks, grown in sandy soil, spaced 5*5 m apart subjected to the drip irrigation system.

Study Site:

Midway through December, the fruits were picked at their best and sent to the lab in plastic crates. Only the healthy and uniformly proportioned fruits were chosen after the diseased and bruised fruits were separated. Fruits at the maturity stage were picked and washed, then dried. This study was conducted in a citrus orchard at the El-Kwamel farm. The experimental site is located at latitude 26 ○ 28ˊ 5.80 ˊˊN, longitude 31○ 40ˊ 10.71ˊˊE Faculty of Agriculture, Sohag University, Egypt. The post- harvest treatments were carried out in the research lab at the Faculty of Agriculture, Sohag University.

Treatments and storage conditions:

This experiment was an attempt for keeping quality and extending the marketing period of Balady orange; the fruit storage period was during the months December, January, February, and March (2021/2022-2022/2023). Figures 1 and 2 showed the daily minimum and maximum temperature obtained from the website (NASA, 2021:2023). It was arranged as a factorial experiment with three replications, and every replicate contained (25) fruits to study the changes in some physical and chemical characteristics of fruit storage at room temperature as affected by nine treatments; the details of the treatment composition were as follows table (1).

Table (1): The treatments and application mechanism

No.	Treatments	Treatments application mechanism
1	Non-treatment	Only washing by distilled water.
2	Hot water Dipping (HWD)	Soak the fruits for a minute at 65 °C in a water bath.
3	Paraffin Oil	Using a brush to coat the fruits with paraffin oil of 100% purity.
4	Sodium Bicarbonate ($NaHCO_3$)	Soak the fruits in a solution of sodium bicarbonate at a 1.5% concentration for 3 minutes.
5	Low Density Polye Ethelene film (LDPE)	Wrap the fruits tightly in one layer by using LDPE.
6	Sodium Bicarbonate + Low Density Polye Ethelene (LDPE)	Soak the fruits in a solution of sodium bicarbonate at a concentration of 1.5% for 3 minutes; after that, leave the fruits for some time before wrap the fruits tightly in one layer by using LDPE.
7	Hot water Dipping + Low Density Polye Ethelene (LDPE)	Soak the fruits for a minute at 65°C in a water bath; after that, leave the fruits for some time before wrap the fruits tightly in one layer by using LDPE.
8	Hot water Dipping + Paraffin Oil	Soak the fruits for a minute at 65 °C in a water bath; after that, leave the fruits for some time before using a brush to coat the fruits with paraffin oil of 100% purity.
9	Sodium Bicarbonate + Paraffin Oil	Soak the fruits in a solution of sodium bicarbonate at 1.5% (conc.) for 3 minutes; after that, leave the fruits for some time before using a brush to coat the fruits with paraffin oil of 100% purity.

Representative samples of two fruits per replicate were taken at random every week during storage period until the percentage of fruit decay 25% in any treatment for the determination of physical and chemical characteristics.

Physical characteristics:

Shelf life or Marketable Period:

By counting the days, it took for the samples to reach the last stage of ripening, but up until the point where they were still suitable for selling, the shelf life of the samples was determined. (Mondal, 2000).

Physiological loss in weight "PLW" (%):

A laboratory weight balance (Schimadzu, BW 320- H) was used to weigh the fruits throughout the investigation after being randomly chosen for each particular condition. The weight loss of fruit samples was calculated by dividing the beginning weight of the samples by the difference between their final weight and initial weight. The same fruits were continually assessed for weight reduction until the experiment's conclusion. The following formula was used to calculate the weight loss of fruits at regular intervals:

$$\mathbf{PLW = [(A-B)/A] \times 100}$$

Where **"A"** was the initial weight at harvesting time (i.e., 0 day-zero time) and **"B"** was the final weight at different storage intervals.

Changes in length and Diameter of fruit (cm):

The length and diameter of the fruits was measured using the Caliper.

Chemical characteristics:

Total soluble solids percentage" TSS" (%):

The TSS % was measured in the juice by using hand refractometer.

Total acidity (T.A.) (%) T.A. was determined using titration and expressed as citric acid according to Hazali *et al.*, (2013).

Ascorbic acid content (vitamin C) mg/100 ml juice

It was discovered using the AOAC-recommended substrate of 2, 6 dichlorophenolendophenol with a 2% solution of oxalic acid (AOAC Association of Official Analytical Chemist, 1994).

Statistical analysis:

The measured data were subjected to analysis of variance in a split plot design in time using SAS software (SAS ver. 9.2, SAS Institute 2008), acceding to Gomez and Gomez (1984). The least significant differences (LSD) between means at 5% level of significant for studied parameters, were estimated according to Snedecor and Cochran (1989).

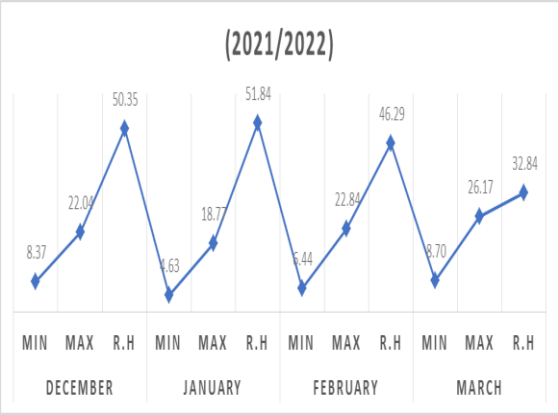

Figure (1): Monthly minimum and maximum temperature during storage period (2021/2022)

