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Jojoba Oil as a Novel Coating for Exported Valencia Orange Fruit Part 1: The Use of Trans (Isomerized) Jojoba Oil

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Abstract: The first utilization of Trans (Isomerized) Jojoba Oil for coating of Valencia orange fruits (*Citrus sinensis*), as a novel waxing material and an alternative to the usual wax used in citrus packinghouses for export fruits was studied. Trans Jojoba Oil (TJO) was prepared via isomerization of Jojoba Oil under optimized conditions to fulfill the coating properties. Hand coated fruits were stored at 5°C up to 60 days before transferred to 20°C for one week as shelf-life period. Waxed orange fruits were compared with untreated ones (control) and also those treated with Exported wax (E. wax) as a simulation of commercial wax. Fruit quality characteristics (weight loss, decay percentages, respiration rate, ssc, acidity and ascorbic acid content) were evaluated periodically at removal from cold storage and after holding at 20°C. TJO treatments were markedly reduced the weight loss and respiration rate than that of control fruits. Whereas, Equal significant values of E-wax treatment and the highest TJO concentration (30%) were observed. Moreover, coated fruit stored for two months at 5°C withstand free from microbial pathogenic incidence, but with softening symptoms ranged between 3.49-5.36% with inversely proportional to the isomerized Jojoba concentrations. Although, SSC showed insignificant differences due to TJO treatments throughout storage period, titratable acid content showed lower decrease percent as TJO concentrations increased, but with a slight increase than its initial content at harvest. Ascorbic acid (Vit. C) content had significant decrease by expanding cold storage period with slight loss in fruits coated with highly concentrations of isomerized jojoba wax. In conclusion, data indicated that 20-30% of Trans Jojoba Oil concentrations proved to be the most capable treatments in maintaining Valencia orange fruit quality up to 60 days storage at 5°C. Moreover, TJO was found efficient enough for coating fruits equal to the export wax and more promising than any other coating materials.

Key words: Valencia orange · jojoba oil · isomerized (Trans) jojoba oil · coating · cold storage · fruit quality · simulation handling

INTRODUCTION

In fruit handling process in the packinghouses, the natural waxes in skin fruit are removed. It is imperative that these natural protectants are replaced by different coatings. Citrus fruit are commonly waxed to give the fruit a shiny, attractive appearance and excellent barrier properties [1-3]. Fruit coatings are used commercially to improve outward appearance; fruit coating and protective film treatments also modify the internal atmosphere of fruit and, as much, have great potential as shelf life extending treatments for apples and other fruits [4-6].

Wax coatings have been shown to extend postharvest quality of fruit and vegetable crops by limiting gas exchange and reducing water loss, skin discoloration, fruit deterioration and should not cause partial anaerobic conditions [7-9]. Since, most waxes used in fruit coating are mainly waxes belong to the non-polar lipid classes and prevent the molecule spreading. It is objective to use other forms of waxes such as Jojoba Oil, which modified via isomerization to produce Trans Jojoba Wax [10-12].

As far as we know, waxing of Valencia orange fruit with Trans Jojoba Oil (TJO) has not been utilized for such

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citrus fruits. It is considered as a novel waxing material for the Valencia orange fruits in citrus packinghouses for export, as an alternative to the usual wax coatings, Trans Jojoba Oil (Isomerized) can be used in this respect [2, 12-14]. Converting the double bonds of Jojoba Oil, which is commonly known as liquid wax, from cis to trans diastereomers produces a soft wax with a low melting point. The results of the oxidation stability of the oil indicate excellent stability [16]. The Trans-Isomerized oil and other Jojoba oil derivatives have a wide range of industrial uses [6, 15-17].

The present study focuses on the evaluation of the influence of Trans Jojoba Oil (TJO) concentrations as conventional coating wax in maintaining Valencia orange fruit quality during cold storage and shelf-life period as a simulation of handling and shipment of citrus fruits for export.

