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ORIGINAL ARTICLES

Effect of Chitosan and Calcium Chloride Spraying on Fruits Quality of Florida Prince Peach Under Cold Storage

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ABSTRACT

This work was carried out during two successive seasons (2009) and (2010) to examine the response of Florida Prince peach fruits to some pre-harvest treatments i.e. chitosan at 0.5 and 1.0% , and $CaCl_2$ at 2 and 4 % as well as their combinations on some fruit quality parameters under cold storage . Fruit weight loss (%), decay (%) and T.S.S.(%) of Florida Prince peach fruits were increased in most cases with advancing the storage duration. However, fruit firmness and titratable acidity (%) were decreased with advancing the storage period. Meanwhile, the lowest values of weight loss (%) and decay (%) and the best results of shelf life and firmness were gained by using the treatment of 1% chitosan + 4% $CaCl_2$. In addition, the highest fruit T.S.S., besides the lowest fruit titratable acidity percentage was scored by control and chitosan treatments during the storage period.

Key words: Florida Prince peach, Pre-harvest treatments, Chitosan, $CaCl_2$, Physical and Chemical properties.

Introduction

Peach is considered one of the most important deciduous fruit that shows great success and is widespread in the newly reclaimed areas in Egypt. The fruit may be consumed fresh or processed into jam or jelly. Plant growth regulators leave residues that are a potential risk to human health and to the environment, and their use is being restricted in developed countries. Thus, it seems necessary to develop new substances to reduce these disorders.Chitosan is non-toxic, non-allergenic, edible and safe for domestic animals (Hirano *et al.,* 1990). It is a low acetyl form of chitin mainly composed of glucosamine, 2-amino-2- deoxy-*β*-D-glucose (Freepons, 1991).

Chitosan is one of the most common natural polymers that can be obtained from various species, particularly from the exoskeletons of crustaceans. It is also found in cuticles of insects as well as in the cell walls of fungi and some algae (Sandford and Hutchings, 1987 and EPA, 1995). Chitosan is a polysaccharide derived from a low acetyl form of chitin, mainly composed of glucosamine and *N*-acetylglucosamine. Its structure and composition is similar to both cellulose and chitin (Freepons, 1991 and Hadwiger and McBride, 2006). Chitosan has been used in agriculture as a coating material for vegetables, fruits and seeds (Zhang and Quantick, 1998; Jiang and Li, 2001and Photchanachai *et al.,* 2006), for controlled agrochemical release of fertilizers (Sukwattanasinitt *et al*., 2001), to stimulate plant immune systems, plant growth and plant production and also to protect plants against attack by microorganisms (Hadwiger *et al*., 2002).Utsunomiya and Kinai (1994) applied chitosan-oligosaccharides to soil used for cultivating passion fruit.

Calcium is the most important mineral element determining fruit quality. The multiple roles of Ca are associated with the plant cell. Soluble Ca is involved in protein phosphorylation via Ca-Cal- modulin binding. A large portion of the Ca in plant cells is located in the cell wall and plasma membrane where it plays a major role in senescence and ripening. Concentrations of 1-5 mm Ca^{2+}occur in the cell wall region (Poovaian *et al*., 1988). Cell wall-bounded Ca is involved in maintaining cell wall integrity by binding carboxyl groups of polygalacturonate chains, which are mainly present in the middle lamella and primary cell wall (Chardonnet *et al*., 2003).Preharvest Ca treatments used to increase Ca content of the cell wall were effective in delaying senescence, resulting in firmer and higher fruit quality (Serrano *et al*., 2004; Kluter *et al.,* 2006 and Raese and Drake, 2006). Furthermore, Hulme (1971) mentioned that K^+ and Ca^{2+} inhibit amylase activity and stimulate invertase activity. Also, the accumulation of K^+ and Ca^{2+} ions in injured tissue might contribute to the difference in the activity of the two enzymes in chilled tissue.

Materials And Methods

"Florida Prince" peach trees 8 years old grown in a sandy soil at a private orchard, El Khatatba City, El-Minufiya Governorate were selected for this study. The selected trees were sprayed three times at two weeks

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intervals starting in the first week of March with 0.5 and 1.0% chitosan and calcium chloride at 2 and 4% in two successive seasons (2009) and (2010), control trees were sprayed with tap water. All treatments were sprayed with handgun till run off, the fruits from each treatment were hand harvested in the second half of April. The harvested mature fruits were at the optimal commercial fresh market flavour development and healthy fruits free from any physiological and pathological disorders were chosen and washed with water containing Borax at 5% as a fungicide and then air dried. Each treatment during the two seasons of the study was replicated three times, each replicate was represented with six boxes, each box was lined with butter paper and contained 2kg of fruits. The boxes were stored at 0±2 ˚C and 90-95 % R.H. Three of these boxes were employed to determine the changes in physical properties and the other ones were employed for the determination of chemical properties during storage. Physical properties i.e. Fruit decay%, weight loses % and firmness were determined every seven days. Also, chemical constituents determinations were carried out every 7 days by using three fruits that were taken from the other boxes employed for chemical properties determination.

Effect of the tested treatments (chitosan and calcium chloride) on "Florida Prince" peach fruits were evaluated through the following determinations:

1. Fruit physical properties:

1.1. Fruit weight loss percentage:

The initial weight of peach fruits was recorded in each treatment and at weekly intervals, then fruit weight loss % was calculated by weighing the same fruits at each interval and at the end of cold storage duration using the following formula:

$$\text{Fruit weight loss \%} = \frac{\text{Initial weight} - \text{Weight at specific interval}}{\text{Initial weight}} \times 100$$

1.2. Fruit decay percentage:

The decayed fruits of each treatment were discarded and weighed. The weight of such discarded fruits related to the initial weight of fruits per each treatment was estimated and decay percentage was calculated.

