Middle Eastern and Russian Journal of Plant Science and Biotechnology ©2008 Global Science Books

Comparison of the Influence of Individual Seal-packaging and Tray Wrap on Moisture Loss and Quality of 'Valencia' Orange

Mohammad Reza Safizadeh*

Department of Plant Production, College of Agriculture and Natural Resources, Shiraz University, Darb, Iran

Correspondence: * safizade@shirazu.ac.ir

ABSTRACT

Individual sealing and tray wrap of orange (*Citrus sinensis* (L.) Osbeck cv. 'Valencia') with heat-shrinkable films of low-density polyethylene (LDPE), high-density polyethylene (HDPE), oriented polypropylene (OPP) and polyvinyl chloride (PVC) were held for a period up to 4 months at 5°C and 85-90% RH. Both methods of film-packaging showed little change in the water relations characteristics, while unwrapped orange lost weight and showed a decrease in the water content of the peel throughout the storage period. Levels of water loss for fruit in over-wrapped trays were greater than in individual sealing packages. Regardless of film thickness, two methods of packaging in LDPE, HDPE, OPP and PVC films inhibited fruit weight loss at maximum and minimum amounts, respectively. However, film thickness had less effect on fruit weight loss than chemical composition of the films. Comparison between tray wrap and individual sealing on total acid, °Brix, flavor and incident of decay showed similar trends, and composition of films did not appear to have any deleterious effect on the juice quality factors. So far, it was observed that the tray wrap technique as individual sealing maintained the freshness of fruit.

Keywords: *Citrus sinensis*, cold storage, firmness, heat-shrinkable films, postharvest, wrapping

INTRODUCTION

A major requirement for extending the postharvest life of citrus is to slow down its transpiration (Porat *et al.* 2004; Alferez *et al.* 2005). Among the various techniques which are developed to extend fruit postharvest life, the usage of plastic film is growing very rapidly because it is convenient in many different conditions throughout the chain of handling from producer to consumer (Ben-Yehoshua 2005). Wrapping or sealing individual citrus fruit in shrinkable film reduced transpiration water loss (Cohen *et al.* 1990) the incidence of superficial flavedo necrosis (Ben-Yehoshua *et al.* 2001) delayed normal deterioration and increased the storage and shelf life of the fruit (Ben-Yehoshua *et al.* 1995; Kader and Arpaia 2002) delayed loss of firmness and coloration (Raghav and Gupta 2000) and prevented spoilage of sound fruit by decayed fruit within the same container. However, the percentage decay in seal packaged fruit increased especially in produce stored without refrigeration (Kader 2002).

Packaging fruit in a tray that is wrapped with plastic film has been reported by some workers (Sharkey *et al.* 1985; D'Aquino *et al.* 2001). Economically, the price of an automatic-individual sealing machine is high in many underdeveloped countries, thereby this new technique has not been in common use for the postharvest, handling and storage of fruit and vegetables, and essentially, a simple technique such as tray wrap is required.

The objectives of this study were: (1) to determine whether individual seal-packaging or tray wrap with commonly available films, in combination with cool-storage, would delay deterioration of oranges more effectively than cool-storage alone; (2) to examine storage life of over-wrapped orange and whether it would substitute for individual seal-packaging; (3) to investigate the effects of film composition on the physiological deterioration of over-wrapped and sealed orange.

MATERIALS AND METHODS

Fruit selection and preparation

'Valencia' orange (*Citrus sinensis* (L.) Osbeck), grown on lime rootstocks, were sampled from 7-year-old trees of the Darab region, an important orange production center of Iran. Fruit were randomly picked from 10 trees in mid-February at their optimum maturity stage. Fruit samples of uniform size and appearance after conventional treatment, which included washing, disinfection with sodium orthophenyl phenate (SOPP), and treatment with the fungicide imazalil (0.1%) (Janssen Pharmeceutica, Beerse, Belgium), were subjected to the proposed treatments at random.

Film and film application

Identification and characteristics of the films tested are summarized in **Table 1**.

Table 1 Properties of heat-shrinkable films used in 'Valencia' orange study.

