American-Eurasian J. Agric. & Environ. Sci., 2 (3): 261-267, 2007
ISSN 1818-6769

Jojoba Oil as a Novel Coating for Exported Valencia Orange Fruit Part 11: the Use of Jojoba Oil Emulsion

Dorria M.M. Ahmed

Department of Pomology, Agriculture and Biological Division,
National Research Center, Dokki, Giza, Cairo, Egypt

Abstract: Jojoba oil emulsion as a novel coating material of Valencia orange fruits (*Citrus sinensis)* as a simulation in citrus packinghouses for export, was investigated. The emulsions from Jojoba oil, prepared by wax to water method at the concentrations of 5, 10, 15, 20, 25 and 30%, were applied. Hand coated fruits were stored at 5°C for 60 days and one week at 20°C as a simulation of land and sea shipment and shelf-life. Coated orange fruits were compared with untreated ones (control) and also those treated with Exported wax (E.-wax) which was used commercially. Fruit quality characteristics (weight loss, decay percentages, respiration rate, ssc, acidity, ssc/acid ratio and ascorbic acid content) were evaluated periodically at removal from cold storage and after holding at 20°C. Jojoba oil emulsions lowered weight loss percent of Valencia orange fruits than that uncoated ones at 5°C, but with further decline weight at 20°C. Also, a noticeable significant decrease in respiration rate was observed with inversely proportional to JOE concentrations increase. Although, orange fruits withstand free from microbial decay as rot symptoms for 60 days of storage either at 5°C or 20°C, whereas, the incidence of breakdown (softening) of coated fruits (at the range of 15-30% of JOE) had lower percent relative to uncoated fruits. Soluble solids content of Valencia orange fruits increased significantly at higher emulsions JOE concentrations (20-30%), meanwhile, titratable acidity showed the opposite trend. Ascorbic acid (Vitamin C) content had significant decrease by expanding storage period with slight loss in fruits coated with highly concentrations of Jojoba oil emulsion coatings. In conclusion, the use of Jojoba oil emulsion-coatings at higher concentration (15-30%), proved to be the most capable treatments in keeping Valencia orange fruit quality for two months of storage at 5°C. This storage duration is enough periods required for land and sea shipment of exported orange fruits.

Key words: Valencia orange · coating · jojoba oil emulsion · emulsifier · cold storage · fruit quality · simulation shipment · shelf-life

INTRODUCTION

Fresh citrus have traditionally been coated with waxes to maintain fruit quality during cold storage or refrigerated shipment, by improving appearance, gloss and function as barriers to water vapor, gases, volatile, ethylene transmission [1, 2]. In addition, postharvest handling has greatly changed with the use of water-soluble wax instead of the petroleum-based wax previously used in the 1980s. [3, 4]. Surface coatings can create different levels of internal atmosphere modification depending on the chemical nature, concentration and thickness of surface cover [5, 6].

Several authors used waxes as emulsion and microemulsions in fruit-coating [7]. The formulae of edible wax coatings were made by microemulsions composed of water, fatty acids, ammonia and various combinations of many waxes [8, 9]. Meanwhile, wax microemulsions used as fruit coatings generally contain morpholine, an ingredient permitted by the U.S. Food and Drug Administration (FDA).The edible coatings are applied to the surface of fresh fruits and vegetables for its protection [10]. Moreover, the application of wax to fruit as microemulsions makes it possible to apply a very thin coating to fruits in which molten wax may not be appropriate [7, 8, 11].

Corresponding Author: Dr. Dorria M.M. Ahmed, Department of Pomology, Agriculture and Biological Division, National Research Center, Dokki, Giza, Cairo, Egypt

It is noteworthy that the use of Jojoba oil has not been used as fruit coating. Jojoba oil is commonly known as liquid wax, colorless and odorless with unique physical and chemical properties. The objective of this study was to define clearly the effect of emulsified Jojoba oil as fruit coatings on maintaining quality of Valencia orange fruit during cold storage and shelf-life

MATERIALS AND METHODS

Fruit: Valencia orange fruits (*Citrus sinensis*) were obtained from a private orchard (Dina), Giza Governorate. Orange trees were 15 years old grown in new lands of sand-loam soil, cultivated in 5 x 5 meters 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 as shown in (Table 1).

