

SAFE POSTHARVEST TREATMENTS FOR MAINTAINING OLINDA ORANGE FRUITS QUALITY DURING MARKETING LIFE

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ABSTRACT

Extending postharvest fruit life demand cold storage period prolongation with reasonable marketing life. In this scope, quality of Olinda orange was determined in response to arabic gum, bee wax, paraffin oil and chitosan coatings during simulated marketing life at 20°C for 12 days after cold storage at 5°C and 90-95% relative humidity for 90 days. All applied coatings had desirable effects on fruit quality compared with the control, where the best treatment was chitosan at 1 and 2% that were effective in maintaining ascorbic acid content compared to the uncoated ones. Chitosan coating at 2% attained the lowest significant weight loss and decay percentages. Also, it delayed changes associated with fruit aging such as colour changes, softening and pectin the methylesterase activity, in addition to valuable means of respiration rate compared to the uncoated ones. Coatings are easily applied tools that could be suitable for extending Olinda orange postharvest marketing life.

Key words: *Citrus, coating, bee wax, gum arabic, chitosan, paraffin oil, storage, shelf life.*

1. INTRODUCTION

Citrus has a great nutritional and marketable rank in Egypt, it is considered one of the strategic export fruits. Olinda Valencia orange took an important abroad marketing position in last years, where traders demand fruits in high specific quality and long life, which practically mean elongation of cold storage and marketing life period. Coating is a traditional handling practice in orange for reparation the natural wax that might be washed away or distraught during fruit handling (Shaw *et al.*, 1993).

Waxing has been used as protection technique for fruits and vegetables (Baldwin *et al.*, 1995), where the main goals of this procedure are to minimize the water loss from the fruits and decrease weight loss. Baldwin *et al.* (1999) reported that coating can decrease fruit mass loss by up to 50%, and it can preserve fruit in high quality. Earlier studies have been dedicated on different wax films for fruits (Saftner, 1999; Shein *et al.*, 2008; El-Anany *et al.*, 2009) and its role, which may be different in regard to storage temperature and conditions, film permeability and fruit surface anatomy. McGuire (1997) found that waxing decreases respiration rate significantly, and coated fruit keep better physical appearance and enhances

the brightness that improve appearance, but showed distinguished taste.

However, many of the commercial waxes are disapproved because of its structure, or being unsafe. Recently, consumers have demand for healthy products that require studies and evaluation for different coating alternatives (Porta *et al.*, 2013).

Arabic gum is a dehydrated and adhesive exudate extracted from the stems or branches of Acacia species, it is considered the smallest gelatinous and most soluble of the hydrocolloids, and is used widely in the industrial purposes in regard to its emulsification, film developing and encapsulation properties (Motlagh *et al.*, 2006). Arabic gum showed significant difference and improved shelf life of fruits (Maqbool *et al.*, 2011).

Chitosan is considered a high molecular weight particles, valuable as antioxidant and eligible for maintaining ascorbic acid in fruit. For this reason, chitosan is a highly suggested edible film (Tendaj and Tendaj, 1998). Citosan is a natural antimicrobial compound and safe coating material (Hirano *et al.*, 1990), used to prolong shelf life and control decay in citrus (Chien *et al.*, 2007), maintained fruit quality and beneficially impacted firmness, total soluble

content, acidity and vitamin C content of citrus fruits after about 2 months of storage at 15°C (Zhang *et al.*, 2011).

Also, coatings of bee wax were approved in some fruits (Shahid and Abbasi, 2011) as an edible film. Waxing also provide a modified atmosphere within the fruit which decreases respiration and delays ripening (Bayindirli *et al.*, 1995). The beneficial role of wax is well known for enhancing shelf life and maintaining postharvest quality of several fruits (Khuyen *et al.*, 2008).

Recent experiments showed that some essential oils are effective for reducing decay, improve quality and postharvest life of many fruits (Serrano *et al.*, 2005). Paraffin oil is a thin layer used for coating fruits, being safe for human. Paraffin plays an important role on fruits storage and marketing, some of these roles are impart a shiny appearance to fruits compared with paraffin wax that was used widely, but was criticized because of its effect on fruit gloss (Salman *et al.*, 2008), and protects them from mechanical damage, physical, chemical and microbiological activities (Magashi and Bukar, 2006).

The scope of this investigation was to evaluate the effects of various coatings; arabic gum, bee wax, paraffin oil and chitosan coatings on the quality changes of Olinda orange during simulated marketing life at 20°C for 12 days after cold storage at 5°C and 90-95% relative humidity for 90 days. The quality studied included physiochemical properties of fruits.

2. MATERIALS AND METHODS

2.1. Fruit materials

This study was applied on Olinda Valencia orange (*Citrus sinensis* L.). Oranges were hand harvested according to indices cited by Kader (1992) from a private field located in El-Behira Governorate, Egypt in both successive seasons 2016 and 2017. Fruits were chosen to be similar in colour and size, and free of any visible pathological or mechanical disorders. Fruits were immediately transported to the laboratory; all fruits washed and dipped in hot water 40°C for 3 min as a recommended quarantine treatment for oranges (Kader, 1992).

2.2. Preparation of the coatings

Coating treatments included; bee wax 10% and 15%, arabic gum 5% and 10%, chitosan 1% and 2%, paraffin oil 75% and 99%, in addition to the control fruits (untreated).