Composition	Film thickness (μm)	Water vapor* Transmission
Low-density polyethylene (LDPE)[W]	22	† 3.25 c
High-density polyethylene (HDPE)[X]	22	5.40 c
Oriented polypropylene (OPP)[Y]	19	17.94 b
Polyvinyl chloride (PVC)[Z]	25	55.a

*g H_2O at 38 °C and 100% RH/m^2-24 hr (†Mean separation among films by Duncan's multiple range test, 5% level)

W,X Films were obtained from Shiraz Naylon Co., Shiraz (local product)

Y Iran Shrink Manufacture, Isfahan (local product)

Z Borden Inc., Borden Chemical Division, Resinite Division, North Andover, Mass, U.S.A.

Individual seal-packaging

Heat-shrinkable polymeric films were applied by inserting individual fruit into film envelopes that were sealed with a hot wire sealer (Model M-101, Polytechnic Khavandy Inc., Shiraz). Films

Received: 24 September, 2008. Accepted: 13 November, 2008.

Original Research Paper

were shrunk onto the fruit by passing them through a heat tunnel (Weldotron model 7121A, Weldotron Corporation, NJ, USA) for 10-15 s at 150-175°C. The short time exposure of the fruit to the high temperature in the heat tunnel did not adversely affect the oranges. Then 12 sealed fruit were packed into each cardboard tray (25 × 35 × 5 cm) (Jonoobgostar Co., Iran).

Tray wrap

Twelve fruit were packed into each cardboard tray and over-wrapped with heat-shrinkable films. Films were shrunk onto the tray and fruit by passing them through a heat tunnel (150 to 175°C). The control consisted of 12 fruit that were shrink-wrapped and passed through the heat tunnel, then stripped of the wrap.

Storage conditions

All trays of fruit were stored at 5°C and 85-90% RH, for 1 to 4 months. Each month, three trays from each treatment were removed from storage and assessed for quality.

Quality assessment

Fruit water relations

The samples were weighed at the beginning of the experiment and at monthly intervals during the course of storage, and the results were expressed as the percentage loss of the initial weight. Fruit firmness was determined with a compression tester modeled after the pressure tester of Ben-Yehoshua *et al.* (1983), using a 1.5 kg weight on its longitudinal axis. Full deformation (mm) was measured 15 sec after exerting the force on the fruit. The firmer the fruit, the lower the reading. Water loss of the peel was determined by drying peel of fruit at 80°C and expressed as the percentage of peel moisture.

Titratable acid

At prescribed times the juice was extracted from individual fruit of each treatment with a small laboratory hand-reamer and analyzed for total acids, soluble solids and flavor.

Titratable acidity was determined by titrating an aliquot of juice against 0.1 N NaOH to pH 8.2 and expressing the result as citric acid.

°Brix

The percentage of total soluble solids was used as an approximation to sugar content. Soluble solids were measured with an Abbe refractometer (American Optical Corp., Buffalo, NY) at 20°C.

Flavor

Triangle taste comparisons were made by ten panelist (6 men and 4 women; aged 18-30) at monthly intervals during the course of storage. The tasters were instructed to discriminate a single sample against identical pair and to rate samples as 4 (very good), 3 (good), 2 (fair) and 1 (bad).

Decay

Microbial source of rots was assessed by a trained microbiologist. Levels of decay were measured after 4 months using all individual of fruits per treatment.

Statistical analysis

Quality assessment of stored fruits was conducted during four consecutive months. Each treatment comprised three replicated boxes (per month), each containing 12 oranges (total of 144 fruit per treatment). Values for all data were averaged over 3 replications and means were subjected to analysis of variance. Duncan's multiple range test with a significance level of $p<0.05$ was performed on all data.

RESULTS

Fruit water relations

Tables 2 and **3** show that in each month and after 4 months of cold storage, sealing individual and tray wrap oranges in polymeric films reduced weight loss significantly, and the control (unwrapped) oranges had the highest weight loss. In general, the loss of weight progressively increased with storage time and was linear for all experimental oranges. Seal-packaging with LDPE reduced weight loss to 90.29% (most effective), and the PVC-tray wrap reduced weight loss to 51.85% (least effective) compared with the control (**Table 3**). In all kinds of polymer films, individually sealed oranges reduced weight loss significantly more than those over-wrapped. No significant differences were found among weight losses of oranges that individually sealed, as well as tray wrapped in HDPE, LDPE and OPP films. However, individual sealed, or tray wrapped oranges with PVC film tended to increase weight loss in comparison with other individual sealing or over-wrapped trays. Both methods of film-packaging reduced deformation and retained peel moisture of fruit as compared with unwrapped fruit. There also was neither apparent effect of film composition nor any apparent difference between two methods of film-packaging on firmness and peel moisture of fruit, except for PVC-packaged fruit, which were softer than other film-packaged fruit (**Table 3**).