Jojoba oil emulsion for coatings: Jojoba oil (Iodine value, 85; saponification value, 93 and acid value, 0.2) was obtained from Egyptian Company for natural oils. The emulsions from jojoba oil were prepared by wax to water method. It is required that water was added to the jojoba oil according to Hagenmaier and Baker [1]. Typically, 5, 10, 15, 20, 25 and 30 ml of liquid Jojoba oil were used for the preparation of different concentrations of Jojoba Oil Emulsion (JOE). Tween 80 as emulsifier material was used in this investigation. A stock solution of Tween 80 was prepared by adding 90 ml of water to 10 ml of Tween 80 to introduce Tween 80 emulsifier at the concentration of 1%. Emulsions of Jojoba oil were prepared by adding the stock solution of Tween 80 to the above mentioned concentrations of Jojoba oil at variable amounts, so that the emulsion was stabilized. Afterthat, the mixtures were completed with water to 100 ml to obtain Jojoba oil emulsion-coatings (JOECs) concentrations of 5, 10, 15, 20, 25 and 30% (v/v). It is worthy to mention that the amount of Tween 80 solution is proportionally increased with Jojoba oil concentrations within the range of 4-12 ml. Emulsions at different concentrations were mixed thoroughly with vortex stirrer before fruit coatings. The stirred Jojoba mixtures (Jojoba oil emulsions) were stored in a closed dark container and were ready for the coating application.

Table 1: Valencia orange fruit characteristics at harvest (average of three seasons)

Fruit quality characteristics at harvest				
Respiration rate ($ml/kg^{-1}hr^{-1}$)	Soluble solids content %	Titratable acidity %	SSC/TA ratio	Vitamin C (mg/100g)
3.11 ± 0.02	11.37 ± 0.14	0.78 ± 0.01	14.64 ± 0.15	46.53 ± 0.89

Fruit Coating Treatments: At the day of harvest, the selected Valencia orange fruits were washed with rotating polyethylene brushes, using only tap water with citrus washer (Tew packaging line). Coating of the selected fruits was carried out with JOE at the concentrations of (5, 10, 15, 20, 25 and 30%). Thus, the JOE mixtures were stirred thoroughly again before the coating process.

Fruits randomly subjected to the different emulsions of Jojoba oil, were hand coated (0.4 ml per fruit) with a paint pad brush at 25±1°C. The coated orange fruits were compared with commercial exported wax (E.-wax) and also with uncoated fruits (control). Export wax which used in citrus packinghouses was obtained from Egyptian company for mechanical & electrical industries. The composition of the Exported wax as water emulsion contained 22% solids materials including shellac, kalaphonia, polyethylene emulsifier and water.

Treated and untreated fruits packed in carton boxes (6 kg in two layers of fruits), were stored at 5°C±1 and relative humidity 85 - 90 % for 60 days as simulation of export shipment. 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 also examined.

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 hr with a cap and a rubber septum. The resulting of O_2 and CO_2 samples of the headspace were taken via septum with a syringe and then 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} hr^{-1} [12].

Soluble Solids Content (SSC): Individual orange fruit was ground in an electric juice extractor for preparing fresh juice. Soluble solids content was measured using a T/C hand refractometer Instrone (Model 10430 Brix-readings 0-30 ranges Bausch & Lomb Co. Calif., USA. [13].

Titratable Acidity (TA): Titratable acidity (expressed as citric acid weight %) was determined by titrating 5-ml juice with 0.1N sodium hydroxide using phenolphthalein as an indicator [13].

Ascorbic acid (Vitamin C): Ascorbic acid content was measured using 2, 5-6 dichlorophenol indophenols' method [13].

Experimental design and statistical analysis: The design for this experiment was a Completely Randomized Design (CRD) with three replicates. 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 of the three investigated seasons [14].

RESULTS AND DISCUSSION

Weight loss and fruit breakdown percentages: The average weight loss percentage of Valencia orange fruits significantly increased as the concentration of Jojoba oil emulsion-coatings (JOECs) decreased during cold storage at 5°C up to 60 days, as well as after shelf-life for 7days at 20°C (Table2).