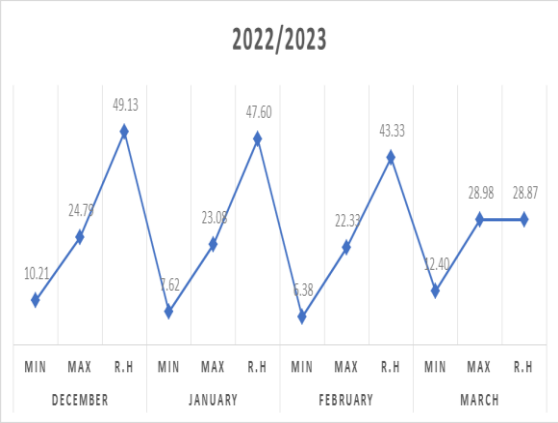

Figure (2): Daily minimum and maximum temperature during storage period (2022/2023)

RESULTS AND DISCUSSION

Physical Characteristics:

Shelf life or Marketable Period:

Table (2) indicate the effects of different post-harvest treatments, namely Hot Water Dipping (65° for a minute in a water bath), Paraffin Oil (100 purity), Sodium Bicarbonate "$NaHCO_3$" (1.5%), Low-Density Polye Ethelene film" LDPE", $NaHCO_3$+ LDPE, Hot Water Dipping + LDPE, Hot Water Dipping +Paraffin Oil and $NaHCO_3$+Paraffin Oil on the shelf life in Balady Orange at room temperature. It is clarified in Table (2) that the treated orange significantly improved Balady orange's shelf life compared to untreated ones in both seasons. The results showed that wrapping orange fruits with $NaHCO_3$+ LDPE T6 was the longest shelf life (85 and 84) days, whereas untreated orange fruits (the control) had the shortest shelf life (45 and 42) days in both seasons, respectively. The $NaHCO_3$+ LDPE treatment had the longest shelf life (86 days in each season), followed by the LDPE treatment (84 days in each season), Hot Water Dipping + LDP E treatment (80 days in each season), Paraffin Oil treatment (67 days in each season), Hot Water Dipping + Paraffin Oil (64 days in each season), and Hot Water Dipping alone (63 days in each season), all of which were followed by Hot Water Dipping treatment (52 and 50) days in both seasons respectively and followed by $NaHCO_3$ treatment (51 and 49) days in each seasons respectively. From all the above results, coating orange fruits with paraffin oil, sodium bicarbonate, and warping with low-density Polye Ethelene film could help to extend their shelf life by reducing gas exchange and respiration rate, which slows down the rate of deterioration. Throughout the storage, there was a significant effect between T3, T6, T7, T8, and T9 orange

fruits and the control orange fruit in both seasons. And there wasn't a significant between the control orange fruits, the T2 and T4 orange fruits. These results agree with this obtained by (Karthi et al., 2023) found that the application of edible coatings is one way to increase the shelf life of post-harvest products. For fresh fruit, these coatings were formed of edible ingredients that are employed to provide a semi-permeable barrier to gases and water, and (Baswal et al., 2020) found that packaging with Polye ethylene film extended the shelf life compared to unpackaged fruits.

Table (2): the effect of different post- harvest treatments on shelf life (days) in Balady Orange during (2021/2022-2022/2023)

Treatments	Shelf life (days)	
	2021/2022	2022/2023
Control	45	42
Hot Water Dipping (HWD)	52	50
Paraffin Oil	67	65
$NaHCO_3$	51	49
LDP E	86	84
$NaHCO_3$+ LDPE	85	84
Hot Water Dipping+ LDP E	80	77
Hot Water Dipping + Paraffin Oil	64	63
$NaHCO_3$+ Paraffin Oil	67	65
LSD 0.05	15.86	16.09

Physiological Loss in Weight "PLW" (%):

Table (3) indicates the effects of different post- harvest treatments namely Hot Water Dipping (65° for a minute in a water bath), Paraffin Oil (100 purity), Sodium Bicarbonate "NaHCO3" (3%), Low-Density Polye Ethelene film "LDPE", NaHCO3+ LDPE, Hot Water Dipping +LDPE, Hot Water Dipping +Paraffin Oil and NaHCO3+Paraffin Oil on physiological loss in weight of Balady Orange under room temperature. The results of the two seasons had approximately the same trend. During the storage of fruit, it is noticed from Table (3) that physiological loss in weight was gradually increased by extending the storage period at room temperature during the two investigated seasons. Throughout the storage, the physiological loss in weight of untreated (the control) orange was significantly greater than the treated fruits. The highest physiological weight loss was in untreated (the control) orange fruits, while the lowest was in warped orange fruits" LDPE". During storage for 6 weeks under room temperature, the least percentage of physiological loss in weight (PLW) was in LDPE treatment ranged from 0.93 % to 8.45 % in first season and ranged from 1.01 % to 8.12 % in second season, followed by NaHCO3+ LDPE treatment ranged from 1.88 % to 14.95 % in first season and ranged from 1.54 % to 15.46 % in second season, followed by paraffin oil treatment ranged from 2.89 % to 14.52 % in first season and ranged from 2.64 % to 15.44 % in second season, followed by Hot Water Dipping+ LDPE treatment ranged from 1.89 % to 18.02 % in first season and ranged from 1.77 % to 17.34 % in second season, followed by NaHCO3 treatment ranged from 3.01% to 16.47 % in first season and ranged from 3.82 % to 19.03 % in second season, followed by NaHCO3+ Paraffin Oil treatment ranged from 3.65 % to 15.99 % in first season and 3.89 % to 17.30 % in second season and followed by Hot Water Dipping treatment ranged from 3.23 % to 21.86 % in first season and 3.90 % to 20.25 % in second season. It is obvious from these results that treated orange fruits were more effective in reducing weight loss during room temperature than untreated oranges (the control). From the above results, the fruit length decreased during storage at room temperature throughout the storage. There was a significant effect between all treatments and the control orange fruit in both seasons. The interaction between the storage period and all the treatments was statistically significant in both seasons. Hot water Dipping Orange fruits was easy to apply, safe (without any chemicals), and inexpensive; its improved preservatives have decreased the amount of chemicals needed to prevent fruit decay, making it more effective and decreasing weight loss. Immersion in hot water promotes a more