The condensation of water droplets (sweating) was prevalent in wrapped trays and wetted the cardboard trays.

Juice quality

There were neither apparent effects of film composition and film thickness nor any apparent differences between individual sealing and over-wrap packaging on total acidity and °Brix. Panelists did not detect any off-flavors in the juice of unwrapped and film-packaged fruit (**Table 4**).

Table 2 Weight loss of 'Valencia' orange that individual sealed or tray wrapped with various heat shrinkable films and stored at 5 °C for 1 to 4 months.

Treatment		Duration (months)			
		1st	2nd	3rd	4th
Control (unwrapped)		3.76 a	6.22 a	10.12 a	13.31 a
LDPE	Ind. sealed	0.43 d	0.62 e	0.77 e	1.43 e
	Tray wrap	1.66 c	2.04 cd	2.12 d	2.74 d
HDPE	Ind. sealed	0.51 d	0.71 e	0.79 e	1.43 e
	Tray wrap	1.38 c	1.54 d	1.85 d	2.95 d
OPP	Ind. sealed	0.42 d	0.68 e	0.91 e	2.01 e
	Tray wrap	1.34 c	1.59 d	1.95 d	2.72 d
PVC	Ind. sealed	1.51 c	2.21 c	2.73 c	5.33 c
	Tray wrap	2.21 b	3.09 b	4.66 b	6.12 b

[x] Mean separation at each month by Duncan's multiple range test, 5% level.

Table 3 Effect of individual sealing or tray wrap with heat-shrinkable films on weight loss (%), reduction in weight loss (%), moisture of peel (%) and firmness (expressed as mm deformation) of 'Valencia' orange stored at 5 °C for 4 months.

Treatment		Weight loss (%)	Reduction in weight loss (%)	Firmness (mm deformation)	Moisture of peel (%)
Control (unwrapped)		8.35 a		3.64 a	76.05 a
LDPE	Ind. sealed	0.81 e	90.29	2.73 d	78.01 a
	Tray wrap	2.14 d	74.37	3.00 cd	77.63 ab
HDPE	Ind. sealed	0.86 e	89.70	2.79 cd	77.12 b
	Tray wrap	1.93 d	76.88	2.95 cd	77.31ab
OPP	Ind. sealed	1.0 1e	87.90	2.83 ed	76.79 b
	Tray wrap	1.90 d	77.24	2.86 cd	77.58 ab
PVC	Ind. sealed	2.94 c	64.79	3.42 ab	77.09 b
	Tray wrap	4.02 b	51.85	3.13 bc	76.86 b

Mean separation in columns by Duncan's multiple range test, 5% level.

Table 4 Effect of individual sealing or tray wrap with heat-shrinkable films on quality of 'Valencia' orange stored at 5 °C for 4 months.

Treatment		Acid (%)	°Brix	Flavor score	Decay incidence (%)
Control (unwrapped)		0.82 ab	8.70 a	3.4 a	0 a
LDPE	Ind. sealed	0.73 b	8.51 a	3.8 a	0.69 a
	Tray wrap	0.75 ab	8.31 a	3.6 a	0 a
HDPE	Ind. sealed	0.79 ab	8.80 a	3.5 a	1.38 a
	Tray wrap	0.84 a	8.25 a	3.5 a	0 a
OPP	Ind. sealed	0.77 ab	8.19 a	3.6 a	0.69 a
	Tray wrap	0.74 ab	8.51 a	3.5 a	0 a
PVC	Ind. sealed	0.83 ab	8.60 a	3.5 a	0 a
	Tray wrap	0.78 ab	8.28 a	3.4 a	2 b

Mean separation in columns by Duncan's multiple range test, 5% level.

Decay

The fruit developed very few blemishes or rots during the course of the experiment. During storage, molds caused by *Penicillium digitatum* and *P. italicum* developed to a small extent (not more than 2%), with no significant difference between film-packages and unwrapped fruit. However, PVC over-wrapped fruit had a greater incidence of rots than other treatments (**Table 4**).