Utilization of JOE showed lower loss in fruit weight at the concentrations ranged between 15-30% relative to uncoated fruits (control). After 8 weeks of cold storage at 5°C, the highest JOE concentration (30%) showed the lower loss in fruit weight (6.65%) compared with control fruit value (8.73%). Meanwhile, fruits coated with exported wax (E-wax) had the lowest significant weight loss value (5.58%) of all stored orange fruits.

In marketable life at 20°C for 7 days, further significant decline weight was observed in orange fruits. The reduction at shelf-life recorded around 1/5 percent of its value after 60 days of storage at 5°C. The same trend was obtained at the three successive seasons of investigations.

In all coated and uncoated fruits, Valencia orange fruits did not show any microbial decay as rot symptoms either at cold storage at 5°C or shelf-life at 20°C. The incidence of breakdown (softening) of Valencia orange fruits coated especially with higher concentrations of JOE, had lower percentage than uncoated ones as well as at marketable period at 20°C (Table 2). It was found that better results superior to the exported wax was found by obtaining the least fruit deterioration (3.53%) occurred in JOE-coating at the concentration of 30%, followed by (3.58%) in fruits coated with exported wax (E-wax).

Table 2: The influence of Jojoba Oil Emulsion Coatings (JOECs) on weight loss and decay (breakdown) percent of Valencia orange fruits after storage at 5°C for 60 days and 7 days at 20°C (shelf-life)

Jojoba oil emulsion concentrations	Weight loss %		Decay (Breakdown) %	
	60 days storage at 5°C			
	At transfer	Plus 7 days at 20°C	At transfer	Plus 7 days at 20°C
TJO 5 %	11.00a±0.038	2.26i±0.025	7.10e±0.020	9.91a±0.046
TJO 10%	10.21b±0.046	2.04j ±0.031	6.13g±0.015	8.44b±0.027
TJO 15%	8.35d±0.041	1.69k±0.023	5.54j±0.030	7.56d±0.030
TJO 20%	7.96e±0.042	1.48l±0.021	4.84l±0.036	6.73f±0.025
TJO 25%	7.44f±0.045	1.35mn±0.025	4.30m±0.035	5.86h±0.038
TJO 30%	6.65g±0.038	1.26n±0.032	3.53n±0.025	4.98k±0.021
E-wax	5.58h±0.049	1.14o±0.010	3.58n±0.015	5.02k±0.023
Control	8.73c±0.066	1.38lm±0.015	5.73i±0.020	7.98c±0.021
LSD at µ 0.05 of storage (S)		0.037	0.026	
LSD at µ 0.05 of Coatings (C)		0.074	0.053	
LSD at µ 0.05 (S X C)		0.105	0.074	

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

On the other side, the highest breakdown value (7.10%) which was obtained in coated fruits with the least concentration of EJO (5%) after two months of cold storage at 5°C. In addition, during shelf-life period, it can be proved that breakdown percent showed the same trend but with more significant increase than cold storage values (Table 2). The differences between the storage period and JOE-coating concentrations were significant.

Respiration rate: Data illustrated in Figure 1, revealed that there was a noticeable significant decrease in respiration rate of Valencia orange fruits with inversely proportional to the JOE concentrations increase.

In general, all JOE-coatings showed significant lower rate of CO_2 production than control fruits, but was higher rate of fruits coated with commercial exported wax (E-wax). Moreover, the good quality of Valencia orange fruits caused by the least respiration rate was observed in E-wax coating application followed by the highest JOE concentration of 30% (4.09 and 4.23 ml kg^{-1} hr^{-1}) respectively. In addition, uncoated fruits (control) had the