MATERIALS AND METHODS

Fruit: Valencia orange fruit (*Citrus sinensis*) were obtained from a private orchard (Dina) in Cairo-Alex road district, Giza Governorate. Fruits were picked from 15 years old trees grown in sand-loam soil and were similar in growth and received common horticulture practices. Mature orange fruits, undamaged, free from apparent pathogen infection, uniform in shape, weight and color, were harvested at the mid of May of 2003, 2004 and 2005 in the full color stage and average weight of 224.3 gm and transported to the laboratory. The initial quality measurements were determined.

Fatty acids and alcohols composition of jojoba oil: The fatty acids and alcohols compositions of jojoba oil (unpublished data) were carried out as follows: the oil was firstly saponified and subsequently acidified, to liberate the free fatty acids, followed by methylation of the product [18]. The methylated product as well as the alcohols fraction was separately subjected to capillary GLC analysis.

Transformation of jojoba oil to trans (Isomerized) oil (TJO): Jojoba oil (Iodine value, 85; saponification value, 93 and acid value, 0.2) was obtained from Egyptian Company for natural oils. The cis unsaturated fatty acids of the oil were functionalized at the bond region to trans-fatty acids. This isomerization acquires the fatty acids solid waxy properties. Among the different methods published for isomerization, Arnon method [15] was selected for transformation of liquid jojoba oil into solid state as follows:

A solution of 500 gm oil in 500 ml petroleum ether (60-80°C) and 50 ml of 2 M $NaNO_2$ was heated until reflux and then 16 ml of 6 M HNO_3 was added by drops within 5 min after which heating was continued for 15-20 min. The hot solution was immediately transferred to a separatory funnel and was washed with hot water (50°C, 5×50 ml) until pH 7 was reached. The solvent was evaporated and the residue was left in a beaker to solidify. The melting point of the product was determined. The conversion of cis-fatty acids of Jojoba oil to trans-fatty acids was followed by Infra-red spectrophotometry (IR) since the trans fatty acids have a strong characteristic absorption in the infrared region of the spectrum at 10.36 microns, while the cis forms of these acids do not have a comparable absorption in this area [15]. The product was subjected to IR analysis to prove the transformation of cis double bonds to trans.

Fruit coating treatments: Coating of the selected Valencia orange fruits was carried out with TJO at the concentrations of (5, 10, 15, 20, 25 and 30%) admixed with Jojoba oil. Thus, the molten TJO and the hot JO (60°C) were mixed thoroughly before the coating process. The selected fruits, which randomly subjected to the different isomerized Jojoba wax, were hand coated (0.4 ml per fruit) at 25±1°C and subsequently air dried.

The coated orange fruits were compared with commercial export wax (E-wax) and also with uncoated fruits (control). Exported wax which used in citrus packinghouses was obtained from Egyptian company for mechanical and electrical industries. The composition of the Export wax in the form of water emulsion, posses 22% solids materials was contained (shellac, kalaphonia, polyethylene emulsifier and water).

Treated and untreated fruits put in carton boxes (6 kg in two layers of fruits), stored at 5°C±1 and relative humidity 85-90% for 60 days as simulation of export shipment and the initial quality measurements were determined. At 15 days intervals, fruit sample (15 fruits for each treatment) was removed from cold storage to determine fruit quality assessments and shelf life at 20°C and 55-60% RH was examined too.

Fruit quality assessments

Weight loss: Fruits were periodically weighed and the loss in mass weight was recorded for each replicate. Data were calculated as percentage.

Decay percent: Decayed fruits (physiological and microbial decay) were discarded in each sample and decay percent was recorded till the end of experiment.

Respiration rate: Individual fruits for each treatment were weighed and placed in 2-liter jars at 20°C. The jars were sealed for 3 h with a cap and a rubber septum. The resulting O_2 and CO_2 samples of the headspace were removed from the septum with a syringe and injected into Servomex Inst. Model 1450C (Food Pack Gas Analyzer) to measure oxygen and carbon dioxide production. Respiration rate was calculated as ml CO_2 kg^{-1} h^{-1} [19].

