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Some Modified Atmosphere Packaging Treatments Reduce Chilling Injury and Maintain Postharvest Quality of Washington Navel Orange

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Abstract: Quarantine treatments must be applied to export citrus fruits to foreign markets because of the endemic presence in the Mediterranean area of the Mediterranean fruit fly (*Ceratitis Capitata*). The current accepted quarantine treatment is fruit exposure to temperature ranging from 1-2°C which can affect fruit quality and make the fruit more prone to chilling injury especially, tropical and subtropical fruits. So, mature Washington Navel orange fruits (*Citrus sinensis* Osbeck) were packed in: I) sealed fresh bags of high ethylene absorption (HEA), II) perforated polyethylene)PPE(, III) polyethylene (PE) film (stretchable cling film), IV) commercial PVC (poly vinyl chloride) V) Freely packed fruits (control) to minimize chilling injury and maintain fruit quality. All modified atmosphere packaging (MAP) treatments showed significantly lower percentage of fruit weight loss, soluble solids content and chilling injury symptoms and higher Vitamin C and total acidity contents as compared with the control. All treatments resulted in optimum colour development. This study indicated that Washington Navel orange fruits can be safely quarantined under modified atmosphere packaging to the longest possible storage period with the most proper fruit quality which ultimately improves marketability.

Key words: Navel orange · Modified atmosphere packaging · Chilling injury · Decay · Fruit quality

INTRODUCTION

Citrus is a major export produce of Egypt. The total cultivated area for citrus fruit is about 409639 feddans and total production is estimated at 3,134,174 ton/year. Navel orange representing about 35% of the total production in 2007 season. The average volume of citrus exported to various countries during 2005-2007 ranged from 610,000 to 796,000 tons [1]. Washington Navel orange fruits (*Citrus sinensis* Osbeck), are non climacteric, with persistently low respiration and ethylene production rates, do not undergo any major softening or compositional changes after harvest and, therefore, can normally be stored for relatively long periods of 6-8 weeks [2].

Low temperature during storage and transport are used to extend postharvest life and for the purpose of insect disinfection, making fruits more prone to chilling injury Development of postharvest rind disorders causes severe economic losses to the entire citrus industry worldwide [3]. CI that, occasionally develop in Navel, following the cold disinfestations treatment required to export the fruit to fly-free zones where quarantine regulations operate. One possible mean to reduce the development of rind disorders in citrus fruit may be the use of modified atmosphere packaging (MAP), by placing the fruit in "bag-in-box" plastic liners or other materials [4].

Chilling damage in citrus fruit may appear in various forms, such as browning of the flavedo (the outer pigmented layer of the rind) as in oranges.

Therefore, MAP provides two advantages: it modifies the atmosphere inside the package to the O_2 and CO_2 levels required to alleviate the development of rind disorders and it maintains a high humidity environment for the commodity inside the plastic film [4].

In addition it protects the produce from mechanical injury and contamination during marketing.

Packaging methods showed great added influence that affect temperature and relative humidity management of produce while in storage or in transit.

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This study clear that, in addition to its role in maintaining freshness, MAP significantly reduced the development of chilling damage and therefore, might be used as a commercially practical mean to maintain fruit quality.

MATERIALS AND METHODS

This study was conducted during two successive seasons of 2007 and 2008 on fruit from Washington Navel orange (*Citrus sinensis* Osbeck) 20 years old trees budded onto sour orange rootstock (*Citrus aurantium*) grown in a commercial orchard, Ismailia Governorate. The trees were spaced at 5 meters apart and received common horticultural managements of citrus orchard.

Fruit chosen for this study were sound and uniform in size, colour and weight. They were picked early in the morning when green-yellow colour covered in 25% or greater of the fruit surface and the SSC/acid ratio of 8 or higher [5].