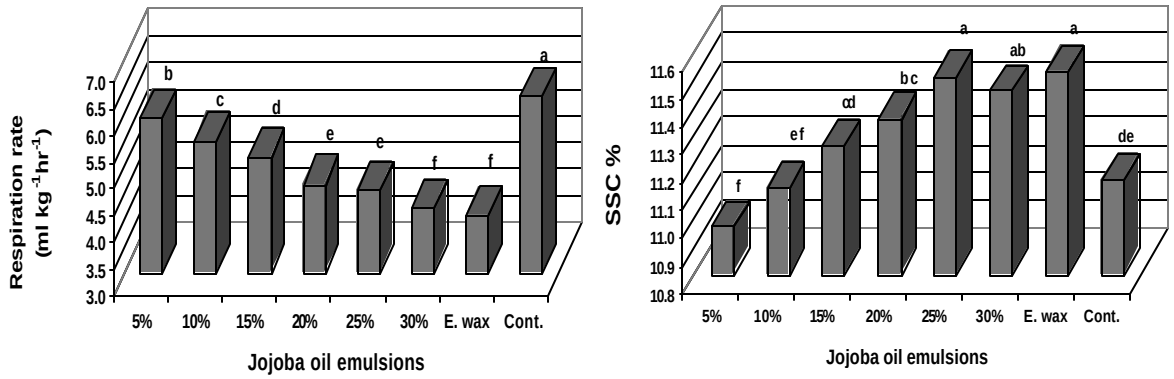

Fig. 1: Respiration rate and soluble solids content of Valencia orange fruits coated after harvest with different concentrations of Jojoba oil emulsions (JOE) and stored at 5°C for 60 days. Values are the means of 3 replicates of 5 fruits each. The letters represents LSD at 0.05 level

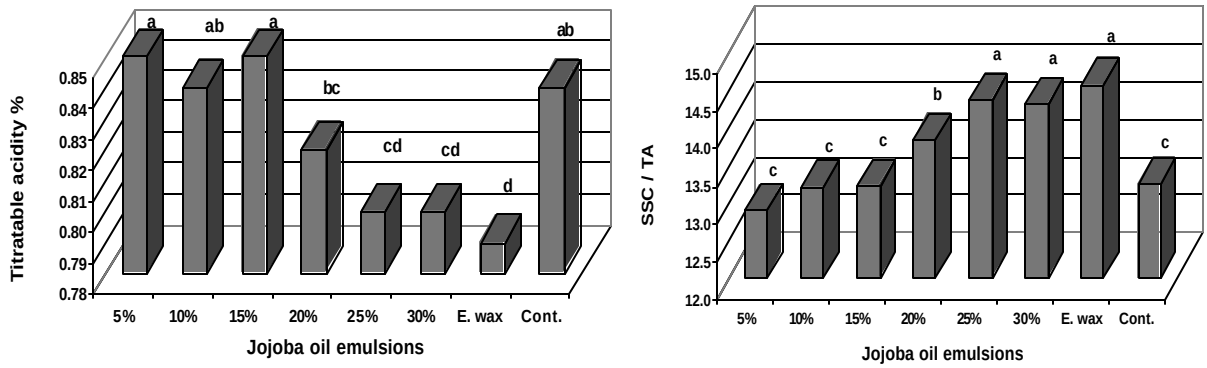

Fig. 2: Titratable acidity and soluble solids /acid ratio of Valencia orange fruits coated after harvest with different concentrations of Jojoba oil emulsions (JOE) and stored at 5°C for 60 days. Values are the means of 3 replicates fruits each. The letters represents LSD at 0.05 level

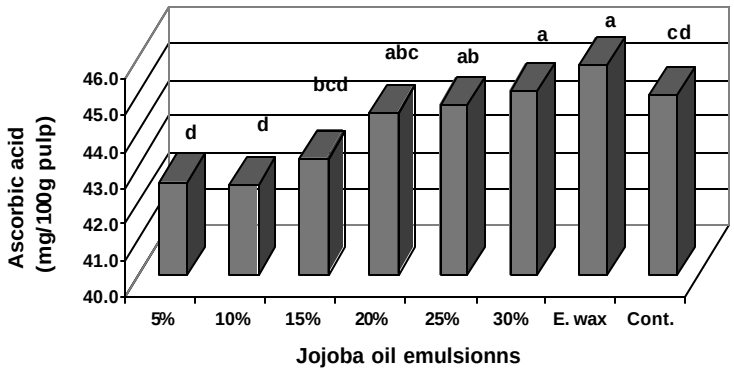

Fig. 3: Ascorbic acid content of Valencia orange fruits coated after harvest with different concentrations of Jojoba oil emulsions (JOE) and stored at 5°C for 60 days. Values are the means of 3 replicates of 5 fruits each. The letters represents LSD at 0.05 level

highest rate of respiration (6.32 ml kg^{-1} hr^{-1}) at 5°C compared with 5% of JOE coating (5.92 ml kg^{-1} hr^{-1} after 60 days).