1.3. Fruit firmness (Ib/inch^2):

Three fruits of each replicate were taken at weekly intervals to determine the changes in fruit firmness using the Effegi firmness tester with an 5/16" plunger (Effegi 48011 Alfonsine, Italy). Fruit firmness was expressed in Ib/inch^2.

1.4. Shelf life (days):

At the end of cold storage period, samples of the treated fruits were taken and left at room conditions (25±5 ˚C and 65-70% R.H.) and the number of days at which treated fruits remained with good appearance were counted and shelf life was determined.

2. Fruit chemical properties:

2.1. Fruit total soluble solids:

Total soluble solids of peach fruit juice were measured using a hand refractometer, according to (A.O.A.C. 1985). The total soluble solids were expressed as a percent.

2.2. Fruit titratable acidity:

Peach fruit juice samples (5 ml) were used and titrated with 0.1 N sodium hydroxide in the presence of phenolphthalein as an indicator, according to A.O.A.C. (1985). The titratable acidity was expressed as grams of malic acid per 100 ml of juice.

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Statistical Analysis:

Data obtained in the two studied seasons were subjected to the analysis of variance according to Snedecor and Cochran (1989) least significant differences (L.S.D.) were used to differentiate between means of the obtained values.

Results And Descussion

Effect of chitosan and calcium chloride treatments on:

1. Fruit physical properties:

1.1. Fruit weight loss percentage:

As for the effect of storage period, data in Table (1) clear that fruit weight loss percentage was increased with increasing the storage period. So, thirty five days storage period under cold storage recorded the highest value, whereas the lowest value was obtained after seven days under cold storage in both seasons. The statistical analysis emphasizes that the differences between the aforementioned cold storage durations were high to be significant.

With regard to the effect of the tested pre-harvest treatments, data reported in Table (1) demonstrate that 1% chitosan + 4% $CaCl_2$ treated-fruits showed to be the superior one in reducing fruit weight loss percentage as compared with control in both seasons. Other treatments registered an intermediate values in comparison with the previously two mentioned categories in both seasons.

Table 1: Effect of some pre-harvest treatments on weight loss % of Florida Prince peach fruits stored at 0±2 ˚C during 2009 and 2010 seasons.

Treatments	2008 season					Means
	Storage periods					
	7	14	21	28	35	
Control	2.57	7.03	12.44	18.72	24.63	13.08 A
Chitosan at 0.5%	2.15	6.90	10.07	14.62	20.87	10.92 C
Chitosan at 1.0%	2.02	6.54	9.92	14.19	20.43	10.62 CD
$CaCl_2$ at 2%	2.33	6.91	12.50	18.36	23.72	12.76 A
$CaCl_2$ at 4%	2.10	6.90	12.11	16.52	21.38	11.80 B
Chitosan at 0.5% + $CaCl_2$ at 2%	1.98	6.32	9.87	13.51	20.47	10.43 CD
Chitosan at 0.5% + $CaCl_2$ at 4%	1.78	5.72	8.35	12.72	19.51	9.62 EF
Chitosan at 1.0% + $CaCl_2$ at 2%	1.70	6.12	9.73	12.87	19.70	10.02 DE
Chitosan at 1.0% + $CaCl_2$ at 4%	1.67	5.43	8.12	11.75	18.11	9.02 F
Means	2.03 E	6.43 D	10.35 C	14.81 B	20.98 A	
L.S.D for the interaction effect between treatments and storage periods at 5% = 1.35						
Treatments	2009 season					Means
Control	2.23	6.11	9.47	14.23	25.13	11.44 A
Chitosan at 0.5%	2.10	5.90	8.01	13.80	21.06	10.17 BC
Chitosan at 1.0%	1.83	5.80	7.84	13.62	19.08	9.64 CD
$CaCl_2$ at 2%	2.32	5.93	8.70	15.35	23.63	11.19 A
$CaCl_2$ at 4%	2.12	5.87	8.43	14.29	21.15	10.37 B
Chitosan at 0.5% + $CaCl_2$ at 2%	1.87	5.15	7.62	12.97	17.53	9.03 D
Chitosan at 0.5% + $CaCl_2$ at 4%	1.73	5.09	7.43	12.71	20.39	9.47 D
Chitosan at 1.0% + $CaCl_2$ at 2%	1.80	4.83	7.31	12.30	19.31	9.11 D
Chitosan at 1.0% + $CaCl_2$ at 4%	1.68	4.73	6.05	10.87	17.72	8.21 E
Means	1.97 E	5.49 D	7.87 C	13.35 B	20.56 A	
L.S.D for the interaction effect between treatments and storage periods at 5% = 1.44						

Concerning the interaction effect between the tested storage periods and pre-harvest treatments, data in the same Table reveal that the lowest fruit weight loss (%) was obtained by the combinations of seven days storage period, especially those interacted with the treatment of 1% chitosan + 4% $CaCl_2$ in both seasons. On the contrary, the highest values in this parameter were gained by the interactions of thirty five days storage period, particularly that of control treatment in both seasons.

The loss in fruit weight is mainly due to water loss as a result of evaporation and transpiration and the amount of dry matter was lost by respiration. Chitosan coatings act as barriers, thereby restricting water transfer and protecting fruit skin from mechanical injuries, as well as sealing small wounds and thus delaying dehydration (Ribeiro *et al.,* 2007). Chitosan coating has been reported as an effective material in controlling water loss from other commodities, including longan fruit (Jiang and Li, 2001), banana and mango (Kittur*et al.,* 2001) and strawberries (Ribeiro *et al.,* 2007).