The different applied coatings were prepared

according to the following procedures; bee wax in two concentrations 10 and 15% was emulsified by melting bee wax (100 and 150 g, respectively) into 1000 ml water phase and heating to 90°C, until all wax became completely hydrated according to Hassan *et al.* (2014).

Arabic gum solutions at 5 or 10% w/v were prepared by dissolving gum arabic in distilled water and heated at 40°C according to the procedure mentioned by Asgar *et al.* (2010), with ongoing basis stirring for 60 min using a magnetic stirrer hot plate until the solution became pure, and the pH of the solution was maintained at 5.6 using 1 N NaOH.

Paraffin oil (75 and 99%) was of chemical grade (El-Gomhouria Co., Al America, - Cairo, Egypt) and used with the procedure reported by El-Anany *et al.* (2009).

According to Kittur *et al.* (2001), chitosan (1 and 2% w/v) was dissolved in an aqueous solution of glacial acetic acid (1% v/v), pH adjusted to 5.2 using 1 N NaOH, the stock solution was heated at 121°C for 20 min.

Coating treatments were applied by dipping the whole fruit surface in the prepared coating materials for 5 min, while the control fruits were dipped in water for the same period.

2.3. Storage conditions

Fruits from each coating treatment were air-dried, and packed in cartoon boxes (12 fruits capacity). Three boxes were used for each treatment, one box to determine decay, the second to determine weight loss and the third for fruits analysis, and each box was replicated four times (to obtain at least three replicates during marketing life). The experiment was repeated twice (2016 and 2017 seasons). Orange fruits were subjected randomly to one of the treatments and stored at 5°C and 90-95% RH for 90 days in laboratory of Refrigeration of Agricultural Systems Improvement Project.

2.4. Marketing life

After cold storage period at 5°C, when discarded fruits percentage reach to about 25% in the control treatment, boxes were transferred and kept at 20°C and 75% RH as marketing life to simulate market conditions for 12 days. All treatments were evaluated for different physiochemical properties before transfer to marketing life conditions at 4 day intervals.

2.5. Fruit physical characteristics

2.5.1. Weight loss percentage

The difference between the initial weight of fruits and that recorded at the date of sampling was translated as weight loss percentage and

calculated as follows; weight loss % = (fruit initial weight - fruit weight at each sampling time) × 100 / fruit initial weight.

2.5.2. Decay percentage

The percentage of discarded fruits included all of the spoiled fruits, resulting from rots, fungus, bacteria, physiological disorders or chilling injury, were assessed and calculated as the number of discarded fruits /total number of fruits at the beginning × 100.

2.5.3. Fruit firmness

Fruit firmness was determined using fruit pressure tester (8 mm diameter probe) on the opposite surfaces of each fruit according to Mitcham *et al.* (2003), and data were scored as lb/inch².

2.5.4. Instrumental colour

Instrumental colour was measured in the CIE *L* a* b** on different places of flavedo layer surface of fruit objectively using a Minolta CR-400 chroma meter (Minolta, Osaka, Japan) according to McGuire (1992).

2.5.5. Respiration rate

Respiration rate, as ml of CO₂/kg/hr was measured by gas analyzer (Model 1450-Servomex 1400), where fruits were incubated in 4-liter airtight glass jars for 24 hr under the same experimental conditions according to McCollum *et al.* (1993).

2.6. Fruit chemical characteristics

2.6.1. Ascorbic acid

Ascorbic acid was measured using titration method against 2,6 dichlorophenol indophenol solution. Results were expressed as mg ascorbic acid per 100 g fresh weight (Mazumdar and Majumder, 2003).

2.6.2. Total soluble solids / acid ratio

Total soluble solids / acid ratio was

calculated using TSS values divided by total acidity values where TSS was evaluated by refractometer using drops of the fruit juice, total acidity was assessed by titration method (AOAC. 1980) and expressed as percentage of the dominant acid in the fruit (citric acid).

2.6.3.Pectin methylesterase (PME) activity

Activity of pectin methylesterase (PME, E.C. 3.1.1.11) was defined as Δ A620 mg⁻¹ protein min⁻¹, according to Jeong *et al.* (2002) procedure. Extraction buffer of 101 M potassium phosphate was used and the reaction was initiated by addition of 6 μl of the cell free protein extract (pH 7.5). Decrement in A620 over a reaction time (10 min) was recorded.

2.7. Statistical analysis procedure

All data parameters studied were analyzed as factorial randomized complete block design in factorial arrangement with hree replication. The differences between means were compared by LSD range test at the 5% level of probability in the two investigated seasons as described by Snedecor and Cochran (1989).

3. RESULTS AND DISCUSSION

3.1. Fruit physical characteristics

3.1.1. Weight loss percentage

Table (1) shows the effect of different coating treatments on Olinda orange weight loss during marketing life for 12 days at 20°C following cold storage at 5°C for 90 days in 2016 and 2017 seasons. Weight loss increased continually in both seasons under all conditions. In the first season, untreated fruits showed the highest significant weight loss value, while 2% chitosan and 99% paraffin showed the lowest significant weight loss values. At the end of marketing life period, the control treatment showed the highest

Table (1): Effect of different coating treatments on weight loss (%) of Olinda orange fruits during marketing life at 20°C in 2016 and 2017 seasons.

