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Research Article

Extending Shelf Life and Maintaining Quality of Valencia Oranges by Some Safe Eco-friendly Treatments

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Abstract:

The objective of this study was to investigate the impact of postharvest eco-friendly components, H_2O_2 (1%), oxalic acid (10mM), Gum Arabic (5%) and Frankincense solutions (5%) on shelf life and quality of Valencia oranges under ambient room temperature were studied. Valencia oranges are treated with solution of distilled water (control), H_2O_2 (1%), Oxalic acid (10 mM), Gum Arabic (5%) and Frankincense solutions (5%). The treated oranges were stored at ambient temperature (25 ±2 ºC & 85 % RH) for 45 days. Customary values of Valencia oranges, fresh weight and juice content, were deteriorated by prolonging shelf-life period. All treatments proved efficiency in maintaining quality of Valencia oranges during shelf life. However, application of H_2O_2 (1%) and Frankincense (5%) were the best treatments in maintaining the Valencia orange fresh weight and juice content, titratable acidity (TA) and reduced total soluble solids / titratable acid ratio (TSS/TA).

1. Introduction

Citrus fruits as the best and most promising export fruits, as well as the most popular fruits in Egypt, due to their excellent taste, flavor and high vitamin C content (**Ahmad et al., 2014**) and for the high nutritional value (**Liu et al., 2012**). Valencia orange is a late-season variety with excellent taste and color and is primarily grown for processing and orange juice production (**Hodgson, 1967**). As it is a widely cultivated late season variety, 'Valencia' oranges are commercially stored for relatively long periods of up to 4–5 months in order to extend the marketing season (**Pekmezci et al., 1995; Ozdemir and Dundar, 2001**). Late harvest leads to deterioration in the quality of the fruits due to heat stress (**Zhang et al., 2022**). Therefore, storage is critical to maintain the quality of fruits and to reduce fruit deterioration (**Mariod et al., 2018**). The solution for maintaining the quality of the fruit may be using safe components (**Ramos et al., 2013**). For reducing the fruit deterioration, an eco-friendly and sustainable approach could be a potential method (**Zahid et al., 2015**). There is an increasing demand in the market for high quality products from the consumers' side. Various factors such as storage temperature and some post- harvest treatments limit the storage life (**Mutari and Debbie, 2011**).

Hydrogen peroxide (H_2O_2) is an eco-friendly compound, and its activity is based on oxidation of fungi and bacteria and used successfully for controlling vegetable pathogens during storage (**Khan, et al., 2018**). It has been considered as an important signaling molecule that mediates various physiological and biochemical processes in plants. Several studies have shown H_2O_2 could respond to abiotic stresses such as drought and salinity (**Mohamed et al., 2015**). It is also a key regular in a broad range of biological processes such as seedling growth and antioxidant enzymes activity under salt stress (**Li et al., 2011; Bagheri et al., 2019)**. In this regard, **Liu et al. (2010**) reported that pre-treatment with low concentration of H_2O_2 increased the enzymatic antioxidant activity and accumulation of ascorbate and reduced glutathione in plants. Postharvest applications of H_2O_2 reduced weight loss, rot rate as well as enhanced antioxidants content and improved general appearance during cold or shelf life (**Bayoumi, 2008)**.

Oxalic acid (OA) is a natural organic acid and plays an important function in systemic resistance and response to the environment (**Jin et al., 2014**). Oxalic acid application is a secure and regulates many processes in plants. It is an important hopeful postharvest handling technology for component in the signal transduction pathway (**Raskin, 1992**), keeping quality and prolonging storage life of fruits **(Zheng and Tain, 2006**). **Wu et al. (2011**) confirmed that OA has shown some antioxidant activities and plays a serious function in systemic strength, programmed cell death, redox homeostasis in plants and an anti-senescence effectiveness in harvested fruits. **Valero et al. (2011)** reported that exogenous OA markedly delayed ripening and softening of sweet cherry. OA can suppress postharvest disorders and prolong the storage life of mangoes because of delaying the ripening process **(Zheng et al., 2012).**

Gum Arabic, a complex polysaccharide, commonly consists of valuable minerals for human health such as magnesium, calcium, and potassium, which is extracted from part of Acacia plants (**Prakash et al., 1990)**.