The effect of $CaCl_2$ on fruit weight loss percentage go in line with earlier studies of Choudhury *et al.* (2003), Serrano *et al.,* (2004), Hafez and Haggag (2007) and Mahmoud (2008). They realized that the loss in fruit weight during storage of sapotas, peaches and nectarines, apples and peaches, respectively was greatly reduced due to pre-harvest sprays of calcium in the form of calcium chloride at 0.3-7.5% or calcium nitrate at 1.0-2.5%.

2. Fruit decay percentage:

It is worthy to notice from Table (2) that there was a steady increase in fruit decay percentage with prolonging the storage period. The gained data confirmed this result, hence the highest fruit decay percentages were recorded after thirty five days of cold stored, followed in a descending order by twenty eight days storage period as compared with those stored for seven days during the first and second seasons, respectively. The differences between the tested storage periods were pronounced to be significant in both seasons.

Table 2: Effect of some pre-harvest treatments on decay % of Florida Prince peach fruits stored at 0±2 °C during 2009 and 2010 seasons.

Treatments	2008 season					Means
	Storage periods					
	7	14	21	28	35	
Control	2.46	10.23	18.30	32.72	52.20	23.18 A
Chitosan at 0.5%	0.00	5.68	12.76	26.70	39.46	16.96 D
Chitosan at 1.0%	0.00	5.50	12.60	26.52	36.21	16.17 DE
$CaCl_2$ at 2%	0.00	7.87	15.03	30.54	46.10	19.91 B
$CaCl_2$ at 4%	0.00	5.42	13.26	28.19	45.70	18.51 C
Chitosan at 0.5% + $CaCl_2$ at 2%	0.00	5.31	12.32	24.39	35.34	15.47 EF
Chitosan at 0.5% + $CaCl_2$ at 4%	0.00	4.29	11.37	22.40	35.29	14.67 FG
Chitosan at 1.0% + $CaCl_2$ at 2%	0.00	4.25	10.13	21.39	33.72	13.90 GH
Chitosan at 1.0% + $CaCl_2$ at 4%	0.00	2.67	9.83	21.27	33.06	13.37 H
Means	0.27 E	5.71 D	12.84 C	26.01 B	39.68 A	
L.S.D for the interaction effect between treatments and storage periods at 5% = 1.95						
Treatments	2009 season					Means
Control	2.58	9.57	16.72	29.71	50.53	21.82 A
Chitosan at 0.5%	0.86	4.93	11.53	25.23	38.70	19.24 CD
Chitosan at 1.0%	0.00	4.81	11.10	24.75	36.14	15.36 D
$CaCl_2$ at 2%	2.45	8.14	15.70	28.20	41.70	19.24 B
$CaCl_2$ at 4%	0.92	8.20	12.15	26.10	38.13	17.10 C
Chitosan at 0.5% + $CaCl_2$ at 2%	0.000	3.97	10.77	23.34	32.77	14.17 E
Chitosan at 0.5% + $CaCl_2$ at 4%	0.00	2.76	9.76	21.15	33.19	13.37 EF
Chitosan at 1.0% + $CaCl_2$ at 2%	0.00	2.53	9.11	19.72	32.80	12.83 FG
Chitosan at 1.0% + $CaCl_2$ at 4%	0.00	2.31	8.71	18.91	31.40	12.27 G
Means	0.76 E	5.25 D	11.73 C	24.12 B	37.26 A	
L.S.D for the interaction effect between treatments and storage periods at 5% = 2.41						

In regard to the effect of the tested pre-harvest treatments, Table (2) demonstrates that all evaluated pre-harvest treatments succeeded in reducing decay percentage of Florida Prince peach fruits during storage duration in comparison with untreated fruits "control" in both seasons. Generally, the treatment of 1% chitosan + 4% $CaCl_2$ proved to be the most efficient treatment in this concern, followed descendingly by 1% chitosan + 2% $CaCl_2$ treatment.

Looking to the interaction effect between the tested storage periods and pre-harvest treatments, it is obvious from Table (2) that the interactions of seven days cold storage duration induced the lowest fruit decay (%), particularly those interacted with the treatment between chitosan and $CaCl_2$ with different concentrations in both seasons. On the opposite, the highest fruit decay (%) were registered by the interactions of thirty five cold storage period, especially untreated fruits "control" in both seasons. The remained interactions of the tested storage periods came in-between in both seasons.

It is likely that chitosan produces a film coating the fruit surface, which would modify its gas exchange with the atmosphere and its internal gas composition. Li and Yu (2000) recorded that chitosan coating often inhibits CO_2 production; consequently ethylene production of the commodity is also reduced. Both inhibitory effects were reported in peaches coated with chitosan. The gained results of pre-harvest chitosan in reducing the decay go in line with findings of Romanazzi *et al.,* (2002) on table grapes, Chien *et al.,* (2007) on citrus, Yu *et al.,* (2007) on apples and Meng *et al.,* (2008) on grapes. Recently, preharvest and postharvest chitosan treatments of table grapes, strawberries and sweet cherries reduce their decay in the field and during storage, with the best performance at the highest tested concentration usually 1% (Romanazzi, 2010).

Conway *et al.,* (1993) reported the effect of Ca in reducing decay and maintaining fruit quality is associates with maintaining cell wall structure by dealing or modifying chemical changes in cell wall composition.

The obtained results of $CaCl_2$ in this concept go in line with findings of Choudhury *et al.,* (2003) on Sapota cv. Pala and Mahmoud (2008) on peach cv. Desert Red and apricot cv. Canino. They sprayed the trees of these fruit species with calcium as a pre harvest treatment to enhance fruit storage life.