uniform dispersion of the cuticular fruit waxes, which cover the flavedo's microfractures and block the evapotranspiration pathway. This type of therapy typically slows weight loss as a result. The use of LDPE film resulted in less water loss from fruits. This is because it reduced the rate at which water vapors were transmitted, thus maintaining the moisture content of the fruits. Coating fruits with a layer of paraffin oil or sodium bicarbonate could be beneficial in preserving their moisture, preventing cell wall breakdown, and keeping them firm during their entire shelf-life. Paraffin oil and sodium bicarbonate was available, and they considered edible coating, which was safe; paraffin oil gave orange fruits a shiny appearance. The coating may reduce respiration rate and helps maintain the fruit's physical appearance, enhancing its brightness and overall appearance while maintaining its unique taste. Warping orange fruit in Polye Ethelene film may help to prevent moisture loss and modified atmosphere that slows down the rate of respiration, transpiration, and other metabolic processes. And after the storage period of the orange fruit, the appearance of packaging oranges and fresh oranges. These results agree with this obtained by (Chen et al., 2020), who showed that the "Nanfeng" Mandarins lost weight after being stored. The control treatment had a weight loss than w the fruits treated with HWD at 50°C for 3 minutes had a lower weight loss, (Aboryia and Omar 2020) found how different edible coatings affected the weight loss of Zaghloul date palm fruits during six weeks of cold storage at 0-1°C. The untreated samples had the highest weight loss percentage, Meanwhile, the samples treated with paraffin oil had a weight loss percentage of 7.5, with 3.04 and 3.94 recorded in two seasons, respectively (Khedr and Yaseen, 2017) found in Olinda orange during the shelf-life period, untreated oranges had the highest weight loss percentage, while 99 % paraffin oil had the lowest percentage.

Change in Fruit Length (cm):

Table (4) indicate the effect of different post- harvest treatments, namely, Hot Water Dipping (65° for a minute in a water bath), Paraffin Oil (100 purity), Sodium Bicarbonate "NaHCO3" (3 %), Low-Density Polye Ethelene film" LDPE", NaHCO3+ LDPE, Hot Water Dipping +LDPE, Hot Water Dipping +Paraffin Oil and NaHCO3+Paraffin Oil on fruit length (cm) in Balady Orange fruits under room temperature. The results of the two seasons took approximately the same trend. During the storage of fruit, it is noticed from Table (4) that fruit length was gradually decreased by extending the storage period at room temperature during the two investigated seasons. After 6 weeks of storage at room temperature, the least mean of fruit length was in untreated (the control) orange fruits compared to the treated orange fruits in both seasons. The orange fruits treated with NaHCO3+ LDPE and Hot Water Dipping+ LDPE had the highest mean fruit length in both seasons, while untreated treatment had the lowest mean of fruit length. During storage for 6 weeks under room temperature, the length of fruit in LDPE treatment ranged from 7.64 to 7.02 in the first season and 7.70 to 7.07 in the second. Hot water treatment ranged from 7.60 to 6.33 in the first season and ranged from 7.62 to 6.25 in the second season, Paraffin oil treatment ranged from 7.70 to 6.74 in the first season and ranged from 7.73 to 6.80, NaHCO3 treatment ranged from 7.88 to 7.03 in the first season and ranged from 7.79 to 6.73 in the second season, Hot Water Dipping + Paraffin Oil treatment ranged from 7.40 to 6.31 in the first season and ranged from 7.45 to 6.31 in the second season, and NaHCO3+ Paraffin Oil treatment ranged from 7.49 to 6.45 in first season and 7.51 to 6.49 in the second season. From the above results, the fruit length decreased during storage at room temperature throughout the storage. In both seasons, there was a significant effect between T3, T4, T5, T6, and T7 treatments and the control treatment. And there wasn't a significant between the control treatment and T2, T8, and T9 treatments. The interaction between the storage period and all the treatments was statistically significant in both seasons. During the storage of the fruits, the decrease in length of the fruit might be due to the increased respiration rate, low relative humidity, and high temperature, which leads to shrinkage of the colored layer (Flavedo) in the fruit.

Changes in Diameter of fruit:

Table (5) indicate the effects of different post- harvest treatments Hot Water Dipping (65° for a minute in a water bath), Paraffin Oil (100 purity), Sodium Bicarbonate "NaHCO3" (1.5%), Low-Density Polye Ethelene film (LDPE), NaHCO3+ LDPE, Hot Water Dipping +LDPE, Hot Water Dipping +Paraffin Oil and NaHCO3+Paraffin Oil on fruit diameter (cm) of Balady Orange fruits under room temperature. The results of the two seasons took approximately the same trend. During the storage of fruit, it is noticed from Table (5) that fruit diameter was gradually decreased by extending the storage period at room temperature during the two investigated seasons. After 6 weeks of storage under room temperature, the least mean of fruit diameter was in untreated (the control) orange fruits compared to the treated orange fruits in both seasons. The orange fruits which were warped with LDPE were the highest mean fruit length in both seasons, while the least mean fruit length was in Hot water Dipping treatment and Hot water Dipping + paraffin oil treatment. During storage for 6 weeks under room temperature, the diameter of fruit in Hot water dipping treatment ranged from 7.86 to 6.41 in the first season and ranged from 7.38 to 5.72 in the second season; Paraffin oil treatment ranged from 7.51 to 6.72 in first season and ranged from 6.94 to 6.24 in second season, NaHCO3 treatment ranged from 7.74 to 7.03 in first season and ranged from 6.54 to 5.88, LDPE treatment ranged from 7.89 to 7.37 in first season and ranged from 6.70 to 6.22 in second season, NaHCO3+ LDPE treatment ranged from 7.64 to 7.09 in first season and ranged from 6.76 to 6.19 in second season, Hot Water Dipping+ LDPE treatment ranged from 7.37 to 6.74 in first season and ranged from 6.51 to 5.86 in second season, Hot Water Dipping + Paraffin Oil treatment ranged from 7.64 to 6.62 in first season and ranged from 6.96 to 5.62 in first season and NaHCO3+ Paraffin Oil treatment ranged from 7.87 to 6.90 in first season and 7.04 to 6.30 second season.

From all the above results, the fruit diameter decreased during storage at room temperature throughout the storage. In both seasons, there was a significant effect between the T5 treatment and the control treatment. And there wasn't any significant difference between the control orange fruits and the other treatments. The interaction between the storage period and all the treatments was statistically significant in both seasons.

During the storage of the fruits, the diameter of the fruit decreased might due to the increased respiration rate, low relative humidity, and high temperature, which leads to shrinkage of the colored layer (Flavedo) in the fruit.

Chemical Characteristics:

Total soluble solid (TSS) %:

Tables (6) indicate the effects of different post- harvest treatments Hot Water Dipping (65° for a minute in a water bath), Paraffin Oil (100 purity), Sodium Bicarbonate "NaHCO3" (1.5%), Low-Density Polye Ethelene film"LDPE", NaHCO3+ LDPE, Hot Water Dipping +LDPE, Hot Water Dipping +Paraffin Oil and NaHCO3+Paraffin Oil on total soluble solid content (%) in Balady Orange fruits under room temperature. The result of the present study showed that as storage advances. A gradual increase in TSS was observed during the entire storage period (Table 6) at room temperature. The TSS content of all treated orange fruit was less than that of control samples. The control fruits registered a faster-increasing rate of the TSS content after 6 weeks of storage, with the highest mean of 11.81 % and 11.90 % TSS content in both seasons, respectively, while the least mean of TSS after 6 weeks was in T5 (LDPE) 10.96 % and 11.16 % in both seasons respectively. The LDPE treatment had the least percentage of TSS; it recorded 10.69 % and 11.16 % in both seasons, followed by NaHCO3+ LDPE treatment was 11.17 % and 11.20 % in both seasons, followed by Hot Water Dipping+ LDPE treatment was 11.24 % and 11.21 % in both seasons, followed by paraffin oil treatment was 11.34 % and 11.56 % in both seasons, followed by NaHCO3 treatment 11.53 % in the first season and 11.57 % in the second season, followed by NaHCO3+ Paraffin Oil treatment was 11.57 % and 11.61 % in both seasons and followed by Hot Water Dipping + Paraffin Oil was 11.74 % and 11.83 % in both seasons. From all the above results, throughout the storage, the percentage of TSS

significantly affected LDPE (T5) orange fruits and the control orange fruit in both seasons. And there wasn't any significant difference between the control orange fruits and the other treatments. The interaction between the storage period and all the treatments was statistically significant in both seasons. The best treatment was T5 (LDPE).it recorded less content of total soluble solid in both seasons of Balady orange fruits. The percentage of total soluble solids in all treated fruits increased over time. The rise in total soluble solids during storage was likely due to the breakdown of complex carbohydrates and the concentration of juice caused by dehydration. These results are in agreement with this obtained by (Kahramanoğlu et al.,2020), who found the TSS content of "Nanfeng" Mandarin fruits treated with HWD was higher than the untreated fruits from day 30 to the end of the 90-day storage period. These results don't agree with this obtained by (Jawandha, and Kirandeep, 2017), who found that the total soluble solids were higher in fruits packed in shrink film trays with 3 % sodium bicarbonate treatment than the untreated ones.

Titratable Acidity (TA) (%):

