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RESEARCH ARTICLE

Maintaining Valencia orange quality during shelf life using different waxes

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ABSTRACT

Extending postharvest fruit life demand elongation cold storage period with reasonable shelf life, in this scope quality of Valencia orange was determined in response for Arabic gum, bee wax, paraffin oil and chitosan coatings during simulated shelf 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, chitosan at 2 and 1% were effective in maintaining ascorbic acid content compared to 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 methylesterase activity. In addition to valuable means of respiration rate compared to uncoated ones.

Key words: Coating, bee wax, Arabic gum, chitosan, paraffin oil, storage

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INTRODUCTION

Citrus has a great nutritional and marketable rank in Egypt. It is considered one of the strategic exportation fruits, orange cv. Valencia took an important abroad marketing position in previous years. Traders demand fruits in high specified quality and long life, which practically mean elongation of cold storage and shelf life period. Coating is a traditional practice in orange handling for reparation the natural wax which might be washed off or distraught during preparation (Shaw et al., 1993).

Waxing has been used as protection technique for fruits and vegetables (Baldwin et al., 1995), the main goals of this application are to reduce the water loss from the fruits, decrease weight loss, Baldwin et al., (1999) reported that coating can decrease fruit weight loss by up to 50%, and it can preserve fruit in high quality. Earlier studies have been focused on different wax films for fruits (Saftner, 1999; Shein et al., 2008; El-Anany et al., 2009). McGuire (1997) found that waxing reduce respiration rate significantly, and coated fruit keep better physical appearance and to enhance the brightness to improve appearance, but showed distinguished taste.

However, many of the commercial coatings are disapproved because its composition or unsafe, recently consumers have demand for healthy products, that need follow up and evaluation for different waxing alternatives (Porta et al., 2013, Nayik and Khalid, 2014). Arabic gum is a dried, gummy exudate from the stems or branches of Acacia species. It is the smallest gelatinous and most soluble of the hydrocolloids, and is used widely in the industrial purposes in regard to its emulsification, film forming and encapsulation properties (Motlagh et al., 2006).

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Chitosan is a high molecular mass, it is effective as antioxidant and capable of in maintaning ascorbic acid in fruit, so that chitosan is a highly recommended polymer for the production of edible films (Tendaj and Tendaj, 1998). Also, coatings of bee wax were used in some fruits (Shahid and Abbasi, 2011) as an edible film. Paraffin waxes are hydrocarbons, mixture of alkanes usually in a symmetric series of chain lengths, paraffin waxes were used in wide range but it has a side effect on fruit gloss (Salman et al., 2008).

This study aimed to evaluate the effects of various coatings; Arabic gum, bee wax, paraffin oil and chitosan coatings on the quality changes of Valencia 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, in demand for comparison studies among different coatings, and determine these coatings on Valencia orange fruit quality during shelf life.

MATERIALS AND METHODS

This study was applied in 2016 and 2017 seasons on Valencia orange (*Citrus sinensis* L.), oranges were hand harvested according to indices that cited by Kader (1992) from a private field located in El-Behira governorate, Egypt.

Fruits were handled 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 (Kader, 1992).

Different waxes prepared as following; 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 was became completely hydrated according to Hassan et al. (2014).

Arabic gum solutions (5 or 10% w/v) were prepared by dissolving arabic gum in distilled water and heated at 40°C according to the method described by Asgar et al. (2010), with ongoing basis stirring for 60 min using a magnetic stirrer hot plate until the solution became pure, 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 Ameria - Cairo, Egypt) and used with the procedure that mentioned by El-Anany et al. (2009).

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

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

Then all fruits were air-dried, and packed in cartoon boxes (12 fruits capacity) and stored at 5°C and 90-95% RH for 90 days, then stored at 5°C and 90% RH to simulate shelf life for 12 days, all fruits were evaluated before transfer to shelf life conditions and at 4 days intervals using three fruits from each replicate of each treatment, taking into consideration it divided in groups for weight loss evaluation, decay monitoring, and sampling for physical and chemical analysis, the following quality parameters were estimated; total soluble solids/ acid ratio calculated using TSS and total acidity data, TSS was evaluated by refractometer using drops of the fruit juice, total acidity was assessed by titration method (A.O.A.C. 1980) and expressed as percentage of the dominant acid in the fruit (citric acid).