Treatment (A)	Days of marketing life at 20°C (B)									
	Season 2016					Season 2017				
	Initial	4	8	12	Mean	Initial	4	8	12	Mean
10% Bee wax	0.00	1.73	6.44	14.76	5.73	0.00	1.93	7.33	14.81	6.02
15% Bee wax	0.00	1.94	6.66	15.09	5.92	0.00	1.72	6.55	15.01	5.82
5% Gum arabic	0.00	1.57	5.96	14.15	5.42	0.00	3.13	6.24	14.96	6.08
10% Gum arabic	0.00	1.48	5.92	15.30	5.68	0.00	1.69	6.65	15.61	5.99
1% Chitosan	0.00	1.54	5.67	15.05	5.57	0.00	1.59	5.67	14.65	5.48
2% Chitosan	0.00	1.44	5.29	13.16	4.97	0.00	1.69	6.10	13.32	5.28
75% Paraffin oil	0.00	1.32	7.36	14.74	5.85	0.00	1.79	6.57	14.46	5.71
99% Paraffin oil	0.00	1.57	5.93	13.92	5.36	0.00	1.63	6.38	14.41	5.60
Control	0.00	1.82	6.96	17.06	6.46	0.00	1.48	7.57	16.43	6.37
Mean	0.00	1.60	6.25	14.80		0.00	1.85	6.56	14.85	
L.S.D ^{0.05}	(A) = 0.44, (B) = 0.29, (A×B) = 0.88					(A) = 0.54, (B) = 0.36, (A×B) = 1.09				

significant weight loss (17.06%), whereas 2% chitosan and 99% paraffin treatments showed the lowest significant values 13.16 and 13.92% respectively.

According to the obtained data in the second season, untreated fruits showed the highest significant value, while chitosan at 2% showed the lowest significant weight loss value. At the end of storage period, the untreated showed the highest significant weight loss value (16.43%), whereas chitosan at 2% showed the significant weight loss percentage (13.32%).

Fruit water loss is a considerable problem during fruit handling. It results in decrement in fruit nutrition value and weight loss and shrinkage. Fruit waxing is one of the most applied solutions for this problem. High rates of respiration are the main cause for moisture loss, coating provides thin film to fruit peel, that is considered a semi permeable barrier versus gas exchange and evaporation (Miranda *et al.*, 2004). The current study report similar findings to those mentioned by Abhay *et al.* (2012) who found effective role of peel coatings on prolonging shelf life and retaining water content of lime fruits. Our findings indicate that treatment of chitosan at 2% was the most effective film in keeping fruit moisture compared with the uncoated orange fruits.

3.1.2. Decay fruit percentage

Data in Table (2) indicate the effect of different coating treatments on discarded fruit percentage of Olinda orange during marketing life at 20°C in 2016 and 2017 seasons. Decay increased gradually in both seasons under all conditions. Chitosan at 2% showed the lowest significant loss, while the untreated fruits showed the highest significant decay percentage in 2016 and 2017 seasons. After 12 days of simulated marketing life period in 2016 season,

the control treatment showed the highest significant decay percentage (68.33%), whereas chitosan at 1 and 2% treatments showed the lowest significant loss (16.66%). In addition, at the end of marketing life period in the second season, the control treatment showed the highest significant decay value (67.22%), whereas 2% chitosan and 99% paraffin treatments showed the lowest significant decay values 15.55 and 16.66% respectively.

Discarded fruits percentage seemed to increase sharply after 8 days of shelf life under the circumstances of the experiment. Maximum retaining of marketable fruits life under coating might be due to minimizing gas exchange and respiration rate, which is reflected in the rate, of deterioration. Also it blocks out minor lesions on the external fruit surface that reduce fruit diseases, and chilling injury (Shaw *et al.*, 1993).

The obtained results declare that chitosan and paraffin were useful in decreasing fruit deterioration. Results were in line with those obtained by El-Anany *et al.* (2009) who noted that using edible coating in combination with cold storage (0°C) on Anna apple reduced discarded fruits percentage occurrence of 1.5 to 3 times compared to the uncoated fruits.

3.1.3. Fruit firmness (lb/inch²)

Fruit hardness is considered one of the limiting marketing life. Table (3) indicates the effect of different coating treatments on Olinda orange firmness during marketing life at 20°C after cold storage in both experimental seasons. Hardness exhibited a steeper decline in both seasons under all conditions. In 2016 season, all coated fruits except both bee wax concentrations, showed higher significant values compared to the control that showed the lowest significant force. By the end of the storage period, 10% arabic gum and 2% chitosan treatment

Table (2): Effect of different coating treatments on discarded fruits percentage of Olinda orange fruits during marketing life at 20 °C in 2016 and 2017 seasons.