Soluble solids content: It can be noticed from (Fig.1) that soluble solids content (SSC) of Valencia orange fruit showed a significant increase relative to the coatings of Jojoba oil emulsion concentrations up to 60 days of storage at 5°C, as well as after shelf-life at 20°C. Significant increase in SSC (11.51 and 11.46%) were obtained when using the high concentrations of JOE-coating (25 and 30%) respectively, with comparison to the initial value at harvest (11.37%). Meanwhile, control fruits had significant decline value (11.14%) which approximately equal to that fruits coated with 10% of JOE (11.11%) with insignificant difference.

Titratable acidity: It can be stated from Fig. 2 that Valencia orange fruits coated with Jojoba oil emulsions, revealed significant decrease with inversely proportional to JOE concentrations increase. Moreover, orange fruits coated with exported wax had the least significant acid content (0.79%) after 8 weeks of storage at 5°C. In addition, the highest titratable acid content (0.85%) was obtained in fruits coated with Jojoba oil emulsions at the concentrations of 5 and 15%. It was followed by fruits treated with 10% JOE and control fruits, which they have the same acid values (0.84%).

Soluble solids/acid ratio: At the end of storage period (2 months), the soluble solids/acid ratio (SSC/TA), as the organoleptic test indicator of stored Valencia orange fruit, as a result of Jojoba oil emulsion-coatings, were illustrated in (Fig. 2). SSC/TA ratio were increased as the concentrations of JOE-coatings increased, but with less significant ratio than their value at harvest (14.64%). Moreover, an equal SSC/TA ratio (13.23 and 13.25%) were noticed in fruits coated with JOE at the concentrations of 10 and 15% respectively, with significant difference. Uncoated orange fruits (control) had the same equal ratio (13.26%) after 8 weeks of cold storage at 5°C. After the marketable life at 20°C for 7 days, the same trends were observed throughout the three successive seasons of investigations.

Ascorbic acid content (Vitamin C): Vitamin C content of Valencia orange fruits at harvest was (46.53 mg/100mg). It is clear from Fig. 3 that orange fruits coated with different Jojoba oil emulsion concentrations, showed significant decrease in vitamin C content after 8 weeks of cold storage at 5°C as well as after holding at 20°C compared with its initial value.

Generally, the higher concentrations of Jojoba oil emulsion kept higher vitamin content. Moreover, orange fruit coated with exported wax (E-wax) had the highest vitamin C content, followed by fruits coated with JOE at 30% (45.77 and 45.03 mg/100g pulp) respectively. In addition, the least ascorbic acid content (42.46 mg/100g pulp) was noticed in orange fruits coated with 10% of Jojoba oil emulsion. At the end of storage period, the differences between JOE-coatings concentrations were significant. The shelf-life period for 7 days at 20°C showed the same trend, with slight changes.

DISCUSSION

The novel utilization of Jojoba oil emulsion as Valencia fruit coating had different proportional contributions to fruit quality characteristics throughout cold storage at 5°C for two months which is enough for sea and land shipment of orange fruits. Increasing the concentration of Jojoba oil emulsion resulted in a quadratic increase in the amount of coating deposit left on the fruit surface. These findings were interpreted by Amarante *et al.* [5] and Banks *et al.* [11] to be as a result of increased total solids concentrations and also by possibly increased coating viscosity rather than by reduced coating surface tension. In addition, the authors reported that, diluted coating concentrations caused very small increases in coating deposit on fruit skin.

Similarly, the results in the current study indicated that increasing the emulsion Jojoba oil concentrations showed a more substantial effect of coatings in reducing permeability of gases and water vapor than lower concentrations as supported by Ben-Yehoshua *et al.* [15] and Amarante *et al.* [5]. This led to maintain Valencia coated fruit quality up to 8 weeks of cold storage at 5°C, especially with highly JOE concentrations.