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

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 using extraction buffer of 101 M potassium phosphate, 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.

Weight loss percentage was calculated using the following formula; (fruit initial weight - fruit weight at each sampling date) × 100 / fruit initial weight.

Decay percentage was calculated as number of discarded fruits / total number of fruits × 100; discarded fruits included any signs of pathological, physiological disorders or chilling injury.

Instrumental slice colour was measured in the CIE L* a* b* on two opposite sides of fruit objectively using a Minolta CR-400 chroma meter (Minolta, Osaka, Japan) according to McGuire (1992).

Fruit firmness was determined according to Mitcham et al. (2003) using fruit pressure tester (8 mm diameter probe) on the opposite surfaces of each fruit, data was presented as lb/inch2. Respiration rate as ml of CO2 / kg / hr was measured by gas chromatography (Model 1450-Servomex 1400), fruits were incubated in 4-liter airtight glass jars for 24 hr under the same experimental conditions according to McCollum et al. (1993).

The obtained data were analyzed according to Snedecor and Cochran (1989), following complete randomized block design; values were compared based on the LSD at the 5% level of significance.

RESULTS AND DISCUSSION

Weight loss

Table 1. shows the effect of different waxes on Valencia orange weight loss during shelf life at 20°C after 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 value, while 2% chitosan and 99% paraffin showed the lowest significant values, at the end of shelf life period control treatment showed the highest 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 value. At the end of storage period untreated showed the highest significant value (16.43%), whereas chitosan at 2% showed the lowest significant percentage (13.32%).

Fruit water loss is a considerable problem during fruit handling, it results in decrease in fruit nutrition value, weight loss and shrinkage, fruit waxing is one of the most applied solutions for this problem.

High rates of respiration are the main responsible for moisture loss, coating provide thin film to fruit peel, that consider a semi permeable barrier versus gas exchange, and evaporation (Miranda, 2004), the current study declare similar findings and proposed treatment of chitosan at 2% as the most effective film in keeping fruit moisture.

Table 1. Effect of different coatings on Valencia orange weight loss (%) during shelf life at 20°C in 2016 and 2017 seasons.

Treatment (A)	Days of shelf life at 20°C (B)									
	Season 2016					Season 2017				
	0	4	8	12	Mean	0	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% Arabic gum	0.00	1.57	5.96	14.15	5.42	0.00	3.13	6.24	14.96	6.08
10% Arabic gum	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	0.00	1.32	7.36	14.74	5.85	0.00	1.79	6.57	14.46	5.71
99 % paraffin	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				

Table 2. Effect of different coatings on Valencia orange Decay (%) during shelf life at 20°C in 2016 and 2017 seasons.

Treatment (A)	Days of shelf life at 20°C (B)									
	Season 2016					Season 2017				
	0	4	8	12	Mean	0	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% Arabic gum	0.00	8.88	12.44	18.89	10.05	0.00	8.33	11.82	19.44	9.90
10% Arabic gum	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	0.00	7.22	12.05	18.33	9.40	0.00	7.77	12.20	18.33	9.58
99 % paraffin	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				

Dacay

Data in Table 2. declare the effect of different waxes on Valencia orange decay during shelf life at 20°C in 2016 and 2017 seasons, Decay increased gradually in both seasons under all conditions. In the first season, untreated fruits showed the highest significant value, while 2% chitosan showed the lowest significant value, after 12 days of shelf life period control treatment showed the highest significant percentage (68.33%), whereas chitosan at 2 and 1% treatments showed the lowest significant value 16.66%.

In the second season, untreated fruits showed the highest significant value, while 2% chitosan showed the lowest significant value, at the end of shelf life period control treatment showed the highest significant value (67.22%), whereas 2% chitosan and 99% paraffin treatments showed the lowest significant values 15.55 and 16.66% respectively.