Treatment (A)	Days of marketing life at 20 °C (B)									
	Season 2016					Season 2017				
	Initial	4	8	12	Mean	Initial	4	8	12	Mean
10% Bee wax	0.00	11.10	13.22	20.55	11.22	0.00	10.55	12.59	20.55	10.92
15% Bee wax	0.00	10.55	12.83	19.44	10.71	0.00	9.44	12.97	20.55	10.74
5% Gum arabic	0.00	8.88	12.44	18.89	10.05	0.00	8.33	11.82	19.44	9.90
10% Gum arabic	0.00	8.33	12.44	18.89	9.91	0.00	7.22	12.59	18.89	9.67
1% Chitosan	0.00	6.10	10.50	16.66	8.31	0.00	5.55	10.67	17.22	8.36
2% Chitosan	0.00	3.88	9.72	16.66	7.57	0.00	4.99	9.15	15.55	7.42
75% Paraffin oil	0.00	7.22	12.05	18.33	9.40	0.00	7.77	12.20	18.33	9.58
99% Paraffin oil	0.00	6.10	11.66	17.22	8.75	0.00	7.22	11.06	16.66	8.73
Control	0.00	27.22	37.62	68.33	33.29	0.00	25.55	38.93	67.22	32.92
Mean	0.00	9.93	14.72	23.89		0.00	9.62	14.66	23.82	
L.S.D ^{0.05}	(A) = 0.93, (B) = 0.62, (A×B) = 1.86					(A) = 0.81, (B) = 0.54, (A×B) = 1.63				

Table (3): Impact of some coating treatments on firmness (lb/inch²) of Olinda orange fruits during marketing life at 20 °C in 2016 and 2017 seasons.

Treatment (A)	Days of marketing life at 20 °C (B)									
	Season 2016					Season 2017				
	Initial	4	8	12	Mean	Initial	4	8	12	Mean
10% Bee wax	16.79	15.78	14.38	11.75	14.68	14.86	14.29	12.86	11.18	13.30
15% Bee wax	16.98	15.85	13.89	11.86	14.64	14.93	14.48	13.36	11.27	13.51
5% Gum arabic	17.39	15.96	15.30	12.15	15.20	15.52	14.77	14.05	12.14	14.12
10% Gum arabic	16.90	16.03	15.64	12.25	15.20	15.64	14.81	14.15	12.39	14.24
1% Chitosan	17.33	15.91	15.17	11.92	15.08	15.08	14.71	13.96	11.55	13.83
2% Chitosan	17.19	16.01	15.71	12.21	15.28	15.71	14.92	14.21	12.73	14.39
75% Paraffin oil	16.82	15.88	15.54	11.90	15.04	15.05	14.63	13.90	11.33	13.73
99% Paraffin oil	17.49	15.89	15.28	12.06	15.18	15.22	14.71	14.04	11.81	13.94
Control	15.46	14.64	12.28	10.12	13.12	12.36	11.84	11.07	9.80	11.27
Mean	16.93	15.77	14.80	11.80		14.93	14.35	13.51	11.58	
L.S.D ^{0.05}	(A) = 0.32, (B) = 0.21, (A×B) = 0.65					(A) = 0.15, (B) = 0.10, (A×B) = 0.31				

maintained the highest significant values as 12.25 and 12.21 lb/inch², while the control recorded the lowest significant firmness (10.12 lb/inch²). In 2017 season, chitosan at 2% retained the highest significant hardness. On the other hand, the untreated fruits showed higher softness. By the end of the storage period, 2% chitosan treatment showed the highest significant rigidity as it recorded 12.73 lb/inch², whereas the control treatments showed the lowest significant value as it reached 9.80 lb/inch².

Shein *et al.* (2008) declared that storage prolongation resulted in higher softening especially with higher temperature conditions that induces cell wall metabolisms and pectin degradation enzymes such as pectin methyl esterase and polygalacturonase. Coatings help in decreasing cell wall breakdown, prevent water loss and maintain fruit firmness during marketing life periods, which is similar to results

reported by Del-Valle *et al.* (2005). Furthermore, higher humidity maintained by these coatings retained turgidity of the cells in addition to reducing the water loss and respiration rate (Ali *et al.* 2004). Chitosan coating beneficially influenced firmness of citrus stored for about 2 months at 15 °C (Zhang *et al.*, 2011).

3.1.4. Instrumental colour

L* score indicates brightness, whereas C colour or chroma score indicates the quality of a colour's pureness and intensity (Nambi *et al.*, 2015). Peel colour is an important quality index, where it reveals fruit general appearance and the consumer acceptability (Campbell *et al.*, 2004).

Table (4) presents the impact of different waxes on C colour of Olinda orange peel during marketing life at 20 °C in 2016 and 2017 seasons. C colour decreased constantly under all conditions in both seasons. In the first season, paraffin at 99% recorded the highest significant C colour value, while the control recorded the

Table (4): Effect of various coating treatments on C colour score of Olinda orange during marketing life at 20 °C in 2016 and 2017 seasons.

Treatment (A)	Days of marketing life at 20 °C (B)									
	Season 2016					Season 2017				
	Initial	4	8	12	Mean	Initial	4	8	12	Mean
10% Bee wax	71.76	71.48	71.22	70.82	71.32	72.24	72.04	71.79	71.63	71.93
15% Bee wax	74.80	74.57	73.74	72.09	73.80	74.30	74.18	73.90	73.29	73.92
5% Gum arabic	72.65	72.04	71.83	71.63	72.04	74.16	74.07	73.81	73.69	73.93
10% Gum arabic	73.61	73.49	73.27	72.38	73.19	74.48	74.05	73.80	73.73	74.01
1% Chitosan	74.48	73.52	72.72	72.31	73.26	74.41	73.99	73.80	73.64	73.96
2% Chitosan	76.27	75.24	74.65	73.79	74.99	75.82	75.68	75.25	74.81	75.39
75% Paraffin oil	73.26	72.88	72.47	71.99	72.65	73.51	73.27	72.90	72.68	73.09
99% Paraffin oil	73.50	73.28	72.96	72.27	73.00	73.60	72.99	72.82	72.71	73.03
Control	72.20	71.87	71.09	70.75	71.48	71.85	71.38	71.00	70.58	71.20
Mean	73.62	73.15	72.66	72.00		73.82	73.52	73.23	72.97	
L.S.D ^{0.05}	(A) = 0.06, (B) = 0.04, (A×B) = 0.12					(A) = 0.10, (B) = 0.07, (A×B) = 0.20				