The Gum Arabic (GA) is a safe compound and commonly employed as a food additive in many industrial sectors as well as is utilized as an emulsifier thank to its better solubility in comparison to other hydrocolloids (**Motlagh et al., 2006**). The antioxidant effects of GA and the positive effects of this substance have been reported on the quality and shelf life of Kinnow mandarin (**Khorram et al., 2017)**, guava (**Gurjar et al., 2018**) and Mexican lime (**Atrash et al., 2018**).

Frankincense essential oil (FO) is an excellent antibacterial and antifungal activity making it suitable for potential use in the preservation of foodstuffs (**Gangwal and Vardhan, 1995**). Also, it had a strong antioxidant and free radical scavenging activities due to the presence of a wide range of terpenes. These terpenes are electron-donor compounds that can react with free radicals to give more stable products, and thus terminate their effect (**Prakash et al., 2014**). **Hammer et al. (1999)** showed that FO exhibited excellent antibacterial and antifungal activities making it suitable for the potential use in the preservation of foodstuffs. The FO can protect food stuff from fungal invasion during storage as it reduces the excretion of toxic aflatoxins excreted by Aspergillus species (**Hussain et al., 2016).**

The suitable storage conditions of fruit cannot be reflected by a single index but require a comprehensive analysis of multiple indexes. Principal component analysis (PCA) is an analysis method that transforms multiple variables into multiple comprehensive variables. Then, the correlation between different characters is explained by Pearson correlation analysis. In this study, we used PCA to establish an evaluation system for the indexes related to treatments at different shelf life periods, which could be used as a basis for comprehensively evaluating Valencia Oranges storage and preservation under different shelf life periods. The suitable shelf life periods of Valencia oranges were screened out, providing a theoretical basis for actual production to reduce losses and thereby help increase profit.

This study was designed as primary experiments aimed to detect the impact of the safety eco-friendly components (H_2O_2, oxalic acid, Gum Arabic and Frankincense solutions) on the shelf life, and quality of Valencia oranges under ambient temperature (25 ±2ºC & 85 % RH).

2. Materials and Methods

Treatments

Valencia orange fruits were picked at maturity yellow-green stage and transferred, to Laboratory of Horticulture Department, Faculty of Agriculture Tanta University, at ambient temperature (25 ºC) in plastic boxes (15 kg capacity). On arrival, the fruits were cleaned, sorted, graded, and then the detective fruits including wounded and other disorders were excluded. The sound fruits at the same maturity stage were washed with 0.01% sodium hypochlorite solution for 2 min and then the fruits were air dried until visible moisture on fruit surfaces disappeared completely. In this study, two separated experiments were carried out as a primary investigation to study the effect of some eco-friendly and safety post-harvest treatments (i.e. Frankincense, Gum Arabic, Hydrogen peroxide and Oxalic acid) on physical and physico-biochemical attributes of Valencia orange fruits during shelf life. Cleaned healthy two hundred and forty oranges were selected randomly and divided into 4 groups (60 oranges for each) and every group was divided to 4 subgroups (for every shelf life period) .

Every subgroup had 3 replications (5 oranges for each) and subjected to one of the following treatments in the first experiment:

1. Control treatment: the fruits were dipped in distilled water for 5 minutes.
2. Hydrogen peroxide (1%) (v/v).
3. Oxalic acid (10 mM) (w/v).
4. The combined treatments of Hydrogen peroxide (1%) and then Oxalic acid (10 mM) 5 minutes for each.