DISCUSSION

This study showed that packaging orange in polymeric films was superior to conventional cold storage in reducing transpiration during storage. All changes in fruit water status; weight loss, firmness deformation, and reduction of peel moisture were greatly reduced by sealing, or by using a tray wrap for oranges in polymeric shrink films. Since transpiration contributes most to the postharvest deterioration of citrus fruit (Alferez *et al.* 2005), more attention has been given to control it rather than respiration. Therefore, two methods of film-packaging benefited oranges from conditions that reduced water loss. High-humidity storage was shown to increase their storage potential (Henriod 2006), and the main effect of polyethlene seal-packaging is to maintain high in-package humidity (Ben-Yehoshua *et al.* 2001). The observation of water droplets in over-wrapped trays is an indication of tray wrap to be also a practical way of treating fruit in a water-saturated atmosphere. However, levels of water loss in fruit in over-wrapped trays were greater than in individual sealing packages, presumably because the cardboard tray in the former absorbed moisture from fruit.

In this study we found that film thickness (ranging from 19 to 25 µm) is of less importance than chemical composition of film in keeping the quality of film-packaged fruit. However, permeability of film to water vapor is probably influenced by chemical composition of the film as well as by film thickness. The weight loss and deformation of fruit packaged with PVC film (25 µm thickness) was higher than other less thick films (19 and 22 µm thickness). Marais *et al.* (2004) demonstrated that the selectivity to water increases with the vinyl acetate (VA) content in the ethylene-co-vinyl acetate (EVA) copolymers and by mixing the glassy PVC polymer with the EVA copolymer a reduction in water and gas selectivity occurred. Evaluation of postharvest changes of *Carambola* slices in three different packages indicated that PVC film did not significantly modify the internal atmosphere and the high water permeability of PVC led to more rapid slice desiccation (Gustavo *et al.* 2007). These observations indicate that PVC film is not selectively impermeable to water. Previous reports (Nur Dirim *et al.* 2004) also considered that polyethylene is the mostly used polymer film for packaging as it offers the advantages of being inert, permeable to oxygen, carbon dioxide, ethylene and comparatively less permeable to water vapour.

The films used in this study did not appear to have any deleterious effect on the juice quality factors determined. O_2 and CO_2 levels were not measured from within the film-packaged fruit because the film seals, made with a hot wire sealer, were not airtight (Miller and McDonald 1989), and so did not appreciably alter these gases of stored fruit (Purvis 1983). It is possible that imperfect seals and minute tears in the film or permeability to gas diffusion of film allowed for adequate gas exchange, and thus off flavors were not produced by the fruit.

Previous studies have indicated that the percentage of decay of citrus fruit was decreased in seal-packaging, because decay is contained within the package, adjacent fruit are not solid with fungus spores and/or decayed tissue (Kader 2002). However, other researchers demonstrated that the disadvantage of film wrapping of citrus may include higher decay rates (Sharkey *et al.* 1985; Rodov *et al.* 2000; Barmore *et al.* 2006). Tray wrap and individual seal-packaging on incidence of decay showed similar trends. Although the main objective of the present study was not to determine the effectiveness of fungicides, our results indicated that disinfection by SOPP and treating fruit with imazalil almost prevented the decay of treatments. It should be noted that the extent of decay of fruit in general and of film-packaged fruit in particular depend on many factors, such as the presence of latent infection, season, fruit type and others (Ben-Yehoshua 2005). The postharvest use of chemicals as fungicides is restricted in most countries. Besides, consumers demand agricultural commodities without pesticides residues. Consequently, because of secondary infection in a tray wrap is of paramount importance, if human-safe and environmentally friendly methods of decay-control are developed, such a simple technique of film-packaging may come into common use in the postharvest handling and storage of citrus fruit, especially in under developed countries.

ACKNOWLEDGEMENTS

This research was supported under grant No. 76-AGD-1015-501, from the Vice-chancellor for Research of Shiraz University. We would like to thank Polytechnic Khavandy Inc., Shiraz, for providing the seal-packaging machine and pressure tester. We also thank Janssen pharmaceutical for imazalil, and Borden Inc. and Shiraz Nylon Co. for providing film.