A perusal of the data in Table (7) shows the effect of different post- harvest treatments Hot Water Dipping (65° for a minute in a water bath), Paraffin Oil (100 purity), Sodium Bicarbonate "NaHCO3" (1.5%), Low-Density Polye Ethelene film"LDPE", NaHCO3+ LDPE, Hot Water Dipping +LDPE, Hot Water Dipping +Paraffin Oil and NaHCO3+Paraffin Oil on the titratable acidity content under room temperature of the Balady orange fruits for the season (2021/2022) and (2022/2023). The mean titratable acidity content was relatively highest at the initial stage and experienced a linear decline with the advancement of storage in both seasons for all treatments. The data are statistically significant during the ambient storage conditions. During the season (2021/2022), the minimum mean of titratable acidity 0.70 % content was recorded in the control. The maximum mean of titratable acidity was 0.97% in T5 (LDPE). A similar trend was also observed during the first season; the minimum mean titratable acidity of 0.68 % content was recorded in the control. The maximum mean of titratable acidity, 1.04 %, was recorded in LDPE treatment. The LDPE treatment was the maximum mean of titratable acidity 0.97% and 1.04 % in both seasons, respectively, followed by the NaHCO3+ LDPE treatment was 0.95 % in both seasons, followed by Hot Water Dipping + Paraffin Oil treatment was 0.93 %, followed by Hot Water Dipping+ LDPE and NaHCO3 treatments were the same percentage 0.93 % and 0.92 % in both seasons, followed by the NaHCO3+ Paraffin Oil treatment was 0.88 % and 0.87 % in both seasons respectively and followed by the Hot Water Dipping treatment was 0.81 % and 0.80 % in both seasons respectively. From all the above results, throughout the storage, the percentage of TSS significantly affected all treated orange fruits and the control orange fruit in both seasons. The interaction between the storage period and all the treatments was statistically significant in both seasons. The packaging films helped in better retention of acidity as compared to control. During the present investigations, according to the data in Table(9), it was observed that the titratable acidity content of Balady orange fruits during storage experienced a linear decline as the storage period advanced in all the treatments. The decrease in titratable acidity content might be due to the rapid utilization of organic acid (citric acid) during respiration as ripening advanced during storage. These results agree with this obtained by (Kahramanoğlu et al., 2020). Who found that there was decreased acidity content in the "Nanfeng" Mandarin fruits during storage. The control fruits had a higher acidity content compared to the HWD-treated fruits. Also, these results agree with this obtained by (Jawandha and Kirandeep, 2017), who found that when storing kinnow fruit for longer periods, its acidity decreased consistently across all treatments. However, fruit treated with 3 % sodium bicarbonate and packed in shrink film tray packaging maintains the highest acidity levels, dropping from 0.79 to 0.57 over time. The Control fruits had the lowest acidity content.

Ascorbic acid (V.C.) (%):

A perusal of the data in Table (8) shows the effect of different post-harvest treatments, namely Hot Water Dipping (65° for a minute in a water bath), Paraffin Oil (100 purity), Sodium Bicarbonate "NaHCO3" (1.5%), Low-Density Polye Ethelene film (LDPE), NaHCO3+ LDPE, Hot Water Dipping +LDPE, Hot Water Dipping +Paraffin Oil and NaHCO3+Paraffin Oil on the ascorbic acid content of the Balady orange fruits in first the season and second season under room temperature. The mean ascorbic acid content was relatively high at the initial storage stage and experienced a linear decline with the advancement of storage in both seasons for all treatments. The data were statistically significant during the ambient storage conditions. During the first season, the minimum mean of ascorbic acid 40.40 % content was recorded in the untreated ones (the control), while the maximum mean was 49.01% in the LDPE treatment. No similar trend was also observed during the second season because of the difference in temperature between the two seasons shown in Table (13). The minimum mean of ascorbic acid was 35.69% content in untreated ones (the control), while the maximum mean of ascorbic acid 48.27 % was recorded in LDPE orange fruits. In the second season, the temperature was higher than the first season, which affected the fruit content of vitamin C, which is known to be highly affected by high temperature. When the temperature increase, that effect is negative on ascorbic acid. The LDPE treatment was the maximum content of ascorbic acid 49.01% and 48.27 % in both seasons, respectively, followed by NaHCO3+ LDPE treatment was 47.77 % and 45.36 % in both seasons, respectively, followed by Hot Water Dipping+ LDPE treatment was 46.60 % and 40.36 % in both seasons respectively, followed by NaHCO3 treatment was 45.84 % and 39.36 % in both seasons respectively, followed by Paraffin Oil treatment was 42.69 % and 37.06 % in both seasons respectively, followed by Hot Water Dipping + Paraffin Oil treatment was 41.33 % and 37.55 % in both seasons respectively, followed by NaHCO3+ Paraffin Oil treatment was 41.25 % and 37.42 % in both seasons respectively and followed by Hot Water Dipping (HWD) treatment was 41.11 % and 36.18 % in both seasons respectively. A perusal of the experimental data, the mean ascorbic acid content followed a gradually declining trend during the stipulated storages from 0 to 6 weeks. From all the above results, throughout the storage, the percentage of ascorbic acid had a significant effect between T4, T5, T6, T7, orange fruits, and the control orange fruit in both seasons. And there wasn't a significant between T2, T3, T8, T9, and the control Balady orange fruits. The interaction between the storage period and all the treatments was statistically significant in both seasons. According to the data in Table (8), it was found that throughout the current experiments, the ascorbic acid content of Balady orange fruits had a linear drop as the storage period progressed in all the treatments. Fruits' respiration, transpiration, and other metabolic processes are slowed down when they are stored in polyethylene films and with edible coatings, which altered the atmospheric conditions around the produce inside the package and allowed for a lesser degree of gas control. Compared to the control, ascorbic acid retention was improved by coating and packaging fruits. The oxidation of L-ascorbic acid into dehydroascorbic acid may be the cause of the ascorbic acid loss during storage. These results are in agreement with this obtained by (Kahramanoğlu et al.,2020), who found that after 90 days of storage, the "Nanfeng" Mandarin fruits treated with H.W.D. had 16.35 mg of V.C. per 100 g, higher than the untreated control fruits with only 13.86 mg of V.C. per 100 g. These results also agree with this obtained by (Khedr, 2018), who found that coating treatments prevented the loss of ascorbic acid during the storage and marketing of Olinda oranges. Ascorbic acid levels in the fruit decreased gradually after harvest, but the difference in levels between coated fruits was insignificant. Uncoated fruits, on the other hand, had significantly lower levels of ascorbic acid. In Valencia oranges coated with paraffin oil 99 %, the ascorbic acid content was 37.24 % after 90 days of cold storage. In comparison, the uncoated control fruit had a value of 35.15%.

Table (3): PLW percentage (%) changes in Balady Orange as different post-harvest treatment under room temperature.