Recent reports on respiration rate have suggested that gases diffuse mainly through pores, while water moves preferentially by a different pathway, probably through a liquid aqueous phase in the cuticle where water conductance is much higher [1, 15]. Also, Banks *et al.* [11] found that the permeability of the coating film is much more important than pore blockage in reducing fruit's water loss and that the modification of fruit internal atmosphere is strongly determined by the proportion of pores blocked by the coating and not by the permeability

of the coating film. In contrast to the two views, Hagenmaier and Baker [8,16] suggested that for both CO_2 and water vapor, the skin permeance of coated fruit was mainly reduced by a coating tendency to seal pores in the fruit peel, besides the resistance of the coating film by itself.

In the present study, Valencia orange fruits coated with different concentrations of Jojoba Oil Emulsion (JOE) showed lower loss in fruit weight and respiration rate at the concentrations ranged between 15-30% in relative to uncoated fruits (Table 2 and Fig. 1). These results were in harmony with those obtained on citrus fruits by Hagenmaier and Baker [1, 7] and Porat *et al.* [17]. They reported that permeability for citrus coatings should be high for O_2, CO_2 and low for water vapor to reduce transpiration as much as possible and not overly restrict respiration. In all cases, it can be concluded that weight loss reduction was indicative to good waxing type. Waxing fruit partially or completely plugs pores, restricting mainly the transport of O_2 and CO_2 and to a less extent, water [5, 18].

With reference to the decay percentage, it was mentioned as a limiting factor for storage life of citrus fruits. The physiological breakdown was the main problem limit the long-term storage capability of Valencia orange fruit used in this investigation [2,20]. Also, Breakdown as softening appearance of coated fruits ranged between 7.10-3.53% with directly proportional to JOE concentrations during storage at 5°C as well as during marketable life at 20°C (Table 2). These results are confirmed with those suggested by Hauting [3] and Ergun *et al.* [18] which they found that Grapefruit handling at the packinghouse reduces fruit resistance to chilling injury because washing influences the fine wax structure of citrus peel. Moreover, Petracek *et al.* [19] and Brown and Miller [4] reported that the effect of waxing on peel disorders is particular interest since subsequent loss of fruit during storage is often substantial. Additionally, the postharvest pitting can be controlled by improving the gas permeability of applied wax citrus peel which caused extending the storage and marketable life.

After two months of cold storage at 5°C as well as at shelf life at 20°C, soluble solids (SSC) were affected slightly either by coatings or cold storage duration (Fig.1). Moreover, titratable acidity (TA) had a slight significant decrease with inversely proportional to EJO concentrations [2, 9]. In addition, SSC/TA ratio were increased as the concentrations of EJO-coatings increased, but with less significant ratio than their value at harvest. The present data are similar to those reported by Landaniya and Sonkar [20] and Ergun *et al.* [18] on mandarin and mamy sapote fruits respectively. Also, Burns and Echeverria [21] and Chien *et al.* [6], found that there is no effect on acidity percent and SSC values of stored 'Valencia' fruit and Murcott tangor citrus fruits due to wax application.

In all JOE coatings studied, 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.* [22] and Chien *et al.* [6] had the same findings after waxing treatments of Clementine and Murcott tangor citrus fruits in this respect.

CONCLUSION

So far, coating of Valencia orange fruit with Jojoba oil emulsion (JOE) has not been utilized for such citrus fruits. It is considered as a new coating material, produced from natural source and suggested as edible and safe wax for fruit coating during postharvest handling in citrus packinghouses for exportation. Generally, the higher concentrations of Jojoba oil emulsion (15-30%) were more effective than lower ones in keeping Valencia orange fruit quality up to 60 days at 5°C as well as at 20°C. Two months of storage is enough period required for land and sea shipment of exported orange fruits.

ACKNOLEDGEMENT

The author acknowledges Dr. M. Hassan El-Mallah and Dr. Safinaz M. El-Shami in the Fats and Oils Department, Food Industry and Nutrition Division, National Research Center, for their help and criticism offered during the preparation of this work. I am also thankful for the financial support from the National Research Center (NRC). Also, I thank the members of Agricultural Development Systems project (ADS) for technical assistance.

REFERENCES

1. Hagenmaier, R.D. and R.A. Baker, 1994. Wax microemulsions and emulsions as citrus coating. J. Agric. Food Chem., 42: 899-902.
2. Kader, A.A. and M.L. Arpaia, 2002. Postharvest handling systems: subtropical fruit In: Kader, A.A. (Ed). Postharvest Technology of Horticultural Crops. Regents of the University of California. Division of Agricultural and Natural Resources, Okland, CA. pp: 375-384.