lowest significant *C* colour value. At the end of marketing life period, 2% chitosan treatment showed the highest significant *C* colour value (73.79), whereas control treatments showed the lowest significant *C* colour value (70.75).

In the second season, chitosan at 2% showed the highest significant *C* colour score, while the lowest significant *C* colour value was in fruits treated by bee wax at 10%. At the end of the storage period, 2% chitosan treatment showed the highest significant chroma (74.81), whereas the control treatments showed the lowest significant value (70.58).

Table (5) shows the effect of different coating treatments on Olinda orange peel *L* colour during simulated marketing life at 20 °C in 2016 and 2017 seasons. *L* colour decreased gradually in both seasons under all conditions. In the first season, 2% chitosan treatment recorded the highest significant *L* value, whereas the control attained the lowest significant value. By the end of storage period, chitosan at 2% treatment showed the highest significant the value (63.80) whereas the control treatments showed the lowest significant value (53.00).

In the second season, the highest significant value was found in 2% bee wax treatment, whereas the control showed the lowest significant lightness. By the end of the storage period, 2% bee wax treatment showed the highest significant value as it recorded 63.43, while the untreated fruits showed the lowest significant *L** colour and lowest brightness (59.23).

Chitosan retain a glossy appearance compared with the untreated fruits that showed unacceptable colour shortly, that might be due to the changes in pigments and the changes in film colour itself (Nath *et al.*, 2012).

Our results are also in agreement with the

findings of Singh *et al.* (1997) who found desirable effect of coating on the postharvest shelf life in fruits. Coating maintains acceptable appearance of fruits and therefore enhance their marketability. This may also be due to delay in deterioration, and uniform colour development in fruits under shine chitosan coating in advanced period of marketing life. Similar results were observed by Pandey *et al.* (2010) in waxed guava fruits.

3.1.5. Respiration rate (ml CO₂ kg⁻¹ hr⁻¹)

Table (6) shows the effect of different coating treatments on Olinda orange respiration rate during marketing life at 20 °C in both studied seasons, where respiration rate increased continually in both seasons under all conditions. Despite orange is classified as non-climacteric fruit and low respiration rate, coated fruits exhibited lower respiration rates compared with the uncoated ones.

In the first season, the control showed the highest significant respiration rate, while 2% chitosan and 10% gum arabic recorded the lowest significant respiration rates. By the end of the storage period, the control treatment showed the highest significant rate 20.23 ml CO₂ kg⁻¹ hr⁻¹, whereas 2% chitosan treatment showed the lowest significant respiration rate 17.18 ml CO₂ kg⁻¹ hr⁻¹.

In the second season, the untreated fruits recorded the highest significant respiration rate, while chitosan at 2% recorded the lowest significant respiration rate. By the end of marketing period, the control showed the highest significant respiration rate 20.64 ml CO₂ kg⁻¹ hr⁻¹, whereas 2% chitosan treatments attained 16.22 ml CO₂ kg⁻¹ hr⁻¹ that was the lowest respiration rate whereas the differences between the different treatments in this date were insignificant.

Table (5): Influence of different coatings on *L* colour score of Olinda orange fruits during marketing life at 20 °C in 2016 and 2017 seasons.

Treatment (A)	Days of marketing life at 20 °C (B)									
	Season 2016					Season 2017				
	Initial	4	8	12	Mean	Initial	4	8	12	Mean
10% Bee wax	65.40	64.23	63.09	61.03	63.44	64.94	64.93	63.12	62.93	63.98
15% Bee wax	65.13	64.18	63.21	61.11	63.41	64.61	64.27	63.75	63.43	64.02
5% Gum arabic	62.66	62.17	61.73	61.33	61.97	62.26	62.17	62.12	61.15	61.93
10% Gum arabic	63.94	62.92	61.95	60.27	62.27	63.47	63.02	62.85	61.64	62.75
1% Chitosan	61.34	60.42	59.49	59.60	60.21	60.82	60.38	60.24	60.01	60.36
2% Chitosan	66.16	66.07	65.97	63.80	65.50	65.68	62.63	62.32	61.85	63.12
75% Paraffin oil	64.37	63.89	63.49	61.54	63.33	63.89	63.64	61.03	60.26	62.20
99% Paraffin oil	64.14	63.58	63.11	61.45	63.07	63.69	62.99	62.84	61.81	62.83
Control	60.36	58.36	55.98	53.00	56.92	60.59	60.00	59.49	59.23	59.83
Mean	63.72	62.87	62.00	60.35		63.33	62.67	61.97	61.37	
L.S.D ^{0.05}	(A) = 0.15, (B) = 0.10, (A×B) = 0.31					(A) = 0.22, (B) = 0.14, (A×B) = 0.43				

Table (6): Effect of different coating treatments on respiration rate (ml CO₂ kg⁻¹ hr⁻¹) of Olinda orange fruits during marketing life at 20 °C in 2016 and 2017 seasons.