Treatments	Weeks (2021/2022)							Mean	Weeks (2022/2023)							Mean
	0	1	2	3	4	5	6		0	1	2	3	4	5	6	
Control	0	0	4.61	9.12	15.42	21.11	24.13	**10.63**	0	0	4.31	9.14	15.84	20.96	24.18	**10.63**
Hot Water Dipping (HWD)	0	0	3.23	4.56	6.22	13.17	21.86	**7.01**	0	0	3.9	5.03	7.61	12.7	20.25	**7.07**
Paraffin Oil	0	0	2.89	3.45	7.11	9.45	14.52	**5.35**	0	0	2.64	3.97	8.01	10.11	15.22	**5.71**
$NaHCO_3$	0	0	3.01	4.52	6.14	12.45	16.74	**6.12**	0	0	3.82	4.96	5.98	12.65	19.03	**6.63**
LDPE	0	0	0.93	1.56	2.54	4.07	8.45	**2.51**	0	0	1.01	2.11	4.22	6.55	8.12	**3.14**
$NaHCO_3$+ LDPE	0	0	1.88	2.33	5.69	11.79	14.95	**5.23**	0	0	1.54	2.45	6.05	12.1	15.46	**5.37**
Hot Water Dipping+ LDPE	0	0	1.89	3.2	4.00	13.15	18.02	**5.75**	0	0	1.77	3.17	4.02	11.23	17.34	**5.36**
Hot Water Dipping + Paraffin Oil	0	0	4.03	6.55	8.24	14.12	16.23	**7.02**	0	0	4.11	6.89	8.89	15.01	17.36	**7.47**
$NaHCO_3$+ Paraffin Oil	0	0	3.65	6.52	8.00	13.89	15.99	**6.86**	0	0	3.89	7.01	8.98	14.95	17.3	**7.45**
Mean	**0**	**0**	**2.90**	**4.65**	**7.04**	**12.58**	**16.77**		**0**	**0**	**3.00**	**4.97**	**7.73**	**12.92**	**17.14**	
L.S.D 0.05																
A				**0.27**								**0.28**				
B				**0.11**								**0.25**				
A. B				**0.55**								**0.83**				

Table (4): Fruit length changes in Balady Orange as different post-harvest treatment under room temperature.

Treatments	Weeks (2021/2022)							Mean	Weeks (2022/2023)							Mean
	0	1	2	3	4	5	6		0	1	2	3	4	5	6	
Control	7.62	7.22	7.2	6.66	6.5	6.35	6.19	**6.82**	7.64	7.62	6.7	6.07	6.05	6.01	5.99	**6.58**
Hot Water Dipping (HWD)	7.6	7.49	7.22	6.9	6.7	6.45	6.33	**6.96**	7.62	7.59	7.48	7.22	6.72	6.38	6.25	**7.04**
Paraffin Oil	7.7	7.67	7.29	7.07	6.95	6.8	6.74	**7.17**	7.73	7.71	7.41	7.4	6.96	6.82	6.8	**7.26**
$NaHCO_3$	7.88	7.84	7.19	7.15	7.09	7.06	7.03	**7.32**	7.79	7.78	7.47	7.46	7.02	6.87	6.73	**7.30**
LDPE	7.64	7.5	7.18	7.15	7.06	7.04	7.02	**7.23**	7.7	7.69	7.37	7.3	7.21	7.17	7.07	**7.36**
$NaHCO_3$+ LDPE	7.88	7.87	7.55	7.48	7.39	7.35	7.25	**7.54**	7.9	7.87	7.83	7.59	7.46	7.2	7.17	**7.57**
Hot Water Dipping+ LDPE	8.03	7.9	7.58	7.41	7.34	7.28	7.23	**7.54**	8.01	7.98	7.84	7.48	7.28	7.2	7.15	**7.56**
Hot Water Dipping + Paraffin Oil	7.4	7.25	7.03	6.92	6.82	6.58	6.31	**6.90**	7.45	7.41	6.75	6.61	6.48	6.35	6.31	**6.77**
$NaHCO_3$+ Paraffin Oil	7.49	7.47	6.83	6.71	6.6	6.56	6.45	**6.87**	7.51	7.49	7.24	6.87	6.67	6.53	6.49	**6.97**
Mean	**7.69**	**7.58**	**7.23**	**7.05**	**6.94**	**6.83**	**6.73**		**7.71**	**7.68**	**7.34**	**7.11**	**6.87**	**6.73**	**6.66**	
L.S.D 0.05																
A				**0.30**								**0.64**				
B				**0.20**								**0.14**				
A. B				**0.59**								**0.73**				

Table (5): Fruit diameter changes in Balady Orange as different post-harvest treatment under room temperature.