In the second experiment, every group had 3 replications (5 oranges for each) and subjected to one of the following treatments:

1. Control treatment: the fruits were dipped in distilled water for 5 minutes
2. Frankincense (5%) (w/v).
3. Gum Arabic (5%) (w/v).
4. Combined treatments dipped in Frankincense (5%) and then dipped in Gum Arabic (5%).

In all treatments for the two experiments, fruits were dipped in the solution for 5 minutes, and then left for 30 minutes to air dry at room temperature in the present an electric fan, then sprayed with wax WATER WAX (FOMESA FRUITECH) mixed by Thiabendazole (TBZ) 0.5% and Imazalil (IMZ) 0.25% and left to air dry. The fruits of each treatment were filled in plastic boxes – (5 fruits in each replicate). The treated fruits were stored in the ambience. The following fruits' physical and chemical properties were recorded in the initial time before shelf life (zero time) and after every 15 days (25 ± 2 ºC & 85% RH):

Fruit physical attributes

Fruit weight loss (%): It was calculated during shelf life periods using a bench-top digital scale Model PC-500 (Doran scales, Batavia, IL, USA) by the following formula:

Fruit weight loss (%) = [100 * (fruit weight at zero time – (fruit weight after each shelf life period)/ (fruit weight at zero time)].

Juice percentage: It was determined according to the following formula:

$$Juice\ (\%) = 100 * \frac{Juice\ volume\ per\ fruit\ (ml)}{fruit\ weight\ (g)}$$

Fruit physio-biochemical attributes

Ascorbic acid (AsA) content: It was determined according to **AOAC (2005).** Briefly, samples of juice were used, oxalic acid solution was added to each sample and titrated with 2,6-dichlorophenol-indophenol dye solution and expressed as a milligram of ascorbic acid/100 ml juice.

Juice pH: The pH of the fruit juice was determined using a pH meter (Style Hanna 8514)

Total soluble solids content (TSS): TSS was measured using a digital hand-held refractometer, (Atago Co., Ltd., Tokyo, Japan) at 25°C, and the results were expressed in °Brix according to **AOAC (2005).**

Oranges juice Titratable acidity (TA %): TA was assayed based on the method of adopting the procedure described by **AOAC (2005).** Aliquot of fruit juice was taken and titrated against0.1 N NaOH in the presence of phenolphthalein as an indicator to the end point and was calculated as grams of citric acid per 100 ml of juice.

TSS/TA ratio was calculated from the values recorded for fruit juice TSS and TA percentages were determined.

Experimental design and Statistical Analysis

Both experiments were arranged in a completely randomized design with three replications and factorial analysis. Data calculated as a percentage was converted to square root of arc sine before analysis. An analysis of variance (ANOVA) was then performed using the MSTAT-C statistical package **(M-STAT, 1993**). Comparisons between means were made by Duncan's multiple range test (DMRT) with probability ≤ 0.05 according to **Duncan (1955).** A correlation between the different Valencia oranges characters during shelf life period was carried out SPSS program.

3. Results

Data in **Table 1** show that the marketing values, fruit weight loss and juice content, were decreased by increasing the shelf life period and recorded the highest deterioration at 45 day period. Whereas, all the applied treatments, especially H_2O_2, maintained these characteristics and detected the lowest fruit weight loss and the highest juice content compared to the other treatments during the shelf life period. The nutritional parameters, total soluble solids (TSS) and titratable acid (TA), showed reduction by advancing the shelf life period and recorded the lowest values at 45 day period. All the treatments had no significant effect on AsA and TSS, while showed significant positive effect and maintained TA during the shelf life period.