Soluble Solids Content (SSC): Individual Valencia orange fruits were ground in an electric juice extractor for freshly prepared juice. Soluble solids content was measured using a T/C hand refractometer Instrone (Model 10430 Brix-readings 0-30 ranges Bausch and Lomb Co. Calif., USA [20].

Titratable Acidity (TA): Total acidity (expressed as citric acid %) was determined by titrating 5-ml juice with 0.1N sodium hydroxide using phenolphthalein as indicator [20].

Ascorbic acid (Vitamin C): Ascorbic acid content was measured using 2, 5-6 dichlorophenol indophenols' method described by A.O.A.C. [20].

Experimental design and statistical analysis: The design for this experiment was a Completely Randomized Design (CRD) with three replications. Data were analyzed with the Analysis of Variance (ANOVA) procedure of MSTAT-C program. When significant differences were detected, treatment means were compared by LSD range test at the 5% level of probability in the three investigated seasons [21].

RESULTS

The transformation of jojoba oil to trans solid waxy material via isomerization by Arnon method [15] gave a good yield (40%) and the product has melting point of 45°C. The formation of trans double bonds was proved by IR spectroscopy (Fig. 1).

IR absorption of the product shows a strong absorption at 10.36 microns, which is characteristic to trans-isomers, indicating the transformation of cis-fatty acids into trans-fatty acids. The GLC analysis of original Jojoba oil (unpublished data) showed the presence of $C_{20:1}$, $C_{18:2}$ and $C_{18:1}$ (eicosaenoic acid, linoleic acid and oleic acid respectively) with long chain fatty alcohols (eicosenol, C_{20} and docosenol, C_{22}).

Fruit quality evaluation

Weight loss percent: Weight loss mainly consists of losses of water through transpiration and carbon gas exchange. Fruit weight loss was directly proportional to the storage period, as shown in (Table 1). The average weight loss percentage of Valencia orange significantly increased gradually with extending storage period up to 60 days at 5°C as well as after holding at 20°C for 7 days (shelf-life).

Although, Trans Jojoba Oil (TJO) treatments caused lower significant weight loss than control fruits, the percentage of weight loss decreased as the concentration of TJO increased (Table 1). After two months of storage at 5°C, the most pronounced loss (5.41%) was recorded in Valencia fruits coated with 30% TJO compared with uncoated fruits (control, 8.73%) and was significantly

Table 1: Weight loss percent of Valencia orange fruits coated after harvest with different concentrations of Trans Jojoba oil coatings (TJOCs) and stored at 5°C for 60 days and kept at 20°C for 7 days (shelf-life)

	4 weeks at 5°C		8 weeks at 5°C	
Trans Jojoba Oil Coatings (TJOCs)	At transfer	7 days at 20°C	At transfer	7 days at 20°C
TJO 5%	4.42b±0.042	0.71f±0.015	8.03b±0.070	1.33ij±0.017
TJO 10%	4.20c±0.038	0.65fg±0.023	7.64c±0.061	1.28ij±0.021
TJO 15%	4.13c±0.053	0.60fgh±0.015	7.09d±0.056	1.23jk±0.012
TJO 20%	4.07c±0.023	0.53gh±0.017	6.24e±0.046	1.15k±0.010
TJO 25%	3.71d±0.045	0.50h±0.012	5.83f±0.068	1.12k±0.017
TJO 30%	3.66d±0.066	0.47h±0.015	5.51h±0.061	1.08k±0.012
E-wax	3.61d±0.029	0.58fgh±0.023	5.58g±0.049	1.14k±0.010
Control	4.73a±0.147	0.89e±0.012	8.73a±0.066	1.38i±0.015
LSD at 0.05 of storage (S)	0.049		0.046	
LSD at 0.05 of Coatings (C)	0.098		0.091	
LSD at 0.05 (S×C)	0.139		0.129	

Data are means of three replicates of 5 fruits each. (Average of three seasons)