Treatments	Weeks (2021/2022)							Mean	Weeks (2022/2023)							Mean
	0	1	2	3	4	5	6		0	1	2	3	4	5	6	
Control	7.89	7.65	7.33	7.04	6.80	6.65	6.4	**7.11**	7.42	6.50	6.29	6.20	5.72	5.34	5.20	**6.10**
Hot Water Dipping (HWD)	7.86	7.45	6.88	6.72	6.62	6.60	6.41	**6.93**	7.38	5.98	5.85	5.83	5.81	5.75	5.72	**6.04**
Paraffin Oil	7.51	7.47	7.03	6.95	6.83	6.79	6.72	**7.04**	6.94	6.8	6.75	6.59	6.44	6.32	6.24	**6.58**
NaHCO3	7.74	7.52	7.47	7.25	7.15	7.07	7.03	**7.32**	6.54	6.40	6.34	6.19	6.13	6.00	5.88	**6.21**
LDPE	7.89	7.83	7.8	7.72	7.52	7.49	7.37	**7.66**	6.70	6.63	6.60	6.54	6.48	6.36	6.22	**6.50**
NaHCO3+ LDPE	7.64	7.52	7.32	7.24	7.21	7.14	7.09	**7.31**	6.76	6.65	6.62	6.49	6.38	6.20	6.19	**6.47**
Hot Water Dipping+ LDPE	7.37	7.31	7.15	7	6.91	6.84	6.74	**7.05**	6.51	6.44	6.41	6.24	6.08	5.96	5.86	**6.21**
Hot Water Dipping + Paraffin Oil	7.64	7.36	6.93	6.82	6.67	6.65	6.62	**6.96**	6.94	6.11	5.98	5.84	5.78	5.71	5.62	**6.00**
NaHCO3+ Paraffin Oil	7.87	7.57	7.26	7.18	7.08	6.93	6.90	**7.26**	7.04	6.83	6.69	6.62	6.50	6.49	6.30	**6.64**
Mean	**7.71**	**7.52**	**7.24**	**7.10**	**6.98**	**6.90**	**6.81**		**6.92**	**6.48**	**6.39**	**6.28**	**6.15**	**6.01**	**5.91**	
L.S.D 0.05																
A				**0.21**								**0.19**				
B				**0.13**								**0.11**				
A. B				**0.36**								**0.22**				

Table (6): TSS percentage (%) changes in Balady Orange as different post-harvest treatment under room temperature.

Treatments	Weeks (2021/2022)							Mean	Weeks (2022/2023)							Mean
	0	1	2	3	4	5	6		0	1	2	3	4	5	6	
Control	10.4	11.2	11.5	11.7	12.0	12.7	13.2	**11.81**	10.5	11.3	11.7	11.6	12.0	12.7	13.5	**11.90**
Hot Water Dipping (HWD)	9.8	10.5	11.2	12.2	12.5	12.8	13.7	**11.81**	10.5	11.2	11.4	11.5	12.9	12.6	12.9	**11.86**
Paraffin Oil	10.4	11.1	11.9	11.5	11.5	10.5	12.5	**11.34**	9.8	11.6	11.1	11.8	11.9	12.0	12.7	**11.56**
$NaHCO_3$	9.9	10.9	11.1	11.8	12.3	12.3	12.4	**11.53**	10.5	11.1	11.5	11.7	11.6	12.1	12.5	**11.57**
LDPE	9.5	10.2	10.7	11.1	11.4	11.8	12.0	**10.96**	10.3	11.3	11.7	10.9	11.0	11.0	11.9	**11.16**
$NaHCO_3$+ LDPE	10.2	11.2	11.1	11.5	12.1	11.4	10.7	**11.17**	9	9.6	10.4	11.3	12.5	12.4	13.2	**11.20**
Hot Water Dipping+ LDPE	10.4	10.1	9.8	11.3	12.0	12.4	12.7	**11.24**	9.5	10.7	10.9	11.5	11.5	11.7	12.7	**11.21**
Hot Water Dipping + Paraffin Oil	10	11.0	12.8	11.7	12.1	12.2	12.4	**11.74**	10.5	11.0	11.2	11.3	12.0	13.3	13.5	**11.83**
$NaHCO_3$+ Paraffin Oil	9.8	10.2	12.1	11.3	11.8	12.8	13.0	**11.57**	10	10.8	11.5	11.7	11.5	12.8	13.0	**11.61**
Mean	**10.04**	**10.71**	**11.36**	**11.57**	**11.97**	**12.10**	**12.51**		**10.07**	**10.96**	**11.27**	**11.48**	**11.88**	**12.29**	**12.88**	
L.S.D 0.05																
A				**0.64**								**0.53**				
B				**0.40**								**0.39**				
A. B				**1.19**								**1.17**				

Table (7): Titratable acidity percentage (%) changes in Balady Orange as different post-harvest treatment under room temperature.

Treatments	Weeks (2021/2022)							Mean	Weeks (2022/2023)							Mean
	0	1	2	3	4	5	6		0	1	2	3	4	5	6	
Non- treatment	1.05	0.96	0.85	0.58	0.51	0.49	0.44	**0.70**	0.92	0.9	0.89	0.64	0.5	0.46	0.45	**0.68**
Hot Water Dipping (HWD)	1.22	1.01	0.9	0.87	0.73	0.5	0.44	**0.81**	1.05	1	0.9	0.84	0.76	0.64	0.44	**0.80**
Paraffin Oil	1	0.97	0.94	0.8	0.8	0.74	0.69	**0.85**	0.90	0.88	0.85	0.85	0.8	0.78	0.70	**0.82**
$NaHCO_3$	1.05	1.02	0.95	0.9	0.89	0.88	0.79	**0.93**	1.06	1.03	0.96	0.89	0.87	0.85	0.8	**0.92**
LDPE	1.08	1.05	1	0.98	0.9	0.89	0.87	**0.97**	1.23	1.11	1.09	1.04	0.99	0.9	0.89	**1.04**
$NaHCO_3$+ LDPE	1.07	1.05	1.02	0.9	0.87	0.88	0.84	**0.95**	1.07	1.03	1	0.98	0.9	0.86	0.8	**0.95**
Hot Water Dipping+ LDPE	1.06	1.03	0.97	0.93	0.84	0.85	0.8	**0.93**	1.07	1.05	0.99	0.9	0.88	0.8	0.78	**0.92**
Hot Water Dipping + Paraffin Oil	1.09	1.07	1.03	0.9	0.85	0.8	0.8	**0.93**	1.09	1.04	1.02	0.9	0.89	0.79	0.75	**0.93**
$NaHCO_3$+ Paraffin Oil	1.08	1.06	1	0.88	0.75	0.96	0.42	**0.88**	1.06	1.02	0.96	0.9	0.87	0.8	0.46	**0.87**
Mean	**1.08**	**1.02**	**0.96**	**0.86**	**0.79**	**0.78**	**0.68**		**1.05**	**1.01**	**0.96**	**0.90**	**0.85**	**0.76**	**0.67**	
L.S.D 0.05																
A				**0.07**								**0.11**				
B				**0.05**								**0.09**				
A. B				**0.16**								**0.26**				

Table (8): Ascorbic acid percentage (%) changes in Balady Orange as different post-harvest treatment under room temperature.