3. Fruit firmness (Ib/inch^2):

It is clear from Table (3) that Florida Prince peach fruits showed gradual loss in their firmness with the advancement of storage period. The obtained results indicate this fact, hence, the initial readings scored the higher values of fruit firmness (Ib/inch^2). Whereas, thirty five days of cold storage recorded the lowest values of fruit firmness. The differences between all studied storage periods were significant in both seasons.

As for the effect of the tested treatments, results in Table (3) reveal that all tested treatments enhanced fruit firmness during storage period as compared with control. The highest values of fruit firmness were recorded by 1% chitosan + 4% $CaCl_2$ treatment in both seasons.

Examining the interaction effect between storage periods and the tested pre-harvest treatments, data presented in Table (3) show that irrespective of the initial readings, the interactions of seven days storage period registered the highest values of fruit firmness, especially 1% chitosan + 4% $CaCl_2$-treated fruits in the first and second seasons. On the contrary, the lowest values of fruit firmness were recorded by the interactions of thirty five days storage period, especially untreated fruits in both seasons. The other values came in-between, and the differences between the different storage period interactions were significant and within each specific storage period were in most cases significant.

Table 3: Effect of some pre-harvest treatments on fruit firmness (Ib/inch) of Florida Prince peach fruits stored at 0±2 ˚C during 2009 and 2010 seasons.

Treatments	2008 season						Means
	Storage periods						
	0	7	14	21	28	35	
Control	8.67	8.00	6.43	4.43	3.13	1.90	5.43 F
Chitosan at 0.5%	9.45	8.73	7.91	5.91	4.00	2.23	6.37 E
Chitosan at 1.0%	9.73	9.22	8.40	6.20	4.13	2.57	6.71 D
$CaCl_2$ at 2%	9.21	8.82	7.72	6.07	3.93	2.07	6.30 E
$CaCl_2$ at 4%	9.57	8.87	7.65	6.13	4.03	2.07	6.39 E
Chitosan at 0.5% + $CaCl_2$ at 2%	10.43	10.03	8.75	6.45	4.60	2.60	7.14 C
Chitosan at 0.5% + $CaCl_2$ at 4%	10.83	10.50	8.95	6.50	4.63	2.77	7.36 B
Chitosan at 1.0% + $CaCl_2$ at 2%	10.91	10.52	9.03	6.47	4.93	3.17	7.50 B
Chitosan at 1.0% + $CaCl_2$ at 4%	11.90	11.33	9.70	7.43	5.10	3.00	8.08 A
Means	10.08 A	9.56 B	8.28 C	6.18 C	4.28 E	2.49 F	
L.S.D for the interaction effect between treatments and storage periods at 5% = 0.38							
Treatments	2009 season						Means
Control	9.13	8.65	7.40	5.23	3.13	2.10	5.94 I
Chitosan at 0.5%	9.57	9.25	8.07	6.90	5.13	2.80	6.95 F
Chitosan at 1%	10.17	9.30	8.55	7.50	5.20	3.10	7.30 E
$CaCl_2$ at 2%	9.50	8.70	7.55	5.30	3.51	2.17	6.12 H
$CaCl_2$ at 4%	9.77	9.10	8.17	6.20	3.73	2.17	6.52 G
Chitosan at 0.5% + $CaCl_2$ at 2%	10.30	10.00	8.90	7.80	5.25	3.03	7.55 D
Chitosan at 0.5% + $CaCl_2$ at 4%	10.90	10.60	8.05	7.80	5.60	3.37	7.72 C
Chitosan at 1.0% + $CaCl_2$ at 2%	11.50	11.10	9.80	8.16	5.60	3.50	8.28 B
Chitosan at 1.0% + $CaCl_2$ at 4%	12.20	11.85	10.00	8.27	5.70	3.50	8.59 A
Means	10.34 A	9.84 B	8.50 C	7.02 D	4.76 E	2.86 F	
L.S.D for the interaction effect between treatments and storage periods at 5% = 0.24							

The decrease in fruit firmness of peaches with the progress of storage period is due mainly to decomposition of enzymatic degradation in insoluble protopectins to more simple soluble pectins, solubilization of cell and cell wall contents as a result of the increasing in pectin esterase activity (Deshpande and Salunkhe, 1964).

The results of pre-harvest chitosan are in harmony with those mentioned by Li and Yu, 2000; Bautista-Banos *et al.,* 2003 and Fernado *et al.,* 2005. They declared that the loss of firmness of the chitosan-treated fruits such as peaches, papayas and Clementine mandarins was delayed during the storage period.

$CaCl_2$ treatment applied on Florida Prince peach fruits showed higher significant flesh firmness for refrigerated fruits at 0±2 ˚C. This result can be explained with the effect of Ca on fruit softening where it is an essential part of the cell wall structure and it also influences cell membrane integrity (Fallahi *et al.,* 1997). Furthermore, $CaCl_2$ treatment may delay glactolipid breakdown, increase the rate of sterol conjugation and they affect membrane organization and function during the postharvest life of fruits (Picchioni *et al.*, 1995).

The decrease in reduction rate of flesh firmness during storage due to the tested pre-harvest sprays of $CaCl_2$ is in agreement with earlier reports of Brar *et al.,* (1997) and Guarinoni *et al.,* (2000) and Mahmoud (2008)on peach fruits.They realized that Ca treatments succeeded in reducing the loss of fruit firmness during storage.