3. Huating, D., 2004. Effect of Coating Application on Chilling Injury of Grapefruit Cultivars. HortScience, 39: 558-561.
4. Brown, G.E. and W.R. Miller, 1999. Maintaining fruit health after harvest, In:L.W. Timmer and L.W. Duncan (Eds.). Citrus Health Mgt., APS Press, St. Paul. Minn., pp: 175-188.
5. Amarante, C., N.H. Banks and S. Ganesh, 2001. Relationshipbetween character of skin cover of coated pears and permeance to water vapour and gass. Postharvest Biol. Technol., 21: 291-301.
6. Chien, P.J., F. Sheu and H.R. Lin, 2007. Coating citrus (Murcott tangor) fruit with low molecular weight chitosan increases postharvest quality and shelf life. Food Chemist., 3: 1160-1164.
7. Hagenmaier, R.D. and R.A. Baker, 1996. Edible coatings from candelilla wax microemulsions. J. Food Sci., 61: 562-565.
8. Hagenmaier, R.D. and R.A. Baker, 1997. Edible coatings from morpholine-free wax microemulsions. J. Agric. Food Chem., 45: 394-352.
9. Mannheim, C.H. and T. Soffer, 1996. Permeability of different wax coatings and their effect on citrus fruit quality. J. Agric. Food Chem., 44: 919-923.
10. FDA. Code Fed. Regul. 1995. Title 21.
11. Banks, N.H., J.G.M. Cutting and S.E. Nicholson, 1997. Approaches to optimizing surface coatings for fruits. N. Z. J. Crop Hort. Sci., 25: 261-272.
12. Lurie, S. and E. Pesis, 1992. Effect of acetaldehyde and anaerobiosis as post harvest treatment on the quality ofpeaches and nectarines. Postharvest Biol.Technol., 1: 317-326.
13. A.O.A.C., 1990. Official methods of analysis. Association of Official Analytical Chemists., Washington, DC, USA.
14. Snedecor, G.W. and W.G. Cochran, 1980. Statistical Methods. 7th Edn. lowa State Univ. press Ames. Low USA.
15. Ben-Yehoshua, S., S.P. Burg and R. Young, 1985. Resistance of citrus fruit to mass transport of water vapor and other gases. Plant Physiol., 79: 1048-1053.
16. Hagenmaier, R.D. and R.A. Baker, 1993. Reduction in gas exchange of citrus fruit by wax coatings. J. Agric. Food Chem., 41: 283-287.
17. Porat, R., B. Weiss, L. Cohen, A. Daus and N. Aharouni, 2004. Reduction of postharvest rind disorders in citrus fruit by modified atmosphere packaging. Postharvest Biol. Technol., 33: 35-43.
18. Ergun, M., S.A. Sargent, A.J. Fox, J.H. Crane and D.J. Huber, 2005. Ripening and quality responses of mamy sapote fruit to postharvest wax and 1-methylcyclopropane treatments. Postharvest Biol. Technol., 36: 127-134.
19. Petracek, P.D., H. Dou and S. Pao, 1998. The influence of applied waxes on postharvest physiological behavior and pitting of grapefruit. Postharvest Biol. Technol., 14: 99-106
20. Landaniya, M.S. and R.K. Sonkar, 1997. Effect of curing, wax application and packaging on collar breakdown and quality in stored 'Nagpur' mandarin (*Citrus reticulate*). Indian Journal of Agricultural Sciences, 67: 500-503.
21. Burns, J.K. and E. Echeverria, 1990. Quality changes during harvesting and handling of Valencia oranges. Proceedings, Florida State Horticulture Society, 103: 225-228.
22. Mahrouz, M., M. Lacroix; G.D. Aprano, H. Oufedjikh, C. Boubekri and M. Gagnon, 2002. Effect of γ-irradiation combined with washing and waxing treatment on physiochemical properties, vitamin c and organoleptic quality of citrus clemantina. Hort. Ex. Tanaka. J. Agric. Food Chem., 50: 7271-7276.