Pre-harvest application of calcium chloride and chitosan on fruit quality and storability of ‘Early Swelling’ peach during cold storage

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ABSTRACT

Studies related with the storage of peach fruits have received great relevance in Egypt. In this study, the effect of pre-harvest sprays of calcium chloride and chitosan, separately and in combination, on quality attributes and storability of peach fruits stored at 0±1 °C was studied. ‘Early Swelling’ peach trees were sprayed twice with 1% or 2% calcium chloride. The first spraying was at pea stage, while the second one was performed at 10 days before harvesting. Chitosan sprays were performed at 0.5 or 1%, alone or in combination with 1 and 2% calcium chloride, at 10 days before harvesting. Untreated trees served as control. Fruits were harvested at maturity stage, then packaged and stored at 0±1 °C and 85-90% of relative humidity. Fruit physical and chemical properties were evaluated at 7-day intervals. Results showed that pre-harvest application with 2% CaCl₂ + 1% chitosan was most effective in minimizing weight loss (%) and decay (%), as well as in maintaining maximum firmness and lengthening shelf life. Fruit color was not affected by any of the treatments, while untreated fruits and calcium chloride treatment alone, at both applied concentrations, maintained higher total soluble solids (TSS, %), total phenolic content, and lower titratable acidity percentage.

Index terms: Alternative chemicals; CaCl₂; quality attributes.

INTRODUCTION

Peach (Prunus persica (L.) Batsch) belongs to the family Rosaceae and is one of the most popular fruits in the world because of its high nutrient value and pleasant flavor. Peach is considered as one of the most important deciduous fruits in Egypt, where it has great success and is widespread in the newly reclaimed areas. The storage of peach fruits is problematic due to a short post-harvest life, as fruits quickly pass from ideal maturity to over ripening phase, readily lose water and shrivel, can be attacked and destroyed by fruit rotting organisms and become unmarketable as a result of the internal breakdown. An increased concern among consumers about food safety and the potentially harmful health effects of chemical residues encouraged research to find safe alternative chemicals which can maintain the marketable quality throughout prolonged storage period of fruits, including peach.
In this sense, pre- and post-harvest application of calcium may delay senescence in fruits with no detrimental effect on consumer acceptance. Calcium is a key plant nutrient that has a significant role in cell functions, including reducing softening and senescence of fruits (Barker; Pilbeam, 2015), and it is also considered the most important mineral element determining fruit quality (El-Badawy, 2012). The role of calcium in stabilizing cellular membranes and delaying senescence in horticultural crops, (Poovaiah; Glenn; Reddy, 1988), as well as its contribution to the linkages between pectic substances within the cell-wall are well known. Pre-harvest calcium treatments to increase calcium content of the cell wall were effective in delaying senescence, resulting in firmer and higher fruit quality (Serrano et al., 2004). The mobility of calcium in trees is low, and the root uptake from fertilized soils is poorly effective in increasing the calcium content in fruits. In this context, Ghani, Awang and Sijam (2011), reported that the direct application of liquid source of calcium on leaves and fruits may offer an alternative solution. Calcium may have also a potential use as an alternative method in integrated disease management (Biggs; Hogmire; Collins, 2000).

Chitosan is an N-acetylated derivative of the polysaccharide chitin. It is a natural polymer with a polycationic nature, which has numerous applications in agriculture (e.g., as soil modifier, films, fungicide, elicitor) and agroindustry, as well as in cosmetics, biomedicine, environmental protection, wastewater management (Deepmala et al., 2014). Chitosan is edible and safe for humans (Rhoades; Roller, 2000), and it is used in human medicine, advised in slimming diets (Maezaki et al., 1993). Due to these properties, chitosan could be applied near harvest time. Many studies have shown the high potential of chitosan for preserving fresh fruits and vegetables. Pre-harvest spraying with chitosan is highly feasible and has a beneficial effect on fruit quality attributes (Reddy et al., 2000). Chitosan has been also considered as a valid alternative to synthetic fungicides (El Ghaouth, 1997). Romanazzi (2010) reported that chitosan has a double mechanism of actions, i.e., it inhibits the development of decay-causing fungi, and induces resistance responses of host tissues. It is considered as an ideal preservative coating because it has a disease suppressive effect, resulting from both physical and biochemical mechanisms. The physical properties of the polymer allow it to produce a film on the surface of treated fruit (Du; Gemma; Iwahori, 1998), and has also the potential to prolong the storage life of many fruits, such as peach, Japanese pear, kiwifruit, strawberry and sweet cherry (Du; Gemma; Iwahori, 1997; EL Ghaouth; Ponnampalam; Boulet, 1991; Romanazzi; Nigro; Ippolito, 2003). Chitosan also induces chitinase activity, and elicits phytoalexins and defense barriers in the host tissues (El Ghaouth et al.,1992), as well as the defense responses in several plant systems.

Calcium has a general application in either pre-harvest or post-harvest treatments, while reports on pre-harvest application of chitosan are limited (El-Badawy, 2012; Reddy et al., 2000). In this study, the effect of pre-harvest application of calcium chloride, chitosan and their combination on storability and quality attributes of peach fruits, cv Early Swelling, has been investigated.