Initial quality of the fruit at harvest was determined using 20 fruits and the data are tabulated as follows:

After conditioning at 15°C for 5 days, fruits were subjected randomly to one of the following treatments:

- Freely packed fruits (control)
- Individual fruit packed in sealed fresh bags of high ethylene absorption (HEA) O_2 permeability 150-300 cm^3/hour.
- Fruit packed in lined perforated polyethylene PPE (30 μm thickness). Inside the boxes there were sacs containing potassium permanganate 10 gm/Kilogram of fruits.
- Fruits were wrapped with polyethylene (PE) film 15 μm thickness (stretchable cling film).
- Fruits were wrapped in a commercial PVC (poly vinyl chloride) film "X-tend wrapping sheets".

All fruits were subjected to quarantine "Q" treatment at (2°C and 90% RH) for two months, followed by a marketing period at (20°C and 65% RH) for 7 days.

Each treatment consisted of 200 fruit, divided into two groups; fruits of the first group were labeled, individually weighted and used for weight loss, the evaluation of chilling injury and decay incidence. The second group was used for chemical analysis, marketability and overall acceptability.

Table 1: Fruit characteristics of Washington Navel orange at harvest during 2007 and 2008 seasons

Parameters	2007 season	2008 season
Fruit weight (g)	410	435
Vitamin (C%)	55	56
Rind thickness (cm)	0.52	0.55
Fruit juice (%)	44	46
SSC/acidity	8.0	8.2

The Following Aspects Were Studied

Weight Loss Percentage: Labeled fruits were weighted individually at each sampling time (15 days) intervals up to 60 days. Weight loss was expressed as a percentage of the original fresh weight of the fruits. The percentage was calculated for each treatment.

The following equation was used:-

$$\text{weight loss \%} = \frac{\text{Initial.weight-sample.weight}}{\text{Initial weight}} \times 100$$

Fruit Firmness: Was measured on the two opposite sides of Navel orange fruit samples (8 fruits) by using a hand Magness Taylor pressure tester (lb/in^2).

Soluble Solids Content (SSC): Was measured in fruit juice by using ATTAGO hand refractometer at 20°C and expressed as percent.

Titratable Acidity: was determined in fruit juice by using 0.1 NaOH in the presence of phenolphthalein until pH 8.0 and expressed as citric acid percent.

Vitamin C: was determined in juice as mg Ascorbic acid / 100 ml fruit juice by titration with 2, 6 dichlorophenol-indophenol solution in the presence of oxalic acid solution [6].

Evaluation of Chilling Injury and Decay: After 6-8 weeks of cold storage at (2°C ± 0.1 and 90% RH) and an additional week at (20°C ± 1and 65% RH) fruits were evaluated for chilling injury severity according to the following scale: 0 = sound (no pitting), 1 = slight (a few scattered pits), 2 = moderate (pitting covering up to 30% of the fruit surface) and 3 = severe (extensive pitting covering more than 30% of the fruit surface). The chilling injury index was determined for each treatment by

multiplying the number of fruit in each category by their score and then dividing this sum by the total number of fruit assessed. The total number of fruit manifesting decay symptoms (mainly green and blue mould) was determined in each treatment and expressed as the decay percentage.

Marketability: At the end of quarantine "Q" treatment at (2°C ± 0.1 and 90% RH) for 60 days, about 20 fruit from every treatment were held at (20°C ± 1) and 65% RH for 7 days to simulate market condition and to assess fruit ripeness as well as ensuring its quality.

Overall Acceptability: Consumer acceptance of fruits after cold storage followed by market period is very important to assess the success of storage. For this test, about 10 consumers were provided 20 Navel orange fruit from each treatment after market period and the taste of fruit was determined by giving a numerical values as follows: like slightly = 1, like moderately = 2 and like extremely = 3, as a degree of liking the number of fruit per each category was assessed. Acceptance percentage was calculated as the number of fruit in like extremely category in relation to the total number of fruit [7].