Table 1: Effect of shelf life periods and eco-friendly components, H_2O_2 and Oxalic acid treatments on physical and nutritional values of Valencia oranges under ambient temperature (25 ±2ºC & 85 % RH)

	Fruit weight loss (%)	Juice content (%)	AsA (mg/ 100 ml)	TSS (%)	TA (%)	pH	TSS/TA
Shelf life period (day)							
0	0.00 c	57.21 a	60.47 b	13.27 a	0.81 a	2.70 c	16.78 c
15	6.26 b	51.29 ab	64.13 ab	11.44 b	0.63 b	2.75 c	18.19 c
30	6.91 b	49.81 b	68.87 a	13.24 a	0.56 b	3.17 b	26.03 b
45	8.37 a	48.86 b	63.81 ab	11.33 b	0.30 c	3.32 a	37.89 a
Treatments							
Control	6.77 a	52.73 ab	64.79 a	12.13 a	0.51 b	2.91 b	27.73 a
H_2O_2 (1%)	4.61 c	53.91 a	64.32 a	12.63 a	0.59 a	3.08 a	23.18 b
Oxalic acid (OA) (10mM)	5.64 b	49.50 b	63.40 a	12.43 a	0.60 a	2.98 b	23.93 b
H_2O_2 + OA	4.53 c	51.03 ab	64.77 a	12.08 a	0.61 a	2.97 a	24.05 b
S* T interaction sig	NS	NS	NS	NS	NS	NS	NS

Means followed by the same letters in the shelf life period or treatments are not significantly different at level $P \leq 0.05$ according to Dunkan Multiple Reng Test (DMRT).

Table 2: Effect of shelf life periods and eco-friendly components, Gum Arabic and Frankincense treatments on physical and nutritional values of Valencia oranges under ambient temperature (25 ±2°C & 85 % RH)

	Fruit Weight loss (%)L	**Juice content (%)**	**Ascorbic acid (mg/ 100ml**	**TSS (%)**	**TA (%)**	**pH**	**TSS/TA**
Shelf life period (day)							
0	0.00 d	51.01 a	60.47a	13.27 a	0.81a	2.75 c	20.63a
15	3.00 c	48.86 ab	48.69b	12.55 b	0.71b	3.77 b	19.18ab
30	6.44 b	47.51 ab	53.12bc	12.65 b	0.65b	3.72 b	17.85bc
45	8.76 a	45.46 b	47.67c	12.48 b	0.65b	3.85 a	16.78c
Treatments							
Control	6.48 a	48.96 a	52.30a	12.78 a	0.61a	3.51 a	20.24a
Gum Arabic (5%)	4.92 b	48.60 a	52.47a	12.93 a	0.64a	3.53 a	18.82ab
Frankincense (5%)	3.06 c	48.43 a	52.52a	12.63 a	0.67a	3.54 a	17.83ab
GA + Fr.	3.74 c	46.84 a	52.66a	12.61 a	0.67a	3.51 a	17.55b
S * T sig	**	NS	NS	NS	NS	NS	NS

Means followed by the same letters in the shelf life period or treatments are not significantly different at level $P \leq 0.05$ according to Dunkan Multiple Reng Test (DMRT).

Data in **Table 2** indicate the marketing characteristics of Valencia oranges, fresh weight and juice content have decreased with prolonging the shelf life period. Whereas all the applied treatments maintained these characters and the Frankincense treatment had detected the best results in this respect. The nutritional characters, including AsA, TSS and TA, were decreased by advancing the shelf life period and recorded the lowest values at the end period. All the applied treatments have no significant effect in this respect, while TSS/TA showed negative response by these treatments and showed a significant reduction compared with the control one.

The use of Principal Component Analysis (PCA) aimed to obtain a broader picture for the effect of eco-friendly treatments on Valencia oranges' physical and chemical properties during shelf life. Regarding the PCA (**Figure 1**), the score plot showed that all treatments affected the fruit's characteristics. After 45 days shelf life, the most pronounced effects were detected with the control and combined (Oxalic acid 10 mM + H_2O_2 1%) treatments, which were correlated with increasing fruit weight loss and maintaining ascorbic acid content, followed by the control and combined (Oxalic acid 10 mM + H_2O_2 (1%)) treatments after 15 days shelf life which were correlated with juice content. On the other hand, treatments of Oxalic acid and H_2O_2 treatments at 45 days followed by the control treatment at 15 days shelf life which correlated with TSS/TA and pH juice values. Other treatments, control at zero time and combined treatment (oxalic acid mM+ H_2O_2 1%) at zero time followed by oxalic acid at 15 days shelf life were mainly effective on TSS and TA. Principle components 1 and 2 accounted for 62.8% during shelf life.