Decay percentage seem 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 minimize gas exchange and respiration rate which is reflected in the rate of deterioration, also it block out minor lesions on the external fruit surface that reduce fruit diseases, and chilling injury.

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 reduce decay percentage occurrence of 1.6 to 3.2 times compared to uncoated fruits.

Firmness

Fruit hardness is considered one of the limiting shelf life, Table 3 declares the effect of different waxes on Valencia orange firmness during shelf life at 20°C after cold storage in 2016 and 2017 seasons, hardness showed a steeper decline in both seasons under all conditions. In 2016 season, all coated fruits except both bee wax concentrations showed the highest significant values compared to control that showed the lowest significant force, by the end of storage period 10% Arabic gum and 2% chitosan treatment maintained the highest significant values 12.25 and 12.21, while control recorded the lowest significant value 10.12. In 2017 season, 2% chitosan was the highest significant hardness and the lowest significant value was control. By the end of storage period 2% chitosan treatment showed the highest significant value 12.73, whereas control treatments showed the lowest significant value 9.80 lb/inch2.

Table 3. Effect of different coatings on Valencia orange firmness (lb/inch2) during shelf life at 20°C in 2016 and 2017 seasons.

Treatment (A)	Days of shelf life at 20°C (B)									
	Season 2016					Season 2017				
	0	4	8	12	Mean	0	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% Arabic gum	17.39	15.96	15.30	12.15	15.20	15.52	14.77	14.05	12.14	14.12
10% Arabic gum	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	16.82	15.88	15.54	11.90	15.04	15.05	14.63	13.90	11.33	13.73
99 % paraffin	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				

Coatings can prevent water loss and decrease cell wall breakdown and maintain fruit firmness during shelf life periods that similar to results mentioned 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).

Instrumental colour

L* score indicate to brightness, chroma is the quality of a colour's pureness and intensity (Nambi *et al*. 2015). Peel colour is an important quality index, it reveal the consumer acceptability (Campbell et al., 2004).

Table 4 presents the impact of different waxes on Valencia orange peel C colour during shelf 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 value, while control recorded the lowest significant value, at the end of shelf life period 2% chitosan treatment showed the highest significant value (73.79), whereas control treatments showed the lowest significant C colour value (70.75).

In the second season, the highest significant value chitosan at 2%, while the lowest significant value was bee wax at 10 %. At the end of storage period 2% chitosan treatment showed the highest significant value (74.81), whereas control treatments showed the lowest significant value (70.58). Table 5. shows the effect of different waxes on Valencia orange peel L colour during shelf 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 value, whereas control was the lowest significant value, by the end of storage period chitosan at 2% treatment showed the highest significant value (63.80) whereas control treatments showed the lowest significant value (53.00). In the second season, the highest significant value was 2% bee wax, the lowest significant value control, by the end of storage period 2% bee wax treatment showed the highest significant value 63.43, while control treatments showed the lowest significant value (59.23).

Table 4. Effect of different coatings on Valencia orange C colour score during shelf life at 20°C in 2016 and 2017 seasons.

Treatment (A)	Days of shelf life at 20°C (B)									
	Season 2016					Season 2017				
	0	4	8	12	Mean	0	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% Arabic gum	72.65	72.04	71.83	71.63	72.04	74.16	74.07	73.81	73.69	73.93
10% Arabic gum	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	73.26	72.88	72.47	71.99	72.65	73.51	73.27	72.90	72.68	73.09
99 % paraffin	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				

Table 5. Effect of different coatings on Valencia orange L colour score during shelf life at 20°C in 2016 and 2017 seasons.

Treatment (A)	Days of shelf life at 20°C (B)									
	Season 2016					Season 2017				
	0	4	8	12	Mean	0	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% Arabic gum	62.66	62.17	61.73	61.33	61.97	62.26	62.17	62.12	61.15	61.93
10% Arabic gum	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	64.37	63.89	63.49	61.54	63.33	63.89	63.64	61.03	60.26	62.20
99 % paraffin	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				

Chitosan retained a glossy appearance compared with untreated fruits that showed unacceptable colour shortly that might be to the higher changes in pigments. These results also in agreement with the findings of Singh et al. (1997). Coating maintain acceptable appearance of fruits and therefore their marketable. This may also due to delay in deterioration, uniform colour development in fruits under shine chitosan coating in advanced period of marketing life, similar results observed by Pandey et al. (2010) in guava fruit treated with waxes.