The following equation was used:

$$\text{Acceptance \%} = \frac{\text{Number.of.fruits.per.each.degree.of.liking}}{\text{Total.number.of.fruit.in.each.treatment}} \times 100$$

Statistical Analysis: Average data of both seasons were statistically analyzed by using split plot design according to procedure outlined by Snedecor and Cochran [8]. Analyses of variance and mean comparison (LSD at 5 %) were performed with Co-Stat program version 3.

RESULTS AND DISCUSSION

Data presented in Table 2 indicated that, the percentage of fruit weight loss increased with extending the storage period up to 60 days. The longer the storage period the higher the fruit weight loss. In addition, control treatment resulted in higher weight loss than other treatments. The general results show that all modified atmosphere packaging treatments reduced significantly the percentage of fruit weight loss in both study seasons, respectively. These observations indicated that all MAP treatments had a relative success in reducing fruit weight loss. These results are confirmed by those of Shahbake [9]; El Rayes and Ahmed [10]; Porat *et al.* [11]; Schirra *et al.* [12]; Alonso *et al.* [13]; Henriod, *et al.* [14] and Henriod [15].

Data presented in Table 3 showed that, a significant increase in the percentage of soluble solids content (SSC) in Washington Navel orange fruits was obtained in both seasons of the study in control treatment. The MAP fruits showed significantly lower fruit SSC% than control ones. Highest fruit SSC% occurred in control treatment. Whereas, the lowest SSC% values were recorded in all fruits treated with MAP. These findings came in agreement with those of El Rayes and Ahmed [10]; Mustafa, *et al.* [16] and Henriod, *et al.*[14].

Juice total acidity of Washington Navel orange was affected significantly by MAP treatments. Data in Table 4 showed that, juice acidity decreased gradually during the storage period. Fruits treated with MAP gave the highest juice acidity during storage period. The lowest juice acidity values occurred in control treatment. These results are in harmony with those of Shahbake [9]; El Rayes and Ahmed [10] with mango fruits;

Table 2: Influence of some modified atmosphere packaging treatments on weight loss (%) of quarantined Washington Navel orange fruits during 2007 and 2008 seasons

	2007 season						2008 season					
	Storage period in days						Storage period in days					
Treatments	0	15	30	45	60	Average	0	15	30	45	60	Average
Control	0	2.3	4.3	6.1	8.9	4.3	0.0	2.3	3.2	4.6	8.5	3.7
(HEA)	0	1.0	1.3	1.9	2.68	1.4	0.0	1.0	1.2	2.0	2.6	1.4
PPE (30 µm)	0	0.9	1.2	2.1	2.43	1.3	0.0	0.9	1.0	1.9	2.4	1.2
PE film (15 µm)	0	0.8	1.1	2.35	2.83	1.4	0.0	0.7	1.0	2.2	2.9	1.4
PVC film	0	0.8	1.0	2.15	2.38	1.3	0.0	0.7	0.8	2.2	2.3	1.2
Average	0.0	1.1	1.8	2.9	3.8		0.0	1.1	1.4	2.6	3.7	

LSD 0.05 (2007 season) Treatments= 0.07 Storage period = 0.23 Interaction = 0.42

LSD 0.05 (2008 season) Treatments= 0.66 Storage period = 0.46 Interaction = 0.99

Table 3: Influence of some modified atmosphere packaging treatments on SSC (%) of quarantined Washington Navel orange fruits during 2007 and 2008 seasons

	2007 season						2008 season					
	Storage period in days						Storage period in days					
Treatments	0	15	30	45	60	Average	0	15	30	45	60	Average
Control	11.3	12.3	13.8	14.6	15.3	13.5	11.1	12.1	13.2	14.5	15.1	13.2
(HEA)	11.3	11.7	12.4	13.4	14.1	12.6	11.2	11.5	12.2	13.1	14.0	12.4
PPE (30 µm)	11.1	11.6	12.7	13.3	14.1	12.6	11.3	11.8	12.5	13.0	14.2	12.5
PE film (15 µm)	11.0	11.7	12.6	13.5	14.1	12.6	11.2	11.7	12.7	13.2	14.0	12.6
PVC film	11.3	11.8	12.6	13.6	14.2	12.7	11.4	11.5	12.6	13.3	14.0	12.6
Average	11.2	11.8	12.8	13.7	14.3		11.2	11.7	12.6	13.4	14.3	