Table 3: The personal correlations between the different characters of Valencia oranges during shelf life (25 ± 2ºC &85 % RH) period and treated with H_2O_2 (1%) and oxalic acid (10mM)

	Weight loss	**Juice content**	**Ascorbic acid**	**TSS**	**TA**	**pH**	**TSS/TA**
weight loss							
Juice content	-.376**						
Ascorbic acid	.132	.023					
TSS	-.245	.275	-.030				
TA	-.630**	.390**	-.154	.530**			
pH	.660**	-.304*	.058	-.097	-.552**		
TSS/TA	.573**	-.297*	-.004	-.243	-.909**	.536 **	

* Correlation is significant at the 0.05 level (2-tailed)

**Correlation is significant at the 0.01 level (2-tailed)

Table 4: The personal correlations between the different characters of Valencia oranges during shelf life (25 ± 2 ºC &85 % RH) period and treated with Gum Arabic (5%) and Frankincense (5%)

	weight loss	**Juice content**	**Ascorbic acid**	**TSS**	**TA**	**pH**	**TSS/TA**
weight loss							
Juice content	.082				.		
Ascorbic acid	-.440**	.089		.	.		
TSS	-.319*	.159	.088				
TA	-.395**	.128	.119	.693**			
pH	.616**	.158	-.404**	-.368*	-.450**		
TSS/TA	.226	-.141	-.174	-.427**	-.876**	.311*	

* Correlation is significant at the 0.05 level (2-tailed)

**Correlation is significant at the 0.01 level (2-tailed)

The use of PCA aimed to obtain a broader picture for the effect of eco-friendly treatments (Gum Arabic 5% and Frankincense 5%) on Valencia oranges' physical and chemical properties during shelf life. Regarding the PCA (**Figure 2**), the score plot showed that all treatments affected the fruit's characteristics. After 45 days shelf life, the most pronounced effects were detected with Gum Arabic treatment at 15 and 30 days shelf life which correlated with juice content and both of TSS and TA, followed by both of Gum treatment at 30 and 45 days shelf life and control at 30 days shelf life which correlated with fruit weight loss and juice pH. The combined treatment (GA + Fr)) after 15 days shelf life was correlated with ascorbic acid content. On the other hand, control and Gum Arabic treatments 15 at days followed by Fr at 15 days shelf life were mainly effective on TSS/TA value. Principle components 1 and 2 accounted for 67.4% during shelf life.