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4. Shelf life (days):

Data presented in Table (4) indicate that shelf life of Florida Prince peach fruits was progressively increased by using all studied pre-harvest treatments, the superior treatment was1% chitosan + 4% $CaCl_2$, followed in a descending order by using the treatments of 1% chitosan + 2% $CaCl_2$ and 1% chitosan + 4% $CaCl_2$ as compared with control in both seasons. Also, the treatments of 0.5% chitosan + 2% $CaCl_2$ and chitosan at 1% scored highly significant increments in this parameter as they gave the same values in both seasons.

Table 4: Effect of some pre-harvest treatments on shelf life (days) of Florida Prince peach fruits after 35 days cold storage at 0±2 ˚C during 2009 and 2010 seasons.

Treatments	shelf life (days)	
	2008 season	2009 season
Control	2.00 D	2.00 D
Chitosan at 0.5%	3.33 BC	2.67 BC
Chitosan at 1.0%	3.33 BC	3.67 BC
$CaCl_2$ at 2%	2.33 D	3.00 C
$CaCl_2$ at 4%	2.67 CD	3.33 BC
Chitosan at 0.5% + $CaCl_2$ at 2%	3.33 BC	3.67 BC
Chitosan at 0.5% + $CaCl_2$ at 4%	4.00 AB	3.67 BC
Chitosan at 1.0% + $CaCl_2$ at 2%	4.00 AB	4.00 AB
Chitosan at 1.0% + $CaCl_2$ at 4%	4.33 A	4.67 A

The abovementioned results of $CaCl_2$ go in line with those of Mahajan and Sharma (2000) on peaches and Mahmoud (2008)on peaches and apricots. They recorded that shelf life was longer in Ca- treated fruits as a pre-harvest treatments.

5. Total soluble solid percentage (T.S.S. %):

Data in Table (5) indicate that the longer the storage period (35 days), the higher was the fruit total soluble solid percentage. However, seven days storage period induced the lowest values of fruit total soluble solid content (irrespective of the initial reading).

Referring to the effect of tested pre-harvest treatments, obtained data in the same Table reveal that all tested treatments affected fruit total soluble solids in both seasons.However, untreated fruits had statistically higher total soluble solids than the majority of tested pre-harvest treatments in both seasons. On the other hand, 1% chitosan + 2% $CaCl_2$ treated- fruits had statistically lower total soluble solids than all tested pre-harvest treatments in the first and second seasons.

Table 5: Effect of some pre –harvest treatments on total soluble solid (T.S.S. %) of Florida Prince peach fruits stored at 0±2 ˚C during 2009 and 2010 seasons.

Treatments	2008 season						Means
	Storage periods (days)						
	0	7	14	21	28	35	
Control	11.90	12.47	12.97	13.80	14.92	15.74	13.63 A
Chitosan at 0.5%	12.23	12.56	13.10	13.76	14.60	15.16	13.57 AB
Chitosan at 1.0%	12.30	12.60	13.10	13.70	14.50	15.07	13.54 ABC
$CaCl_2$ at 2%	11.56	12.32	12.87	13.62	14.86	15.63	13.48 BCD
$CaCl_2$ at 4%	11.62	12.24	12.78	13.70	14.80	15.52	13.44 CD
Chitosan at 0.5% + $CaCl_2$ at 2%	11.97	12.39	12.90	13.71	14.52	15.43	13.49 BCD
Chitosan at 0.5% + $CaCl_2$ at 4%	12.08	12.40	12.97	13.75	14.43	15.72	13.48 BCD
Chitosan at 1.0% + $CaCl_2$ at 2%	11.92	12.37	12.86	13.72	14.40	15.20	13.41 D
Chitosan at 1.0% + $CaCl_2$ at 4%	12.23	12.51	13.08	13.71	14.22	15.10	13.48 BCD
Means	11.98 F	12.43 E	12.96 D	13.72 C	14.58 B	15.35 A	
L.S.D for the interaction effect between treatments and storage periods at 5% = 0.26							
Treatments	2009 season						Means
Control	11.56	11.95	12.72	14.20	15.42	15.23	13.51 A
Chitosan at 0.5%	11.70	12.12	12.57	13.42	14.40	15.10	13.22 C
Chitosan at 1.0%	11.78	12.12	12.60	13.33	14.40	15.15	13.23 C
$CaCl_2$ at 2%	11.43	11.90	12.65	13.97	15.33	15.42	13.45 AB
$CaCl_2$ at 4%	10.85	11.70	12.57	13.90	15.27	15.30	13.26 C
Chitosan at 0.5% + $CaCl_2$ at 2%	11.62	11.82	12.50	13.90	14.80	15.30	13.32 BC
Chitosan at 0.5% + $CaCl_2$ at 4%	11.60	11.85	12.50	13.67	14.76	15.20	13.26 C
Chitosan at 1.0% + $CaCl_2$ at 2%	11.62	11.90	12.42	13.60	14.53	15.20	13.21 C
Chitosan at 1.0% + $CaCl_2$ at 4%	11.70	11.90	14.40	13.60	14.37	15.13	13.18 C
Means	11.54 F	11.92 E	12.55 D	13.73 C	14.81 B	15.23 A	
L.S.D for the interaction effect between treatments and storage periods at 5% = 0.43							

Evaluating the interaction effect between storage periods and the tested treatments, data presented in Table (5) show that the interactions of thirty five cold storage period, registered the highest values of fruit total soluble solids percentage, especially untreated fruits "control" in the first season and 2% $CaCl_2$- treated fruits in the second one.

On the opposite, the lowest fruit total soluble solids percentage were recorded by the interactions of zero day storage period (initial readings), especially 2% $CaCl_2$- treated fruits in the first season and 4% $CaCl_2$- treated fruits in the second one. The remained interactions of the tested storage periods came in-between in both seasons.