Table 2: Decay percentage of Valencia orange fruits coated after harvest with different concentrations of Trans Jojoba oil coatings (TJOCs) and stored at 5°C for 60 days and kept at 20°C for 7 days (shelf-life)

	4 weeks at 5°C		8 weeks at 5°C	
Trans Jojoba Oil Coatings (TJOCs)	At transfer	7 days at 20°C	At transfer	7 days at 20°C
TJO 5%	1.29i±0.017	1.79i±0.021	5.36b±0.044	7.58b±0.021
TJO 10%	1.13j±0.015	1.68j±0.027	4.88c±0.061	6.89c±0.020
TJO 15%	0.92k±0.017	1.44k±0.015	4.26d±0.040	5.98d±0.025
TJO 20%	0.84l±0.012	1.38l±0.017	4.03e±0.023	5.36e±0.020
TJO 25%	0.70m±0.015	1.26m±0.012	3.60f±0.052	5.14f±0.017
TJO 30%	0.66m±0.010	1.18n±0.015	3.49g±0.012	5.00g±0.015
E-wax	0.68m±0.021	1.20n±0.015	3.58f±0.015	5.02g±0.023
Control	1.41h±0.017	1.89h±0.023	5.73a±0.020	7.98a±0.021
LSD at 0.05 of Storage (S)	0.026		0.019	
LSD at 0.05 of Coatings (C)	0.053		0.037	
LSD at 0.05 of (S×C)	0.074		0.053	

Data are means of three replicates of 5 fruits each. (Average of three seasons)

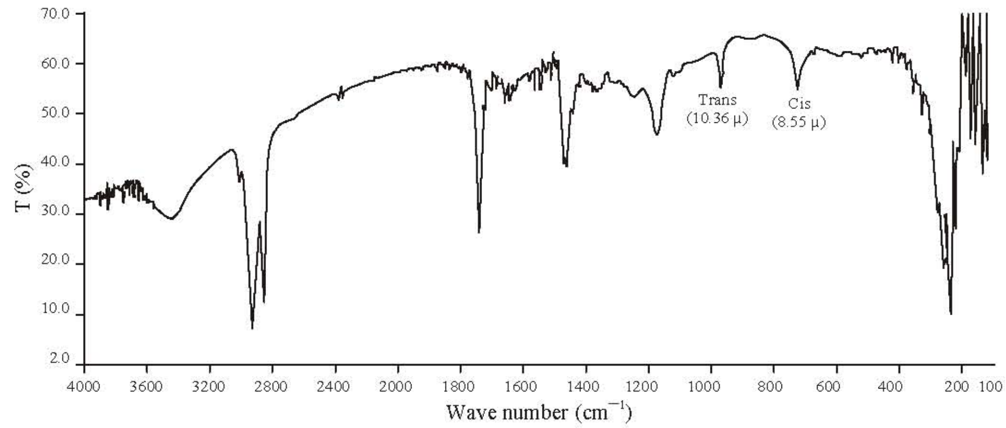

Fig. 1: Infra-red spectroscopy of isomerized jojoba oil

equal to fruits waxed with commercial export wax (5.58%). Further significant increase in weight loss percent was noticed after fruits kept at 20°C for one week (marketability).

It can be concluded that, the same trend of weight loss was obtained with approximately loss in weight by sixth percent than weight loss after cold storage whether at one or two months in all coated and control fruits.

Decay percent: Valencia orange fruits coated with all concentrations of TJO-coatings and also control fruits withstand free from pathogenic rots or microbial fruit deterioration during cold storage up to 60 days at 5°C. It can be stated that the average decay percent shown in (Table 2) recorded the percentage of softening mere incidence or breakdown, either during storage or marketing life at 20°C for one week. Table 2 revealed that decay percent in Valencia orange, as softening symptoms, significantly increased as TJO-coatings concentrations decreased during cold storage at 5°C as well as after shelf-life at 20°C for one week.