REFERENCES

Alferez F, Zacarias L, Burns JK (2005) Low relative humidity at harvest and before storage at high humidity influence the severity of postharvest peel pitting in citrus. *Journal of American Society for Horticultural Science* **130**, 225-231

Barmore CR, Purvis AC, Fellers PJ (2006) Polyethylene film packaging of citrus fruit: Contaminant of decaying fruit. *Journal of Food Science* **48**, 1558-1559

Ben-Yehoshua S (2005) *Environmentally Friendly Technologies for Agricultural Produce Quality*, Culinary and Hospitality Industry Publication Services, Texas, USA, 552 pp

Ben-Yehoshua S, Shapiro B, Even-Chen Z, Lurie S (1983) Mode of action of plastic film in extending life of lemon and bell pepper fruits by alleviation of water stress. *Plant Physiology* **73**, 87-93

Ben-Yehoshua S, Fang D, Rodov V (1995) New developments in modified atmosphere packaging. *Plasticulture* **106**, 29-37; **107**, 33-40

Ben-Yehoshua S, Peretz J, Moran R, Lavie B, Kim JJ (2001) Reducing the incidence of superficial flavedo necrosis (noxan) of Shamouti oranges (*Citrus sinensis* Osbeck). *Postharvest Biology and Technology* **22**, 19-27

Cohen E, Lurie S, Shapiro B, Ben-Yehoshua S, Shalom Y, Rosenberger I (1990) Prolonged storage of lemons using individual seal-packaging. *Journal of the American Society for Horticultural Science* **115**, 251-255

D'Aquino S, Schirra S, Agabbio M (2001) Quality and physiological changes of film packaging 'Malvosio' mandarins during long term storage. *LWT-Food Science and Technology* **34**, 206-214

Gustavo HA, Durigan JF, Richardo EA, Timothy JO (2007) Use of modified atmosphere to extend life of fresh-cut carambola (*Averhoa carambola* L. cv. Fwang Tung). *Postharvest Biology and Technology* **44**, 80-85

Henriod RE (2006) Postharvest characteristics of navel oranges following high humidity and low temperature storage and transport. *Postharvest Biology and Technology* 42, 57-64

Kader AA (2002) Postharvest biology and technology: an overview. In: Kader AA (Ed) *Postharvest Technology of Horticultural Crops*, Regents of the University of California, Division of Agricultural and Natural Resources, Oakland, CA, pp 39-48

Kader AA, Arpaia ML (2002) Postharvest handling systems: Subtropical fruit. In: Kader AA (Ed) *Postharvest Technology of Horticultural Crops*, Regents of the University of California, Division of Agricultural and Natural Resources, Oakland, CA, pp 375-384

Marais S, Bureau E, Gouanve F, Ben Salem E, Hirata Y, Andrio A, Cabot C, Atmani H (2004) Transport of water and gasses through EVA/PVC blend film- permeation and DSC investigation. *Polymer Testing* **23**, 475-486

Miller WR, McDonald RE (1989) Condition of waxed or film-wrapped 'Minneolta' tangelos after harvest. *Proceedings of the Florida State Horticultural Society* **102**, 190-192

Nur Dirim S, Özlem Özden H, Bayndirli A, Esin A (2004) Modification of water vapour transfer rate of low density polyethylene films for food packaging. *Journal of Food Engineering* **63**, 9-13

Porat R, Weiss B, Cohen L, Daus A, Abarni N (2004) Reduction of postharvest rind disorders in citrus fruit by modified atmosphere packaging. *Postharvest Biology and Technology* **33**, 35-43

Purvis AC (1983) Effect of film thickness and storage temperature on water loss and internal quality of seal-packaged grapefruit. *Journal of the American Society for Horticultural Science* **108**, 562-566

Raghav PK, Gupta AK (2000) Quality and shelf life of individually shrink wrapped 'Kinnow' fruits. *Journal of Food Science and Technology* **37**, 613-616

Rodov V, Aga T, Peretz J, Nafussi B, Kim JJ, Ben-Yehoshua S (2000) Effect of combined application of heat treatments and plastic packaging on keeping quality of 'Orblanco' fruit (*Citrus grandis* L. × *C. paradise* Macf.). *Postharvest Biology and Technology* **20**, 287-294

Sharkey PJ, Little CR, Thornton IR (1985) Effects of low-density polyethylene liners and high-density polyethylene wraps on quality, decay and storage life of lemon and tangor fruits. *Australian Journal of Experimental Agriculture* **25**, 718-721