The gained results of calcium as a pre-harvest treatment are in harmony with the analogous ones mentioned by Siddiqui and Bangerth (1995) on apple and Montanaro *et al.,* (2006) on kiwifruit.

6. Total acidity percentage (T.A.%):

Data in Table (6) illustrate that prolonging the storage period induced a remarkable decrease in fruit total titratable acidity content of Florida Prince peach fruits, where the initial value of fresh fruit (Zero day storage) recorded the highest readings of total titratable acidity percentage in comparison with the other tested storage periods. Consequently, the lowest values of this parameter were recorded by those cold stored for thirty five days. The differences between the studied storage periods in this respect were significant from the standpoint in both seasons.

As for the effect of pre- harvest treatments, data in the same Table show that all tested treatments increased the titratable acidity as compared with control, except for the treatment of chitosan at 1%which decreased this parameter with non-significant differences in both seasons. However, the highest value of this parameter was gained by using 0.5% chitosan + 4% $CaCl_2$ - treated fruits in both seasons.

Concerning the interaction effect between the tested treatments and storage period, it is quite clear from Table (6) that the interactions of zero day storage period (initial readings) scored the highest values of fruit total acidity content, especially 4% $CaCl_2$-treated fruits in both seasons. On reverse, the lowest values of this parameter were registered by the combinations of thirty five days storage duration, particularly those interacted with the treatment of 1% chitosan + 2% $CaCl_2$ in the first season and control in the second one. The remained interactions of the studied storage periods came in-between in both seasons.

Table 6: Effect of some pre- harvest treatments on titratable acidity (T.A. %) of Florida Prince peach fruits stored at 0±2 ˚C during 2009 and 2010 seasons.

Treatments	2008 season						Means
	Storage periods (days)						
	0	7	14	21	28	35	
Control	0.97	0.93	0.81	0.67	0.47	0.57	0.74 B
Chitosan at 0.5%	0.93	0.91	0.84	0.72	0.58	0.51	0.75 B
Chitosan at 1.0%	0.91	0.90	0.80	0.70	0.56	0.53	0.73 B
$CaCl_2$ at 2%	1.03	0.95	0.86	0.72	0.60	0.54	0.78 A
$CaCl_2$ at 4%	1.05	0.95	0.87	0.74	0.62	0.54	0.79 A
Chitosan at 0.5% + $CaCl_2$ at 2%	0.97	0.93	0.87	0.70	0.62	0.56	0.78 A
Chitosan at 0.5% + $CaCl_2$ at 4%	1.01	0.95	0.87	0.70	0.65	0.53	0.79 A
Chitosan at 1.0% + $CaCl_2$ at 2%	0.95	0.93	0.86	0.75	0.67	0.50	0.78 A
Chitosan at 1.0% + $CaCl_2$ at 4%	0.93	0.92	0.84	0.75	0.70	0.54	0.78 A
Means	0.97 A	0.93 B	0.85 C	0.72 D	0.61 E	0.54 F	
L.S.D for the interaction effect between treatments and storage periods at 5% = 0.05							
Treatments	2009 season						Means
Control	1.08	1.05	0.86	0.60	0.42	0.39	0.73 EF
Chitosan at 0.5%	1.07	1.01	0.83	0.63	0.51	0.45	0.75 E
Chitosan at 1.0%	1.05	0.97	0.83	0.60	0.46	0.43	0.72 F
$CaCl_2$ at 2%	1.13	1.07	0.93	0.67	0.53	0.43	0.79 BCD
$CaCl_2$ at 4%	1.15	1.07	1.00	0.73	0.61	0.49	0.84 A
Chitosan at 0.5% + $CaCl_2$ at 2%	1.10	1.03	0.86	0.65	0.55	0.47	0.78 D
Chitosan at 0.5% + $CaCl_2$ at 4%	1.13	1.07	0.90	0.70	0.59	0.47	0.81 B
Chitosan at 1.0% + $CaCl_2$ at 2%	1.11	1.03	0.87	0.65	0.58	0.45	0.78 CD
Chitosan at 1.0% + $CaCl_2$ at 4%	1.13	1.05	0.90	0.70	0.55	0.47	0.80 BC
Means	1.11 A	1.04 B	0.89 C	0.66 D	0.53 E	0.45 F	
L.S.D for the interaction effect between treatments and storage periods at 5% = 0.05							

The decrease in fruit acidity during storage period may be due to the metabolic changes in fruits or due to the use of organic acids in respiratory process (Echeverria and Valich, 1989). Li and Yu (2000) found that at the end of the storage period, titratable acidity was increased on the chitosan-treated peaches, while in other crops such as longan and mangoes, acidity was slowly reduced, associating this decrease with loss of eating quality (Jiang and Li, 2001 and Srinivasa *et al.,* 2002).

The recorded results of $CaCl_2$ dealing with their prospective effect on improving fruit flavour, enhancing fruit quality are in harmony with earlier works of Brar *et al.* (1997) on peach cv. Shan-1-Punjab, Choudhury *et al.* (2003) on sapota cv. Pala and Mahmoud (2008) on peach cv. Desert Redand apricot cv. Canino.

The aforementioned results of chitosan may be due to that chitosan can be used as a plant growth enhancer for orchid production especially for immature plants or in tissue culture. Possibly, chitosan may induce a signal to synthesize plant hormones such as gibberellins. In addition, chitosan may enhance growth and development by some signaling pathway related to auxin biosynthesis via a tryptophan- independent pathway. Moreover, chitosan has inconsistent effects on growth and development of mature orchid plants. Chitosan can reduce disease severity in orchids, possibly by increasing the activity of PAL and PPO, lignification resulting from increased biosynthesis of phenolic compounds or induced secondary metabolites and SAR. Also, increased disease resistance may be mediated in part via an increase in the concentrations of jasmonic acid. Furthermore, resistance to disease infections may also involve closure of stomata by ABA (Apiradee *et al.,* 2007).