Treatment (A)	Days of marketing life at 20 °C (B)									
	Season 2016					Season 2017				
	Initial	4	8	12	Mean	Initial	4	8	12	Mean
10% Bee wax	3.30	9.63	12.37	17.59	10.72	3.43	9.50	12.54	16.60	10.52
15% Bee wax	3.26	9.92	12.32	17.43	10.73	3.37	9.41	12.40	16.56	10.44
5% Gum arabic	3.23	9.87	12.18	17.32	10.65	3.33	9.53	12.24	16.30	10.35
10% Gum arabic	3.21	9.52	12.14	17.25	10.53	3.32	9.62	12.36	16.26	10.39
1% Chitosan	3.33	9.68	12.45	17.84	10.82	3.45	9.43	12.41	16.64	10.48
2% Chitosan	3.20	9.53	12.17	17.18	10.52	3.28	9.25	12.22	16.22	10.24
75% Paraffin oil	3.36	9.71	12.52	17.77	10.84	3.48	9.55	12.52	17.04	10.65
99% Paraffin oil	3.23	9.90	12.22	17.40	10.69	3.36	9.64	12.35	16.38	10.43
Control	4.04	10.55	17.37	20.23	13.05	4.18	10.98	17.64	20.64	13.36
Mean	3.35	9.81	12.86	17.78		3.47	9.66	12.96	16.96	
L.S.D ^{0.05}	(A) = 0.29, (B) = 0.19, (A×B) = 0.58					(A) = 0.27, (B) = 0.18, (A×B) = 0.54				

Coatings and films act as semi permeable films that manage the movement of gases and water vapor which finally reduce the rate of respiration and water loss from the fruit. In other words, coatings reduced oxygen and increased CO₂ within the fruit (Porat *et al.*, 2005). Coating provides a modified atmosphere within fruit that decreases respiration (Bayindirli *et al.*, 1995).

Coating establishes thin film of the coating substance to the fruit peel. These coats play as a semi permeable wall against oxygen, carbon dioxide, moisture and solute movements. Therefore, they can control respiration metabolism, and oxidation reaction (Baldwin *et al.*, 1999). Also, in this respect Miranda *et al.* (2004) found that chitosan compound films reduced gas movement through fruit surfaces.

3.2. Fruit chemical characteristics

3.2.1. Ascorbic acid (mg/100 g fresh weight)

The effect of different coating compounds on ascorbic acid content in Olinda oranges during marketing life at 20 °C following cold storage at 5 °C for 90 days in 2016 and 2017 seasons is

presented in Table (7). Ascorbic acid decreased gradually in both seasons under all circumstances. In the first season, chitosan at 2%, followed by 1%, attained the highest significant ascorbic acid content, while the control showed the lowest significant content, after 90 days of cold storage followed by 12 days marketing life chitosan at 2% exhibited the highest ascorbic acid value 37.73 mg/100g fresh weight, whereas uncoated fruits showed the lowest significant ascorbic acid content 35.15 mg/ 100 g fresh weight. In 2017 season, the differences were insignificant between different coated fruits, but the uncoated fruits were significantly lower in ascorbic acid than coated ones. By the end of the storage period, 2% chitosan treatment maintained the highest ascorbic content 36.97 mg/100 g fresh weight. It should be noted that there was no significant difference between the applied coatings in respect to ascorbic acid content on this date, however the uncoated fruits recorded the lowest significant ascorbic acid content 35.94 mg/100 g fresh weight.

Table (7): Effect of different coating treatments on ascorbic acid content of Olinda orange (mg / 100 g FW) during marketing life at 20 °C in 2016 and 2017 seasons.

Treatment (A)	Days of marketing life at 20 °C (B)									
	Season 2016					Season 2017				
	Initial	4	8	12	Mean	Initial	4	8	12	Mean
10% Bee wax	47.27	44.26	38.26	36.48	41.56	47.64	43.29	38.46	36.54	41.48
15% Bee wax	47.35	44.33	38.33	36.96	41.74	47.67	43.32	38.38	36.57	41.48
5% Gum arabic	47.21	44.20	38.20	36.08	41.42	47.62	43.26	37.99	36.51	41.35
10% Gum arabic	47.60	44.59	38.92	37.14	42.06	48.00	43.32	38.34	36.73	41.60
1% Chitosan	47.82	44.82	39.15	37.58	42.34	48.10	43.08	38.22	36.85	41.56
2% Chitosan	47.84	44.84	39.18	37.73	42.40	48.14	43.13	38.21	36.97	41.61
75% Paraffin oil	47.56	44.44	38.44	37.07	41.88	47.88	43.34	38.39	36.61	41.55
99% Paraffin oil	47.77	44.76	39.16	37.24	42.23	48.02	43.19	38.26	36.80	41.57
Control	46.36	40.77	37.84	35.15	40.03	46.59	40.60	37.89	35.94	40.25
Mean	47.42	44.11	38.61	36.83		47.74	42.95	38.24	36.61	
L.S.D ^{0.05}	(A) = 0.52, (B) = 0.35, (A×B) = 1.04					(A) = 0.36, (B) = 0.24, (A×B) = 0.73				