**MATERIAL AND METHODS**

The present study was conducted through two successive seasons (2014 and 2015) on peach (Prunus persica), cv Early Swelling. Trees were grown in a private orchard at El- Khatatba City, in El-Menoufiya Governorate, Egypt, in a sandy soil. Trees were 7 years old, budded on ‘Nemaguard’ peach rootstock, cultivated at 4×4 m distance, open-vase shape trained, drip irrigated, and received normal cultural practices adopted in the orchard.

**Experimental design**

Each treatment consisted of three trees in a randomized complete block design where a single tree represented the experimental unit. The experiment consisted of a total of nine treatments (including the control) for each season. The treatments were: (i) 1 or 2% calcium chloride, with two sprayings of trees, the 1st at “pea stage”, the 2nd 10 days before harvesting, (ii) 0.5 or 1% chitosan, alone or in combination with 1 or 2% calcium chloride, with only one spraying, 10 days before harvesting. A set of trees were left untreated and served as control. Trees were sprayed with hand-sprayer, till fruits were completely wet to run off. Samples of fruits at full maturation from each treatment were hand-harvested during the first two weeks of May. In the laboratory of the Faculty of Agriculture, Cairo University, fruits of each treatment were then sorted and selected for uniformity of weight, size, and absence of mechanical damage or visible pathological infections. The selected fruits were packed in carton boxes (2 kg capacity). Each treatment was triplicated. Fruits were then stored for 35 days at 0±1 °C with a relative humidity (RH) of 85-90%. Fruit physical and chemical quality attributes were periodically assessed at intervals of 7 days throughout all the storage period.
Quality assessments of fruits by physical characteristics

The following physical characteristics were evaluated:

**Weight loss:** Samples of each treatment were weighed at weekly intervals until the end of experiment. Weight loss (%) was calculated as follows:

\[
\text{Fruit weight loss} \% = \left( \frac{\text{initial weight} - \text{weight at sampling date}}{\text{initial weight}} \right) \times 100.
\]

**Fruit decay percentage:** evaluated by type, as skin appearance, shriveling, chilling injury and pathogenic rots. In every inspection date, decayed fruits were discarded and the relative amount expressed as decay percentage.

**Fruit firmness (kg/cm}^2\):** fruits from each replicate were taken at weekly intervals to determine the changes in fruit firmness using stationary firmness tester. Fruit firmness was measured in two opposite sides of the equatorial fruit zone after removing the peel, and expressed in kg/cm\(^2\).

**Shelf life (days):** after 35 days of cold storage, fruit samples of each treatment were placed at ambient temperature, and shelf life was determined as a number of days of which fruits maintained acceptable eating quality and appearance.

**Color assessment:** hue angle (h°) values of fruits were assessed using a Minolta colorimeter CR-40 (Konica Minolta Sensing Inc, Sakai, Japan).

Quality assessments of fruits by chemical characteristics

The following chemical characteristics were evaluated:

**Fruit total soluble solids:** total soluble solids (TSS) were measured using digital pocket refractometer (model PAL 1, ATAGOTM, Tokyo Tech.) and expressed as percentage.

**Fruit titratable acidity:** titratable acidity (TA) was measured in the juice of fruit sample for each replicate by titration against calibrated 0.1N NaOH solution in the presence of phenolphthalein as an indicator. Acidity was calculated as percentage of malic acid according to A.O.A.C. ([https://archive.org/details/gov.law.aoac.methods.1.1990](https://archive.org/details/gov.law.aoac.methods.1.1990)).

**Total phenols:** total phenolics were analyzed spectrophotometrically using the method described by Swain and Hillis (1959). Results were expressed as g of gallic acid /100 g fresh weight (FW).

Statistical analysis

The experiment was conducted using a completely randomized design with three replicates. Data from the analytical determinations were subjected to analysis of variance (ANOVA). Mean comparisons were performed by Duncan’s Multiple range test at 5% level (Snedecor; Cochran, 1982).

RESULTS AND DISCUSSION

Weight loss (%)

The percentage of weight loss increased all through the storage period (Table 1). With regard to the effect of the tested pre-harvest treatments, considering mean values at the end of the analyzed period of time, in both seasons the highest significant weight loss percentage was obtained by untreated fruits (control), while treatments with chitosan and CaCl\(_2\) (at different concentrations, depending on the season) recorded the lowest significant weight loss. Other treatments did not show clear differences among them, especially in the first season, although mean values resulted always significantly higher than the control fruits. The lowest fruit weight loss (%) was obtained in fruits treated with 1% CaCl\(_2\) + 1% chitosan after 7 days of storage.

Weight loss of fresh fruits is mainly due to water loss as a result of evaporation and transpiration, while the amount of dry matter is lost by respiration. Results of this study on weight loss reduction are in accordance with what observed on ‘Florida prince’ peach (El-Badawy, 2012) and plums (Kirmani et al., 2013), where a progressive and significant increase in physiological loss in weight (PLW) of fruits with the increase in storage duration was recorded. However, the increase in PLW of calcium chloride-treated fruits was relatively slower and, consequently, these fruits exhibited significantly lower overall losses as compared to other treatments and control fruits. The reduction in weight loss in CaCl\(_2\) treated fruits might be due to the maintenance of fruit firmness and tissue rigidity by decreasing the enzyme activity responsible for disintegration of cellular structure, which decreases the gaseous exchange (Levy; Poovalia, 1979).