LSD 0.05 (2007 season) Treatments= 0.23 Storage period = 0.23 Interaction = 0.50
LSD 0.05 (2008 season) Treatments= 0.25 Storage period = 0.26 Interaction = 0.55

Table 6: Influence of some modified atmosphere packaging treatments on chilling injury (%) of quarantined Washington Navel orange fruits during 2007 and 2008 seasons

	2007 season					2008 season				
	Storage period in days					Storage period in days				
Treatments	15	30	45	60	Average	15	30	45	60	Average
Control	0.57	1.05	1.70	1.95	1.3	0.70	1.20	1.98	2.10	1.5
(HEA)	0.03	0.26	0.26	0.33	0.2	0.00	0.33	0.20	0.26	0.2
PPE (30 µm)	0.06	0.39	0.37	0.35	0.3	0.05	0.45	0.30	0.31	0.3
PE film (15 µm)	0.03	0.36	0.14	0.19	0.2	0.05	0.33	0.10	0.18	0.2
PVC film	0.00	0.22	0.08	0.15	0.1	0.00	0.18	0.05	0.16	0.1
Average	0.14	0.5	0.5	0.6		0.2	0.5	0.5	0.6	

LSD 0.05 (2007 season) Treatments= 0.07 Storage period = 0.06 Interaction = 0.10
LSD 0.05 (2008 season) Treatments= 0.08 Storage period = 0.07 Interaction = 0.10

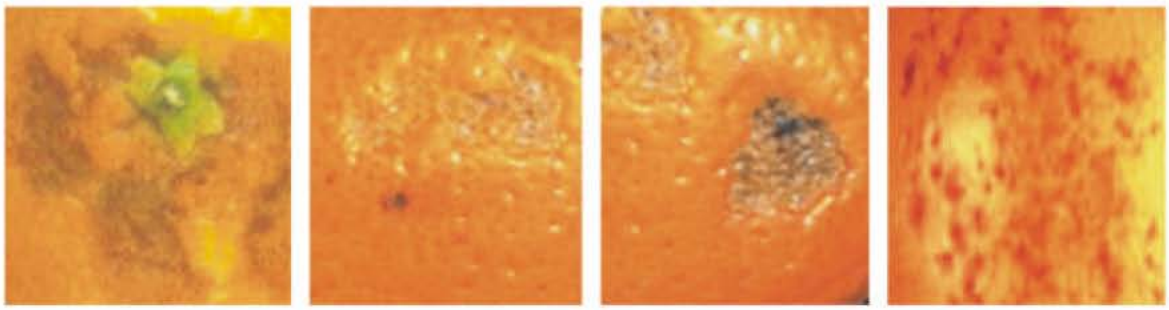

Fig. 1: Manifestations of chilling injury on navel orange fruit during cold storage.

Nanda *et al*. [17] with pomegranate fruits cv. Ganesh; Schirra, *et al*. [12] and Mustafa, *et al*.[16].

Data presented in Table 5 indicated that, vitamin C contents decreased gradually during storage period. Fruits treated with MAP gave the highest vitamin C content throughout the storage period in addition, the lowest vitamin C content occurred in control fruits. These results are in harmony with those of Shahbake [9]; El Rayes and Ahmed [10] with mango fruits; Nanda *et al*. [17] with pomegranate fruits cv. Ganesh and Mustafa, *et al*. [16].