Ascorbic acid is the key antioxidant found in citrus fruits (Abhay *et al.*, 2012). Its preservation has been reported as a quality indicator during marketing life of citrus fruits (Lee and Kader 2000). The loss in ascorbic acid during storage was in line with the study of Nath *et al.* (2012). Lee and Kader (2000) found that ascorbic acid oxidase, polyphenol oxidase and peroxidase activity are considered the main reasons for ascorbic degradation. The present study demonstrated that the coating treatments delayed the loss of ascorbic acid at the marketing life of stored Olinda oranges. Wax significantly caused an inhibition in ascorbic acid reduction of Valencia orange (Dang *et al.*, 2010). Meanwhile, chitosan coating beneficially influenced ascorbic acid content on citrus (Zeng *et al.*, 2010).

Our findings were similar to Kumar *et al.* (2000) results; this preservation of ascorbic acid in coated fruits might be due to the delaying or decreased oxidation of ascorbic acid content, which finally resulted in higher vitamin C content compared with the control.

3.2.2. Total soluble solids / acid ratio

Data presented in Table (8) illustrate the influence of different applied coatings on TSS/acid ratio of Olinda oranges during marketing life at 20°C in 2016 and 2017 seasons. TSS/acid ratio increased continually in both seasons under all conditions. In the first season, the untreated fruits attained the highest significant ratio. On the other hand, 2% chitosan exhibited the lowest significant ratio. By the end of the storage period, the control and paraffin (at 75%) treatments showed the highest significant TSS/acid ratios (12.57 and 12.52, respectively). While, 2% chitosan recorded the lowest significant TSS/acid ratio (12.08). In the following season, the highest significant

TSS/acid ratio appeared in the control, while 2% chitosan, 1% arabic gum, 2% bee wax and 10% arabic Gum showed the lowest significant ratios. By the end of the storage period, the untreated fruits showed the highest significant ratio (12.38), On the contrary, 2% chitosan and 10% arabic gum treatments showed the lowest significant TSS/acid ratios as 11.75 and 11.81 respectively.

From the obtained results TSS/ acid ratio increased gradually during marketing life period. It might be mainly because of the decreased acidity due to consumption of acids during respiration processes (Kittur *et al.*, 2001). Also, deterioration of ascorbic acid leads to sugar formation (Lee and Kader, 2000). Similar observations were found in pervious work by Sindhu and Singhrot (1996) on lime fruits. Meanwhile chitosan treatment had higher ability to manage the decrease in the total acidity of citrus fruits after about 2 months of storage at 15°C (Zhang *et al.*, 2011).

3.2.3. Pectin methyl esterase activity (Δ A620 $\text{mg}^{-1} \text{protein min}^{-1}$)

Table (9) shows the effect of different coating treatments on pectin methyl esterase activity of Olinda oranges during marketing life at 20°C in 2016 and 2017 seasons. Results indicated a diminishing tendency of pectin methyl esterase activity in both seasons under all conditions. In the first season, 2% chitosan showed the highest significant pectin methyl esterase activity value, whereas the lowest significant value was found in the control. At the end of the storage period, chitosan at 2% treatment showed the highest significant pectin methyl esterase activity (1.083), whereas the control showed the lowest significant pectin methyl esterase activity (0.985).

Table (8): Impact of some coating treatments on TSS /acid ratio of Olinda orange during marketing life at 20 C in 2016 and 2017 seasons.

Treatment (A)	Days of marketing life at 20°C (B)									
	Season 2016					Season 2017				
	Initial	4	8	12	Mean	Initial	4	8	12	Mean
10% Bee wax	8.37	10.67	11.37	12.31	10.68	8.33	10.62	11.30	11.98	10.56
15% Bee wax	8.26	10.45	11.32	12.30	10.58	8.27	10.38	11.24	11.90	10.45
5% Gum arabic	8.21	10.56	11.18	12.18	10.53	8.29	10.47	11.17	11.85	10.44
10% Gum arabic	8.23	10.63	11.14	12.14	10.54	8.26	10.56	11.18	11.81	10.45
1% Chitosan	8.31	10.71	11.45	12.46	10.73	8.31	10.64	11.37	12.12	10.61
2% Chitosan	8.20	10.52	11.17	12.08	10.49	8.27	10.47	11.19	11.75	10.42
75% Paraffin oil	8.42	10.85	11.52	12.52	10.83	8.35	10.75	11.44	12.19	10.68
99% Paraffin oil	8.30	10.69	11.22	12.25	10.61	8.31	10.62	11.20	11.91	10.51
Control	8.63	10.96	12.20	12.57	11.09	8.42	10.91	12.19	12.38	10.97
Mean	8.32	10.67	11.40	12.31		8.31	10.60	11.37	11.99	
L.S.D ^{0.05}	(A) = 0.10, (B) = 0.07, (A×B) = 0.21					(A) = 0.22 (B) = 0.15, (A×B) = 0.44				

Table (9): Effect of different coating treatments on pectin methyl esterase activity* of Olinda orange during marketing life at 20 °C in 2016 and 2017 seasons.