Respiration rate

Table 6 shows the effect of different waxes on Valencia orange respiration rate during shelf life at 20°C in 2016 and 2017 seasons, Respiration rate increased continually in both seasons under all conditions. In the first season, control showed the highest significant value, while 2% chitosan and 10% Arabic gum recorded the lowest significant values, by the end of storage period control treatment showed the highest significant value 20.23, whereas 2% chitosan treatments showed the lowest significant value 17.18.

In the second season, untreated fruits recorded the highest significant respiration rate, while chitosan at 2% rercorded the lowest significant rate, by the end of marketing period control showed the highest significant value 20.64, whereas 2% chitosan treatments attained 16.22 that was the lowest value whereas the difference between the different treatments in this date were insignificant. Coatings and films act as semi permeable films that manage the movement of gases and water vapor to reduce the rate of respiration and water loss from the fruit. In other words coatings reduced oxygen and increase CO_2 within the fruit (Porat et al. 2005).

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).

Table 6. Effect of different coatings on respiration rate (ml CO_2/ kg/hr) during shelf life at 20°C in 2016 and 2017 seasons.

Treatment (A)	Days of shelf life at 20°C (B)									
	Season 2016					Season 2017				
	0	4	8	12	Mean	0	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% Arabic gum	3.23	9.87	12.18	17.32	10.65	3.33	9.53	12.24	16.30	10.35
10% Arabic gum	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	3.36	9.71	12.52	17.77	10.84	3.48	9.55	12.52	17.04	10.65
99 % paraffin	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				

Ascorbic acid

The effect of different coating compounds on ascorbic acid content in Valencia orange during cold storage at 5°C followed by shelf life at 20°C in 2016 and 2017 seasons is presented in Table 7., ascorbic decreased gradually in both seasons under all circumstances. In the first season, chitosan at 2 and 1% attained the highest significant content, while control showed the lowest significant value, after 90 days of cold storage followed by 12 days shelf life chitosan at 2% exhibited the highest value 37.73, whereas uncoated fruits showed the lowest significant value 35.15, In the other season, the differences were insignificant between coated fruits, but uncoated was significantly lower than coated ones, by the end of storage period 2% chitosan treatment maintained the highest ascorbic content 36.97, It should be noted that there was no significant difference between the applied waxes in respect to total ascorbic acid content in this date, however uncoated fruits recorded the lowest significant content 35.94 mg/100 g FW.

Table 7. Effect of different coatings on Valencia orange ascorbic (mg / 100 g FW) during shelf life at 20°C in 2016 and 2017 seasons.

Treatment (A)	Days of shelf life at 20°C (B)									
	Season 2016					Season 2017				
	0	4	8	12	Mean	0	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% Arabic gum	47.21	44.20	38.20	36.08	41.42	47.62	43.26	37.99	36.51	41.35
10% Arabic gum	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	47.56	44.44	38.44	37.07	41.88	47.88	43.34	38.39	36.61	41.55
99 % paraffin	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, 2012). Its preservation has been reported as a quality indicator during shelf-life of citrus-derived products (Lee and Kader 2000). The loss in ascorbic acid during storage was in line with the study of Nath et al. (2010). Lee and Kader (2000) found that ascorbic acid oxidase, polyphenol Oxidase and peroxidase activity the main reason for ascorbic degradation. 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 control.