Additionally, calcium appears to have an important regulating role in the metabolism of tree fruits. Metabolic disorders are reduced if calcium is present in sufficiently high quantities in fruit. Several metabolic disorders are associated with the high rate of respiration or over maturity of the fruit. This suggests that calcium may regulate respiration and perhaps other metabolic processes in the mature fruit (Miklos and Shear, 1972).

Conclusively, the results obtained in this work indicated that chitosan alone or in combination with calcium chloride as pre-harvest treatments, is effective methods for extending the storage life of Florida Prince peach fruits. The most effective treatment in maintaining fruit quality was 1.0 % chitosan + 4% $CaCl_2$ during cold storage period at 0±2 ˚C.

References

A.O.A.C., 1985. Association of Official Agricultural Chemists.Official Methods of Analysis. 4th ed. pp. 495-510. Benjamin Franklin Station, Washington. D.C., U.S.A.

Apiradee, U., A.T. Jaime and O. Kullanart, 2007. Chitosan for Improving Orchid Production and Quality. Orchid Science and Biotechnology, 1(1): 1-5.

Bautista-Banos, S., M. Hernandez-Lopez, E. Bosquez-Molina and C.L. Wilson, 2003. Effects of chitosan and plant extracts on growth of *Colletotrichumgloeosporioides,* anthracnose levels and quality of papaya fruit. Crop Prot., 22: 1087-1092.

Brar, S.S., S.S.A. Simnani and G.S. Kaundal, 1997. Effect of pre-harvest sprays of calcium nitrate on the storage life of Shan-I-Punjab peach.Journal of Research, Punjab, Agricultural University, 34(2): 174-180; 9 ref.

Chardonnet, C.O., C.S. Charron, C.E. Sams and W.S. Conway, 2003.Chemical changes in the cortical tissue and cell walls of calcium – infiltrated “Golden Delicious” apples during storage. Postharvest Biology and Technology, 28: 97-111.

Chien, P.J., F. Sheu and H.R. Lin, 2007. Coating citrus (Murcotttangor) fruit with low molecular weight chitosan increases postharvest quality and shelf life. Food Chem., 100: 1160-1164.

Choudhury, S., D.P. Ray, B.K. Das and G.S. Sahu, 2003. Effect of pre and post-harvest chemical treatments on ripening, quality and storage life of sapota [*Manilkaraachras* (Mill.)Forberg] cv. ‘Pala’.Orissa Journal of Horticulture, 31(2): 54-57, 8 ref.

Conway, W.S., C.E. Sams and R.B. Tobias, 1993. Reduction in storage decay in apples by postharvest calcium infiltration. Acta Horticulturae, 326: 115-121; 26 ref.

Deshpande, P.B. and D.K. Salunkhe, 1964. Effect of maturity and storage on certain biochemical changes in apricots and peaches. Food Tech., 18(18): 85-88.

Echeverria, E. and J. Valich, 1989. Enzymes of sugar and acid metabolism in stored Valencia oranges. J. Am. Soc. Hort. Sci., 114: 445-449.

EPA, 1995. Poly-D-glucosamine (chitosan); exemption from the requirement of a tolerance U.S. Environmental Protection Agency, Final Rule. *Federal Register,* 60: 19523-19524.

Fallahi, E., W.S. Conway, K.D. Hickey and C.E. Sams, 1997. The role of calcium and nitrogen in postharvest quality and disease resistance of apple. Hort. Science, 32(5): 831-835.

Fernando, F., A. Vicente, A. Manuel and A. Manuel, 2005. Low concentrations of chitosan coating reduce water spot incidence and delay peel pigmentation of Clementine mandarin fruit. Journal of the Science of Food and Agriculture., 85: 1105-1112.

Freepons, D., 1991. Chitosan, does it have a place in agriculture? Proceedings of the Plant Growth Regulation Society of America, pp: 11-19.

Guarinoni, A., A. Ferenczi, A. Silvera and R. Mori, 2000. Evaluation of post-harvest fruit quality of flavor crest peach growing under an integrated production system.IIR. Conference, October 2000, Murcia, Spain, 69: 81.

Hadwiger, L.A. and P.O. McBride, 2006. Low-level copper plus chitosan applications provide protection against late blight of potato. Plant Health Progres.s April, pp: 123-131.

Hadwiger, L.A., S.J. Klosterman and J.J. Choi, 2002. The mode of action of chitosan and its oligomers in inducing plant promoters and developing disease resistance in plants.*Advances in Chitin Science,* 5: 452-457.

Hafez, O.M. and K.H.E. Haggag, 2007. Quality improvement and storability of apple cv. Anna by pre-harvest Applications of Boric acid and Calcium Chloride J. Agric. & Biol. Sci., 2(3): 176-183.

Hirano, S., C. Itakura, H. Seino, Y. Akiyama, I. Nonaka, N. Kanbara, T. Kanakami, K. Arai and T. Kinimaki, 1990. Chitosan as an ingredient for domestic animal feeds. J Agric Food Chem 38, 1214–1217.

Hulme, A.C., 1971. The biochemistry of fruits and their products.Academic Press, London and New York, 2: 788.

Jiang, Y.M. and Y.B. Li, 2001. Effects of chitosan coating on storage life and quality of longan fruit. Food Chem., 73: 139-143.