It is clear from Table 6 that, the control fruit had the highest significant chilling injury incidence in both study seasons (1.3 and 1.5). Meanwhile, general results showed that all MAP treatments used in this study significantly reduced chilling injury incidence. The percentage of injured fruit by chilling increased gradually during the storage period. Lowest percentage of injured fruit occurred in PVC film treatment (0.1) in both studied seasons. The symptoms of chilling injury appeared in the form of discoloured, small pitted areas and skin depressions irregularly distributed over the fruit surface (Fig. 1).

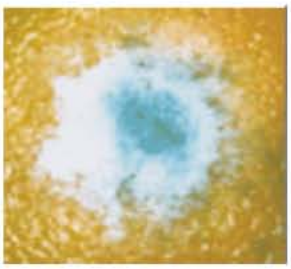

Fig. 2: Symptoms of decay on navel orange fruit during cold storage

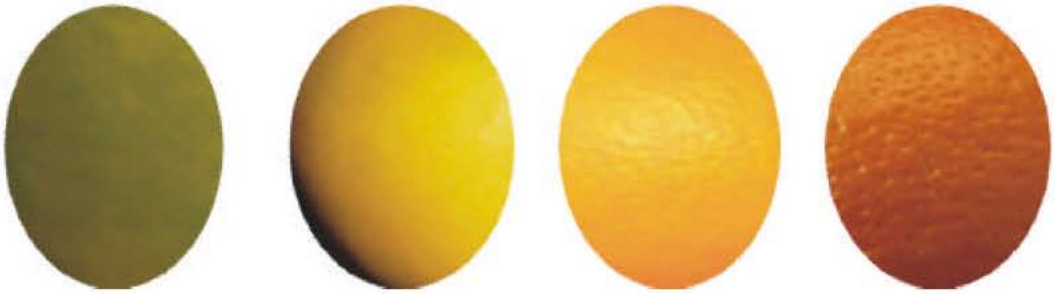

Fig. 3: The development of rind colour of navel orange fruit during cold storage

Table 7: Physical and chemical characteristics of quarantined Washington Navel orange fruits as affected by some modified atmosphere packaging treatments and placed for 7 days at 20°C for determining fruit marketability and consumer acceptance percentage (average of two seasons)

Treatments	weight loss%	SSC%	Acidity%	Vitamin C %	Consumer acceptance%
Control	6.3 a	15.6 a	0.3 b	39 b	94.3 c
(HEA)	4.7 b	15.7 a	0.35 ab	42.3 ab	97.7 b
PPE (30 µm)	4.4 bc	15.5 a	0.36 ab	44 a	99 ab
PE film (15 µm)	4.2 bc	15.4 a	0.38 a	44.7 a	100 a
PVC film	3.9 c	15.8 a	0.38 a	46.3 a	100 a

Values followed by the same letter (s) in each column are not significantly different at 5% level of probability.

Considering the effect of MAP treatments on decay percentage of Washington Navel orange fruits, all treatments prevented decay in both seasons till the end of storage period. Meanwhile, decay percentage was 7.5 % in control treatment at the end of storage period (Fig. 2).

It is clearly revealed from Fig. 3 that, all treatments resulted in good colour development.

Concerning the effect of market period at (20°C ± 1) and 65% RH for 7 days on fruit parameters, data presented in Table 7 (average of two seasons) showed an increment in physiological weight loss and SSC % in all treatments. There was a slight decrease in titratable acidity. Concerning ascorbic acid level, it is almost steady in all treatments, but control treatment showed less significant average.

Concerning consumer acceptance percentage of Washington Navel orange after marketing period, all treatments were judged like extremely the fruits had a very good taste, texture flavour and overall acceptance.

CONCLUSION

This study indicated that Washington Navel orange fruits (*Citrus sinensis* Osbeck) could be safely quarantined under modified atmosphere packaging to the longest possible storage period (60 days) with the most proper fruit quality which ultimately improves marketability.

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