Total soluble solids / acid ratio

Data presented in Table 8 illustrates the influence of different applied waxes on Valencia orange TSS/acid ratio during shelf life at 20°C in 2016 and 2017 seasons, TSS/acid ratio increased continually in both seasons under all conditions. In the first season, untreated fruits attained the highest significant ratio, on the other hand 2% chitosan scored the lowest significant ratio, by the end of storage period control paraffin at 99 and 75% showed the highest significant ratios (12.57 and 12.52 respectively). While 2% chitosan recorded the lowest significant ratio (12.08). In the followed season, the highest significant ratio was control, while 2% chitosan , 1% Arabic gum, 2% bee wax and 10% Arabic gum showed the lowest significant ratios, by the end of storage period untreated fruits showed the highest significant ratio 12.38, On the contrary 2% chitosan and 10% Arabic gum treatments showed the lowest significant ratios 11.75 and 11.81 respectively.

Table 8. Effect of different coatings on Valencia orange TSS /acid ratio during shelf life at 20°C in 2016 and 2017 seasons.

Treatment (A)	Days of shelf life at 20°C (B)									
	Season 2016					Season 2017				
	0	4	8	12	Mean	0	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% Arabic gum	8.21	10.56	11.18	12.18	10.53	8.29	10.47	11.17	11.85	10.44
10% Arabic gum	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	8.42	10.85	11.52	12.52	10.83	8.35	10.75	11.44	12.19	10.68
99 % paraffin	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				

As it can be distinguished from the obtained results TSS/ acid ratio increased gradually during shelf life period, it might be mainly because decreased acidity due to consumption of acids during respiration processes. Similar observations were found in pervious work by Sindhu and Singhrot (1996) on lime fruits, Also, deterioration of ascorbic acid lead to higher sugare (Lee and Kader, 2000) .

Pectin methyl esterase

Table 9 shows the effect of different waxes on Valencia orange Pectin methyl esterase activity during shelf life at 20°C in 2016 and 2017 seasons, Results indicated a diminishing tendency pectin methyl esterase activity in both seasons under all conditions, in the first season, 2% chitosan showed the highest significant value, the lowest significant value Control, at the end of storage period 2% chitosan treatment showed the highest significant value (1.083), whereas control showed the lowest significant activity (0.985). In the second season, 2% chitosan showed the highest PME activity, while control showed the

lowest PME activity, but the differences were insignificant between all treatments. After 12 days of shelf life period 2% chitosan treatment showed the highest significant activity 1.114, whereas control showed the lowest significant activity 0.979.

Table 9. Effect of different coatings on Valencia orange Pectin methyl esterase activity* during shelf life at 20°C in 2016 and 2017 seasons.

Treatment (A)	Days of shelf life at 20°C (B)									
	Season 2016					Season 2017				
	0	4	8	12	Mean	0	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% Arabic gum	1.136	1.084	1.041	1.015	1.069	1.156	1.112	1.084	0.993	1.086
10% Arabic gum	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	1.143	1.104	1.097	1.050	1.098	1.178	1.149	1.106	1.032	1.116
99 % paraffin	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 Δ A620 mg-1 protein min-1

PME and PG (polygalacturonase) are the main responsible enzymes of cell wall changes and softening and actions of these enzymes often increase during over ripening (Carvalho et al. 2009). Pectin methyl esterase activity depend on pectin content, and conversion of insoluble proto pectin into soluble pectin that acts as a substrate for PME enzyme, PME hydrolyzed pectic substances, leading them to expose for PG action (Wong, 1995). Results are in similar trend with those mentioned by Carvalho et al. (2009); PME activity was found to after 75 days , this decline in activity might be due to pectin decrease that the substrate for this enzyme. The presented data illustrated that fruits coated by chitosan recorded higher PME activity, which declare delayed hydrolysis in pectin substances, and maintaining firmness. Finally, In spite of quality changes with prolongation storage time, chitosan at 2% achieved the lowest significant weight loss and decay percentages after 90 days of cold storage and 12 days of shelf life. Also chitosan at 2% delayed the colour changes, and decreased respiration compared to control. All coatings, especially chitosan at 2 and 1% were effective in maintaining ascorbic acid content compared to uncoated ones. Additionally 2% chitosan recorded the lowest significant TSS/acid ratios rather than control that showed the highest, moreover that it maintained the highest significant hardness. Which suggested the appreciable role of chitosan as applied coating during cold storage and prolongation marketing life.

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