Treatments	Weeks (2021/2022)							Mean	Weeks (2022/2023)							Mean
	0	1	2	3	4	5	6		0	1	2	3	4	5	6	
Control	55.29	50.11	45.22	40.56	36.13	30.26	25.24	**40.40**	55.08	45.11	40.22	35.16	29.89	25.14	19.22	**35.69**
Hot Water Dipping (HWD)	55.44	51.16	47.14	41.22	36.17	29.49	27.16	**41.11**	55.22	46.22	39.25	35.22	28.89	25.65	22.78	**36.18**
Paraffin Oil	55.36	52.33	49.17	42.15	38.54	33.85	27.4	**42.69**	55.03	49.11	42.65	33.17	29.89	26.37	23.19	**37.06**
$NaHCO_3$	55.11	52.47	50.45	48.22	42.23	39.16	33.24	**45.84**	55.16	50.24	43.15	39.18	32.45	29.16	26.17	**39.36**
LDPE	55.24	53.48	51.26	49.27	46.54	44.11	43.17	**49.01**	55.24	53.65	50.22	49.16	46.11	43.65	39.89	**48.27**
$NaHCO_3$+ LDPE	55.22	53	50.28	48.16	45.22	42.64	39.89	**47.77**	55.28	52.46	49.11	46.15	45.55	40.16	28.79	**45.36**
Hot Water Dipping+ LDPE	55.11	50.17	49.22	47.45	44.36	41.25	38.66	**46.60**	55.13	50.17	45.88	42.16	38.89	27.82	22.45	**40.36**
Hot Water Dipping + Paraffin Oil	55.03	51	47.11	41.36	37.18	30.29	27.33	**41.33**	55.07	49.18	41.12	38.55	28.78	26.79	23.35	**37.55**
$NaHCO_3$+ Paraffin Oil	55.18	51.22	48	41.25	37.45	29.89	25.79	**41.25**	55.11	48.35	42.25	39.16	29.1	23.12	24.82	**37.42**
Mean	**55.22**	**51.66**	**48.65**	**44.40**	**40.42**	**35.66**	**31.99**		**55.15**	**49.39**	**43.76**	**39.77**	**34.39**	**29.76**	**25.63**	
L.S.D 0.05																
A				**3.63**								**2.93**				
B				**2.13**								**2.05**				
A. B				**6.37**								**6.15**				

CONCLUSION

Storing Balady orange fruits at room temperature. It was found that using wrapping with low-density polyethylene film only, without treating the fruits with any other material, was the best treatment in prolonging the shelf life of the fruit and preserving the physical and chemical characteristics of the fruits, which is reflected in the quality of the fruits.

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تأثير معاملات ما بعد الحصاد على دورة حياة الثمرة وتغير صفاتها الفيزيائية والكيميائية في البرتقال البلدي

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الملخص العربى

أجريت الدراسة في معمل ما بعد الحصاد، كلية الزراعة ، سوهاج ، خلال موسمي 2022/2021 و 2023/2022 ، على ثمار برتقال بلدي لتحديد أفضل معاملة وأطول فترة صلاحية مرغوبة تحت درجة حرارة الغرفة. أجريت هذه الدراسة للتحقق من آثار نقع الثمار في الماء الساخن ، وزيت البرافين ، وبيكربونات الصوديوم ، وتغليف بولي إيثلين منخفض الكثافة ، وبيكربونات الصوديوم بالإضافة إلى بولي إيثيلين منخفض الكثافة ، والماء الساخن بالإضافة إلى البولي إيثلين منخفض الكثافة ، الغمس بالماء الساخن بالإضافة إلى زيت البرافين ، بيكربونات الصوديوم بالإضافة إلى زيت البرافين على برتقال "بلدي" بعد الحصاد المخزن تحت ظروف درجة حرارة الغرفة. أوضحت نتائج التجربة أن البرتقال المعالج أدى إلى تحسن معنوي في العمر التخزيني لبرتقال بلدي مقارنة بالبرتقال غير المعالج في كلا الموسمين. أظهرت النتائج أن لف ثمار البرتقال بـ البولي ايثلين مع البيكربونات الصوديوم أعطت أطول فترة صلاحية (85 ، 84) يوم ، بينما كان لثمار البرتقال غير المعاملة أقصر مدة صلاحية (45 ، 42) يوم في كلا الموسمين ، على التوالي. كانت أعلى خسارة في الوزن الفسيولوجي في المعاملة غير المعاملة، بينما كانت أقلها في ثمار البرتقال المغلفة بالبولي ايثلين .وأظهرت أعلى جودة فيزيائية وكيميائية للثمار البرتقال المغلفة بالبولي ايثلين .

الكلمات المفتاحية : الموالح- معاملات ما بعد الحصاد- المدة التخزينية – جودة الثمار