Fruits waxed with TJO at 30% had the least deterioration percent (o.66 and 3.49%) followed with that treated with Export wax (E wax) and 25% TJO (0.68, 3.58 and 0.70, 3.60%) respectively, compared with unwaxed fruit (control) showed the highest percent (1.41and 5.73%) after the two periods of cold storage (4 and 8 weeks) throughout the successive seasons of study.

On the other side, shelf-life as marketability indicator was inspected after kept Valencia orange fruit for 7 days at 20°C after removal from cold storage. It can be concluded that, the same trend of decay percentage was found significant in all TJO treatments and control ones. Meanwhile, it can be concluded that the softening incidence through shelf-life period increased by 1.4% than decay percent during cold storage either one nor two months in all coated and control fruits.

Respiration rate: It can be seen from (Fig. 2) that there was a noticeable significant increase in respiration rate of coated Valencia orange fruits reaching a peak value after 4 weeks. Subsequently, the decrease after 8 weeks of cold

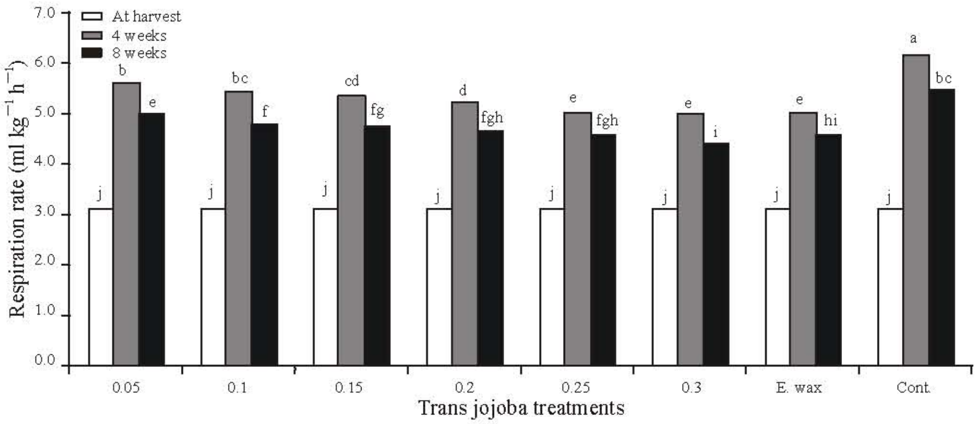

Fig. 2: Respiration rate of valencia orange fruits coated after harvest with different concentrations of Trans Jojoba Oil (TJOCs) and stored at 5°C for 60 days. Values are the means of 3 replicates of 5 fruits each. The letters represents LSD at 0.05 level

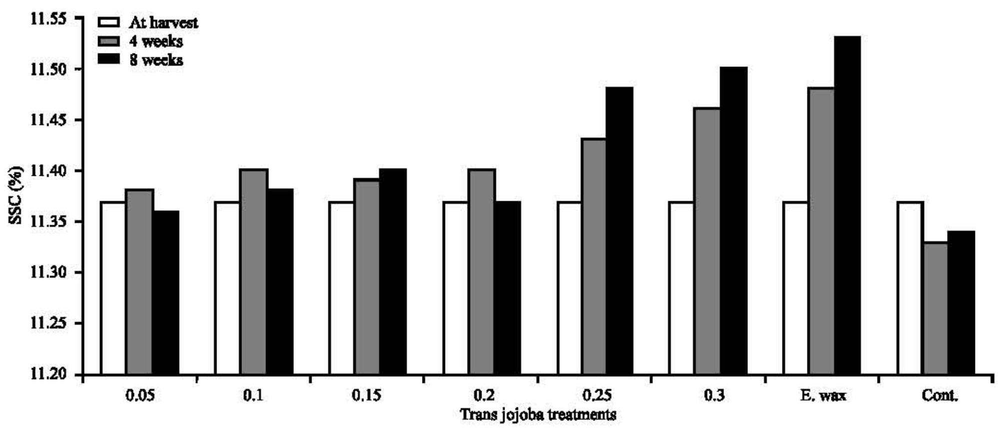

Fig. 3: Soluble solids content (SSC) of valencia orange fruits coated after harvest with different concentrations of Trans Jojoba Oil (TJOCs) and stored at 5°C for 60 days. Values are the means of 3 replicates of 5 fruits each. The letters represents LSD at 0.05 level

storage at 5°C was slight during the three seasons of investigation. The high coating concentrations of TJO tended to have the effective role in reducing the rate of respiration of orange fruits than control ones as well as in export wax treatment.