Treatment (A)	Days of marketing life at 20 °C (B)									
	Season 2016					Season 2017				
	Initial	4	8	12	Mean	Initial	4	8	12	Mean
10% Bee wax	1.167	1.076	1.027	1.008	1.070	1.213	1.128	1.088	0.983	1.103
15% Bee wax	1.147	1.110	1.078	1.055	1.098	1.198	1.149	1.075	1.046	1.117
5% Gum arabic	1.136	1.084	1.041	1.015	1.069	1.156	1.112	1.084	0.993	1.086
10% Gum arabic	1.126	1.114	1.113	1.058	1.103	1.150	1.145	1.118	1.049	1.115
1% Chitosan	1.139	1.094	1.086	1.035	1.089	1.168	1.136	1.092	1.028	1.106
2% Chitosan	1.117	1.208	1.151	1.083	1.140	1.121	1.120	1.120	1.114	1.119
75% Paraffin oil	1.143	1.104	1.097	1.050	1.098	1.178	1.149	1.106	1.032	1.116
99% Paraffin oil	1.138	1.086	1.058	1.022	1.076	1.162	1.131	1.088	1.005	1.096
Control	1.247	1.066	0.972	0.985	1.067	1.218	1.090	1.045	0.979	1.083
Mean	1.151	1.105	1.069	1.034		1.174	1.129	1.091	1.025	
L.S.D ^{0.05}	(A) = 0.025, (B) = 0.017, (A×B) = 0.051					(A) = 0.036, (B) = 0.024, (A×B) = 0.073				

* PME activity was defined as $\Delta A_{620} \text{ mg}^{-1} \text{ protein min}^{-1}$.

In the second season, 2% chitosan showed the highest pectin methyl esterase activity, while the control showed the lowest pectin methyl esterase activity, but the differences were insignificant between all treatments. After 12 days of marketing life period, 2% chitosan treatment showed the highest significant pectin methyl esterase activity 1.114, whereas the control showed the lowest significant activity (0.979). Pectin methyl esterase and polygalacturonase are the main responsible enzymes of cell wall changes and softening and the actions of these enzymes often increase during over ripening (Carvalho *et al.*, 2009).

Pectin methyl esterase activity depends on pectin content, and conversion of insoluble proto pectin into soluble pectin that acts as a substrate for pectin methyl esterase enzyme, this enzyme hydrolyzed pectin substances, leading them to expose for polygalacturonase action (Wong, 1995). Results are in similar trend with those mentioned by Carvalho *et al.* (2009), PME activity was found to decrease sharply after eight days, where this decline in activity might be due to pectin decrease that works as the substrate for this enzyme.

The presented data illustrated that fruits coated by chitosan recorded higher pectin methyl esterase activity, which declare delayed hydrolysis in pectin substances, and maintaining firmness. The results are in line with Ali *et al.* (2004) findings that approved the role of wall degrading enzymes on pectin changes and firmness of tropical fruits.

Conclusion

Coating Olinda oranges fruits with different coatings as bee wax, chitosan, paraffin oil and

arabic gum prolong marketing life with higher fruit quality compared with the uncoated fruits. The results indicated that chitosan, at 2%, provided the lowest significant weight loss and discarded fruits percentages after 90 days of cold storage and 12 days of simulated marketing life. In addition, chitosan at 2% delayed the colour changes, and decreased respiration rate compared to the control. All coatings, especially chitosan (at 2 and 1%) were effective in maintaining ascorbic acid content compared to the uncoated fruits. Moreover, it managed fruit compositions such as TSS/acid ratio. Additionally, 2% chitosan maintained pectin substances and delayed the hydrolysis by pectin methyl esterase enzyme that attained higher firmness compared with the control during marketing life. This suggested the appreciable role of chitosan coating enhancing marketing life and improving postharvest quality of Olinda orange fruits.

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استخدام بعض معاملات ما بعد الحصاد الآمنة للحفاظ على جودة ثمار البرتقال الاوليندا
خلال فترة العمر التسويقي

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ملخص

يتطلب إطالة عمر الثمار بعد الحصاد زيادة العمر التخزيني خلال التخزين المبرد مع فترة عمر تسويقي مناسبة. تم في هذا الاطار تقدير مدى استجابة بعض خصائص الجودة للبرتقال الاوليندا للمعاملة بالصمغ العربي، شمع نحل العسل، زيت البرافين والشيتوزان خلال فترة محاكاة العمر التسويقي على 20°م لمدة 12 يوم و ذلك عقب التخزين المبرد على 5°م ورطوبة نسبية 90-95% لمدة 90 يوم. أعطت جميع المعاملات تأثيرات مرغوبة على خصائص الجودة مقارنة بالثمار غير المعاملة، كانت المعاملة بالشيتوزان بتركيزات 1 و 2% هي الأفضل حيث أدت إلى الحفاظ على حامض الاسكوربيك بصورة كبيرة مقارنة بالثمار غير المعاملة. كما أظهرت المعاملة بالشيتوزان بتركيز 2% أقل معدلات من الفاقد في الوزن والفاقد من الثمار، وأيضا أبطأت من التغيرات المصاحبة لشيخوخة الثمار كتغيرات اللون ، الليونة و نشاط انزيم البكتين ميثيل استريز، وفضلا عن ذلك تأثيرها المعنوي على معدل التنفس مقارنة بالثمار غير المعاملة. ان استخدام معاملات التشميع قد تكون وسيلة سهلة وفعالة لإطالة العمر التسويقي لثمار البرتقال الاوليندا.

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