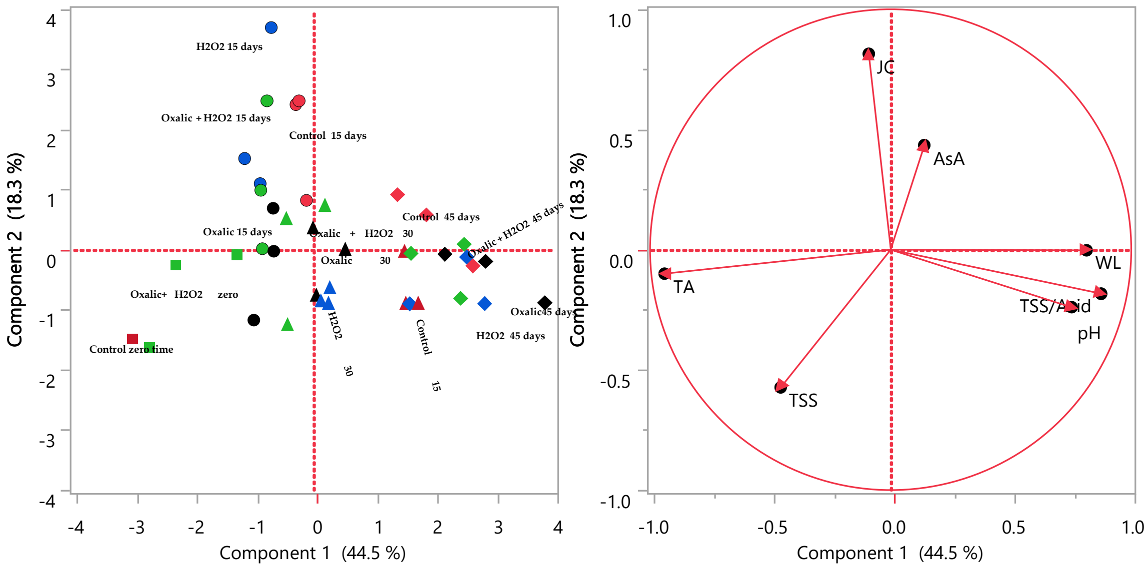

Figure 1. Principal component analysis (PCA) showing the score and loading plots of postharvest applications of oxalic acid and H_2O_2 during shelf life periods at 25±2°C on Valencia oranges and fruit characteristics. Values are the means of three replicates (n = 3).

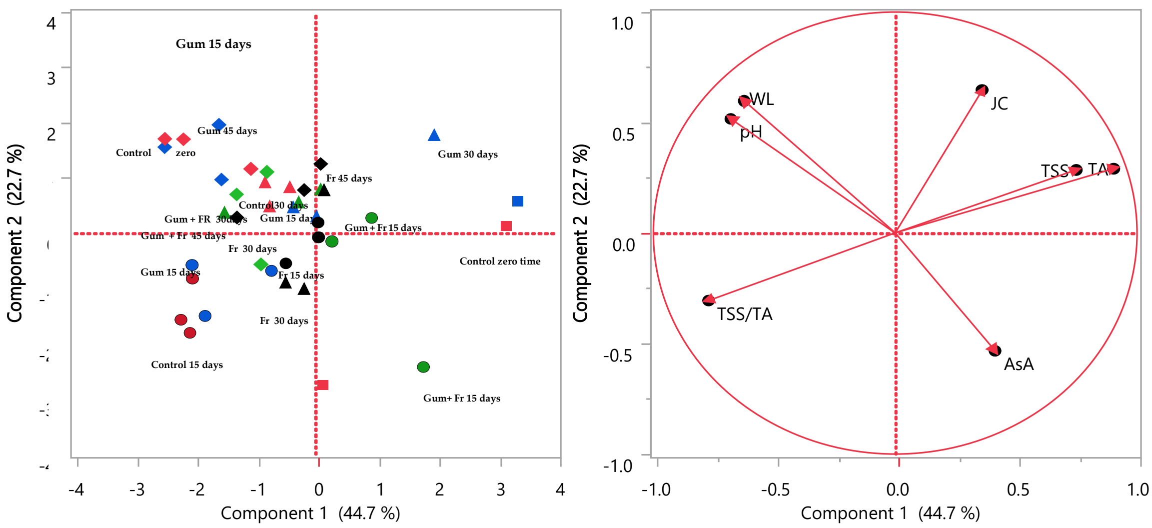

Figure 2. Principal component analysis (PCA) showing the score and loading plots of postharvest applications of Gum Arabic 5% and Frankincense 5% during shelf life periods at 25± 2°C & 85% RH on Valencia Oranges and fruit characteristics. Values are the means of three replicates (n = 3)