Although, fruits waxed with 25% TJO showed equal respiration rate with export wax treatment (5.03, 4.58 and 5.03, 4.55 ml kg^{-1} h^{-1}) respectively. The Trans Jojoba Oil treatment at 30% showed the least rate of respiration (4.98, 4.43 ml kg^{-1}hr^{-1}) after one and two months respectively. Control fruits had the highest respiration rate (6.17 and 5.51 ml kg^{-1} h^{-1}) compared with the initial value of (3.11 ml kg^{-1} h^{-1}) at harvest.

These results indicated that beneficial effect of TJO treatments on the reduction of respiration rate was maintaining Valencia orange fruit quality and expanding their storage duration and marketable life.

Soluble Solids Content (SSC %): According to Fig. 3, it is clear that soluble solids content (SSC) of Valencia orange fruit was not affected significantly either by Trans Jojoba Oil coatings or cold storage duration. However, it was noticed that, there was no clear change in SSC content in isomerized jojoba treated fruits throughout the period of cold storage at 5°C, in comparison with the initial SSC value at harvest (11.37%).

At the end of the storage, the highest soluble solids content (11.53%) was obtained in fruits coated with exported wax (E wax), followed with fruits coated with 30 and 25% TJO which exhibited equal SSC values (11.50 and

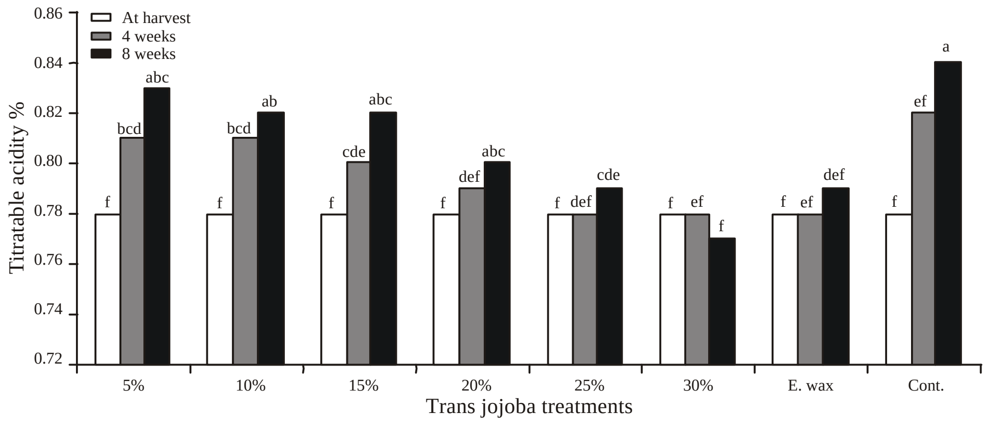

Fig. 4: Titratable acidity (as citric acid%) of valencia orange fruits coated after harvest with different concentrations of Trans Jojoba Oil (TJOCs) and stored at 5°C for 60 days. Values are the means of 3 replicates of 5 fruits each. The letters represents LSD at 0.05 level