Kittur, F.S., N. Saroja and R.N. HabibunnisaTharanathan, 2001. Polysaccharide-based composite coating formulations for shelf-life extension of fresh banana and mango. Eur. Food Res. Technol., 213: 306-311.

Kluter, R.A., D.T. Nattress, C.P. Dunne and R.D. Popper, 2006. Shelf life Evaluation of Bartlett Pears in Retort Pouches. Journal of Food Science, (6): 1297-1302.

Li, H. and T. Yu, 2000. Effect of chitosan on incidence of brown rot, quality and physiological attributes of postharvest peach fruit. J. Sci. Food Agric. 81: 269-274.

Mahajan, B.C. and R.C. Sharma, 2000. Effect of pre-harvest application of growth regulators and calcium chloride on chemical characteristic and storage life of peach cv. Shane -e- Punjab Haryana. Journal of Horticultural Sciences, 29(1-2): 41-43.

Mahmoud, M.M., 2008. Influence of Gamma Rays and Some Pre and Post Harvest Treatments on Behavior of Some Fruits During Cold Storage. M.Sc. Thesis, Environmental Sci., Institute of Environmental Studies and Research. Ain Shams Univ., Egypt.

Meng, X.H., B.Q. Li, J. Liu and S.P. Tian, 2008. Physiological responses and quality attributes of table grape fruit to chitosan preharvest spray and postharvest coating during storage. Food Chem., 106: 501-508.

Miklos, F. and C.B. Shear, 1972. The effect of calcium on respiration of apples. J. Amer. Soc. Hort. Sci., 97(3): 364-369.

Montanaro, G., B. Dichio, C. Xiloyannis and G. Celano, 2006. Light influences transpiration andcalcium accumulation in fruit of kiwifruit plants. Plants Science, 170: 520-527.

Photchanachai, S., J. Singkaew and J. Thamthong, 2006. Effects of chitosan seed treatment on *Colletotrichum sp*. and seedling growth of chili cv. 'Jinda'. ActaHorticulturae, 712: 585-590.

Picchioni, G.A., E.A. Watada, W.S. Conway, B.D. Whitaker and C.E. Sams, 1995. Phospholipid, galactolipid and steryl lipid composition of apple fruit cortical tissue following postharvest $CaCl_2$ infiltration.Phytochemistry, 39 (4): 763-769 (C. F. Hort. Abst. 65(12): 10470.

Poovaian, B.W., G.H. Glenn and A.S.N. Reddy, 1988. Calcium and fruit softening: Physiology and biochemistry. Hort. Rev., 10: 107-152.

Raese, J.T. and S.R. Drake, 2006. Calcium Foliar Sprays for Control of Alfalfa Greening, Cork Spot, and Hard End in 'Anjou' Pears. Journal of Plant Nutrition., 29(3): 543-552.

Ribeiro, C., A.A. Vicente, J.A. Teixeira and C. Miranda, 2007. Optimization of edible coating composition to retard strawberry fruit senescence. Postharvest Biol. Technol., 44: 63-70.

Romanazzi, G., 2010. Chitosan treatment for the control of postharvest decay of table grapes, strawberries and sweet cherries. Global Science Books, Fresh Produce 4 (Special Issue 1): 111-115.

Romanazzi, G., F. Nigro, A. Ippolito, D. Di Venere and M. Salerno, 2002. Effects of pre and postharvest chitosan treatments to control storage grey mold of table grapes. J. Food Sci., 67: 1862-1867.

Sandford, P.A. and G.P. Hutchings, 1987. Chitosan- a natural, cationic biopolymer: commercial applications. In: Yapalma M (Ed) *Industrial Polysaccharides: Genetic Engineering, Structure/Property Relations and Applications*, Elsevier Science Publishers B.V., Amsterdam, The Netherlands, pp: 363-376.

Serrano, M., D. Martinez- Romero, S. Castillo, F. Guillen and D. Valero, 2004. Effect of preharvest sprays containing calcium, magnesium and titanium on the quality of peaches and nectarines at harvest and during postharvest storage. Journal of the Science of Food and Agiculture, 84(11): 1270-1276.

Siddiqui, S. and F. Bangerth, 1995. Effect of pre harvest application of calcium on flesh firmness and cell-wall composition of apples- Influence of fruit size. J. Hort. Sci., 70: 263-269; 22 ref.

Snedecor, W. and W.G. Cochran, 1989. Statistical Methods, 8th ed. Iowa State Univ. Press Ames. Iowa. U.S.A.

Srinivasa, P.C., R. Baskaran, M.N. Armes, K.V. Harish Prashanth AND R. N. Tharanathan, 2002. Storage studies of mango packed using biodegradable chitosan film. Eur. Food Res. Technol., 215: 504-508.

Sukwattanasinitt, M., A. Klaikherd, K. Skulnee and S. Aiba, 2001. Chitosan as a releasing device for 2,4-D herbicide. Chitin and Chitosan in Life Science, Yamaguchi Japan, pp: 198-201.

Utsunomiya, N. and H. Kinai, 1994. Effect of chitosan-oligosaccharides soil conditioner on the growth of passionfruit. Journal of the Japanese Society for Horticultural Science, 64: 176-177.

Yu, T., H.Y. Li and X.D. Zheng, 2007. Synergistic effect of chitosan and Cryptococcus laurentii on inhibition of Penicilliumexpansum infections.Int. J. Food Microbiol., 114: 261-266.

Zhang, D. and P.C. Quantick, 1998. Antifungal effects of chitosan coating on fresh strawberries and raspberries during storage. The Journal of Horticultural Science and Biotechnology, 73: 763-767.