Discussion

Weight loss during postharvest storage is mainly due to transpiration by the diffusion of water from the peel surface to the environment and is one of the main factors that may results in softening and shriveling, leading to the loss of fruit quality (**Ben-Yehoshua, 1987**). The loss of moisture *via* transpiration and respiration occurs rapidly after harvest, promoting fruit decay **(Chalutz et al., 1989; Purvis, 1983)**. The effect of H_2O_2 on reducing weight loss may be due to reduced respiration rate during storage **(Du et al., 2007)** and retarding the fruit ripening and induced stomatal closing of guard cells **(Desikan et al., 2004).**

Similar findings were observed by **Singh and Reddy (2006)** who reported that the oranges weight and juice percentage losses were higher after 17 days of storage at ambient conditions (58% RH and 28ºC) than the initial time of storage. Similarly, **Mohamed et al. (2016)** reported that treated 'Valencia' oranges with 10 mM plus 10 mM OA or 2% H_2O_2 decreased loss juice content and fruit firmness. In the present study, oxalic acid showed a partial increase in juice percentage compared to the control. In the same way, **Razavi et al. (2017)** showed that treated peach fruit with oxalic acid exhibited a significantly higher juice percentage. Moreover, **Yongdong et al. (2019)** found that mean juice losses significantly differ from green stage to yellow stage and increased significantly with the extension of cold storage periods. In contrast to this, **Mohamed et al. (2016)** found that treated 'Valencia' oranges with 10 mM OA or 2% H_2O_2 increased juice contents of soluble solids content (SSC) and SSC/TA ratio during cold storage period followed by shelf life. While **Shehata et al. (2021)** revealed that H_2O_2 treatment resulted in significant decrease in tomato TSS and juice pH. This could be due to synthesizing acids (malic and ascorbic acids which are major determinants of pH) which may be responsible for the increment of the pH levels observed **(Cepeda et al, 1993).**

Our findings are in contrary with those obtained by **Obenland et al. (2011)** who reported that cold storage reduced losses of mandarins' fruit continually increased TSS as well as TSS/acid ratio. The reduction in TA with prolonging shelf life period might be due to the degradation of citric acid during storage or their conversion into sugars and further utilization in metabolic process in the fruit **(Rathore et al., 2007).**

Our findings are in the same way as those obtained by **Obenland et al. (2011)** reported that cold storage reduced losses of mandarin's fruit decreased titratable acidity. Also, they mentioned that cold storage reduced losses of mandarins slowed down enzyme activities which resulted in delaying declining of vitamin C contents. **Yongdong et al. (2019)** confirmed that vitamin C content in the Eureka lemon fruit juice of cold stored fruit was not significantly affected by cold storage periods.

Oranges under all treatments showed no significant differences in ascorbic acid content compared to the control one. In the previous studies, it was recorded that H_2O_2 treatment detected highly ascorbic acid content compared to the control during storage (**Bayoumi, 2008** in pepper fruits; **Mohamed et al., 2016**; in Valencia oranges; **Shehata et al., 2021** in tomatoes). In contrast, **AL-Saikhan and Shalaby (2019)** showed that H_2O_2 treatment had no significant effect on ascorbic acid content compared with differences treatments.

Valencia oranges customary values were deteriorated by prolonging shelf life period, and postharvest application of H_2O_2 and Frankincense proved efficiency in maintaining Valencia oranges during shelf life. H_2O_2 and Frankincense treatments have detected the best results by maintaining the Valencia oranges fresh weight the juice content, maintained TA value and reduced the maturity index (TSS/TA value). The results revealed that postharvest application of H_2O_2 (1%) and Frankincense (5%) can be as an eco-friendly and safe components and as excellent antibacterial and antifungal activity making them suitable for potential use in the preservation of Valencia oranges and maintaining fruit's physiological and physio-biochemical attributes during shelf life. The effect of these treatments, singly or in combination, on the physiological and biochemical attributes of Valencia orange fruits ambient room conditions (25± 2°C & 85% RH) is recommended.

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