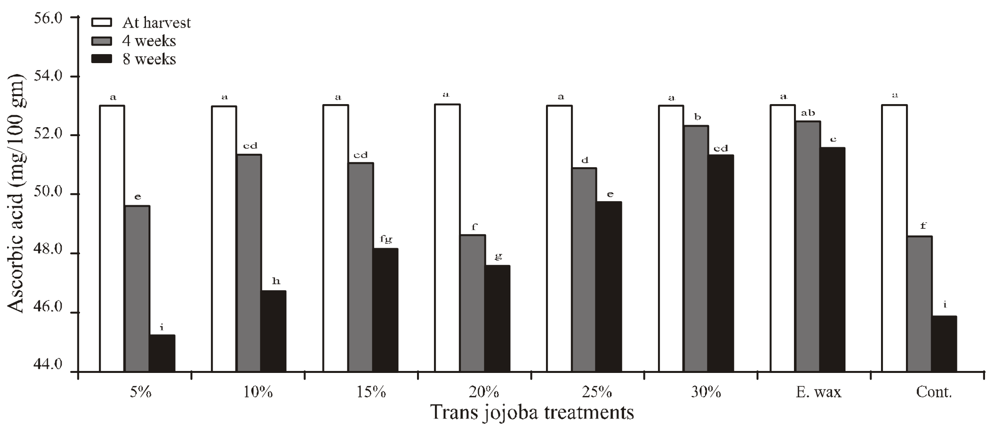

Fig. 5: Ascorbic acid content of valencia orange fruits coated after harvest with different concentrations of Trans Jojoba Oil (TJOCs) and stored at 5°C for 60 days. Values are the means of 3 replicates of 5 fruits each. The letters represents LSD at 0.05 level

11.48%) respectively. Whereas, control fruits had the least significant value (11.34%) with respect to all treatments under investigation.

Titratable Acidity (TA %): Concerning the changes of titratable acidity (TA) of Valencia orange fruits due to the coatings of TJO and cold storage treatments, (Fig. 4), there was a slight significant increase in fruit acid content as the storage period progresses, however, it decreased with increasing Trans Jojoba Oil concentrations.

At the end of the storage period, control fruits showed the highest significant titratable acidity content (0.84%) compared with its initial value at harvest (0.78%) The lowest acid value (0.77%) was recorded in fruits previously waxed with 30% TJO. Meanwhile, both Exported wax (E wax) and 25% TJO coated fruits had equal acid content (0.79%) at the 8th week storage at 5°C of the three successive seasons.

Ascorbic acid content: Ascorbic acid content (Vitamin C) of Valencia orange fruit showed a progressive and significant decrease due to coatings with isomerized Jojoba wax under cold storage period including control fruits (Fig. 5).

After 8 weeks of cold storage at 5°C, it is remarkable to conclude that, uncoated fruits (control) lost 13.50% of its vitamin C content compared with 3.35% in the content of orange fruit coated with 30% Trans Jojoba Oil. The same trend was observed at shelf-life period, when treated orange fruits are transferred from cold storage at

5°C and kept at 20°C for one week. The differences between treatments, storage period and their interaction were significant.

DISCUSSION

In the present study, the first applications of Trans Jojoba Oil (TJO) coatings, maintained the quality of Valencia orange fruits up to 8 weeks storage at 5°C. Respiration rate were indicative of significant increase rate till the peak value (4 weeks), followed by reduction trend during the second month of cold storage relative to TJO treatments. The Application of Jojoba-based waxes significantly reduced internal O_2 levels and increased internal CO_2 and were consistent with the reports of Hagenmaier and baker [7], Ergun *et al.* [9] and Petracek *et al*. [22]. They found that there was no relationship between the gas permeability of the coatings and the concentration of oxygen and carbon dioxide inside the fruits. These findings indicate that the O_2 and CO_2 gases do not leave the fruits according to their permeability values but that there is apparently another pathway through which the passages of the gases take place. Moreover, Mannheim and Soffer [5] and Hagenmaier and Shaw [14] claim that there are two pathways for gas exchange: (1) the coatings forms an additional barrier on the peel through which the gas must be permit or (2) the coatings plug openings in the peel [5]. In addition, Saftner *et al.* [23] explain these findings that the coatings were additionally inhibiting the out migration of ethylene and possibly other volatile from the fruit. During storage at 20°C, fruits produced high amounts of CO_2 but with lower values in TJO coating treatments than uncoated fruits which are inconformity with that reported by Ergun *et al.* [9] and Petracek *et al.* [22].

Regarding the effectiveness of TJO treatments in reducing fresh weight loss percent and maintaining good visual appearance in Valencia orange fruits (either at storage at 5°C or marketable period at 20°C), were similar (Table 1). This was reported for citrus fruits by Hagenmaier and Shaw [2], Ergun *et al.* [9], Saftner *et al.* [23]and Parat *et al.* [24] on mamy sapote fruits and ‘Gala’ apples. In almost all cases, waxed commodities lost weight more slowly than unwaxed controls. In fact, weight reduction has been recommended as a criterion of good waxing [14]. However, it would go too far to recommend by Hagenmaier and Shaw [14] that the permeability for citrus coatings, as barriers should be low for water vapor to reduce transpiration as much as possible. Moreover, the use of wax-based coatings treatment in refrigerated air storage, as potential alternatives to CA storage, offered a potential extension of storage life in apples [23] and Grapefruit [11, 22] over air storage. In contrast to gas exchange, the resistance of peel to water vapor transport is more dependent on the coating thickness than on the type of coatings [5].

Decay was mentioned as one of the limiting factors for postharvest life of citrus fruit because of removing the natural wax of citrus peel through the handling in packinghouses [6, 22]. There are two major problems limit the long-term storage capability of citrus fruits: the first: is pathological breakdown, leading to decay; the second: is physiological breakdown, resulting in the appearance of the various rind disorders [24]. In this study, Valencia orange fruits coated with different concentrations of TJO could be stored for 8 weeks at 5°C without pathological breakdown (rots) as shown in (Table 2). While, physiological breakdown as softening appearance ranged between 5.36-3.49% with directly proportional to TJO concentrations. These results of TJO treatments confirmed the previous findings of Huating [6] who observed that the Chilling Injury (CI) percentage score higher than 5% will indicate that the fruit’s appearance is damaged and thus has an impact on the consumer’s purchasing decision. Moreover, Petracek *et al.* [22] suggested that postharvest pitting as physiological disorder can be controlled by improving the gas permeability of applied wax citrus peel barrier. In addition, similar significant trend of decay percentage at 20°C (shelf or marketable life) were noticed in TJO-coated fruits. While, the softening incidence during shelf-life period increased by approximately 1.4% than decay percent through cold storage at 5°C for one or two months (Table 2). Also Huating [6] and Ergun *et al*. [9] suggested that marketable life was extended of waxed fruits due to the appearance of decay and slight fungal decay on fruit surfaces in former treatments compared with unwaxed fruits.

Upon soluble solids (SSC) and titratable acid (TA) content, were not significantly affected either by coatings or cold storage duration (Fig. 3 and 4), which are similar to that reported byBalduin *et al.* [8], Ergun *et al.* [9] and Landaniya and Sonkar [17] on mandarin, mamy sapote fruits and mango, respectively. Bums and Echeverria [25] reported that wax application had no effect on acidity (%) and brix level of stored ‘Valencia’ fruits. Although TA showed a slight increase throughout storage period, the highest TJO concentration (30%) had the lowest acid value relative to waxed and control fruits.

In all cases investigated, a significant decrease of vitamin C could be observed in Valencia orange fruit between the initial value and the Vitamin C content at the end of storage period. Mahrouz *et al.* [26] had the same findings in the waxing treatments of Clementine citrus fruits.

CONCLUSIONS

It can be concluded that, the first utilization of Trans Jojoba Oil (TJO) as Valencia orange fruit coating is promising wax than the other investigated coating materials, especially in the range of 20-30% concentrations. It can be predicted that TJO coating's resistance to gas exchange is strongly influenced its ability either by blocking pores on the surface of the fruit or, acting as barriers not only to gases migration to restrict respiration, but also to water vapor transfer reducing transpiration and weight loss. Finally, TJO wax can use successfully without any additives as coating product from natural source. It is substitute or alternative to commercial wax used in handling citrus fruit for export. Valencia orange fruit coated with TJO stored in a good quality up to 8 weeks, which was enough period for sea or land shipment for exported citrus fruit.

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