In this study, chitosan proved to be an effective coating reducing weight loss, alone as reported on longan fruit (Jiang; Li, 2001), or in combination with calcium chloride on peach (El-Badawy, 2012). 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).
Table 1: Effect of some pre-harvest treatments on weight loss (%) of ‘Early Swelling’ peach fruits stored at 0±1 ºC during 2014 and 2015 seasons. Different letters indicate significantly different values by ANOVA followed by Duncan test at P≤0.05 (small letters refer to values recorded in each season, capital letters refer to mean values).

<table>
<thead>
<tr>
<th>Treatment</th>
<th>2014 season</th>
<th>2015 season</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Storage period (days)</td>
<td>Storage period (days)</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>Mean</td>
</tr>
<tr>
<td>Control</td>
<td>8.67nop</td>
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</tr>
<tr>
<td></td>
<td>12.72hij</td>
<td>16.47hij</td>
</tr>
<tr>
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<td>9.04qrs</td>
</tr>
<tr>
<td></td>
<td>11.38j-m</td>
<td>14.23hi</td>
</tr>
<tr>
<td>0.5% Chitosan</td>
<td>5.00rs</td>
<td>9.20m-p</td>
</tr>
<tr>
<td>1% Chitosan</td>
<td>5.67qrs</td>
<td>13.34h-k</td>
</tr>
<tr>
<td>1% CaCl₂ + 0.5% chitosan</td>
<td>4.67rs</td>
<td>7.00m-p</td>
</tr>
<tr>
<td></td>
<td>9.74mno</td>
<td>12.26i-l</td>
</tr>
<tr>
<td>2% CaCl₂ + 0.5% chitosan</td>
<td>7.00qrs</td>
<td>11.34h-k</td>
</tr>
<tr>
<td></td>
<td>13.36hijk</td>
<td>17.04f-g</td>
</tr>
<tr>
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</tr>
<tr>
<td></td>
<td>9.52m-p</td>
<td>13.26i-l</td>
</tr>
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</table>

Decay (%)

In both seasons, decay percentages had progressive increment as the storage period increased (Table 2). Decay incidence started at the second week of storage, and gradually increased up to day 35 of storage. Pre-harvest treatments of 2% CaCl₂+1% chitosan, 1% CaCl₂+0.5% chitosan, 2% CaCl₂+0.5% chitosan, and 2% CaCl₂+1% chitosan, in this order, recorded the lowest significant decay percentages. On the whole, the lowest fruit decay (%) was obtained when the fruits were treated with 2% CaCl₂+1% chitosan and stored for 14 days; on the contrary, the highest significant decay percentage was gained following 35 days of storage period of untreated fruits (control).

Results here may be attributed to the role of calcium ions in reducing fruit softening by strengthening the cell walls, as well as of chitosan covering cuticle and lenticels. Moreover, their high antifungal activity reduces respiration, ripening processes and infection during storage. Results of this study are in agreement with previous reports which indicated that calcium chloride spray reduces physiological disorders of fruits and increases their resistance to infection than untreated ones (Kirmani et al., 2013).

Chitosan modifies gas exchange of fruit with the atmosphere, and its internal gas composition by producing a film coating on the surface. The suppressive effect on decay by chitosan can be in part attributed to delaying the senescence process. Chitosan, as a natural polycation compound, c limit fungal decay of fruits by its direct antifungal activity (Bautista-Banos et al., 2006), induction of host resistance to pathogens (Trotel-Aziz et al., 2006), and its self-polymerisation that covers the fruit surface (Gonzalez-Aguilar, 2009). It offers a protection against deterioration by slowing decay and ripening; moreover, its protective effect is very high against infection (Reddy et al., 2000). For all these properties, chitosan has a potential to prolong storage life and control decay of fruits. As for the combination of chitosan and calcium chloride, its potential as fungal decay inhibitors has been reported also by Muñoz et al. (2008).

The results of pre-harvest chitosan efficiency in reducing decay percentages are in accordance with those obtained by Reddy et al. (2000) that evidenced the protection effect against infection due to pre-harvest chitosan spray of Botrytis cinerea. Similar findings have been also reported on grape (Meng et al., 2008), citrus (Chien; Sheu; Yang, 2007), ‘Florida prince’ peach (El-Badawy, 2012).
Table 2: Effect of some pre-harvest treatments on decay (%) of 'Early Swelling' peach fruits stored at 0±1 ºC during 2014 and 2015 seasons. Different letters indicate significantly different values by ANOVA followed by Duncan test at P ≤ 0.05 (small letters refer to values recorded in each season, capital letters refer to mean values).

<table>
<thead>
<tr>
<th>Treatment</th>
<th>2014 season</th>
<th>2015 season</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Storage period (days)</td>
<td>Mean</td>
</tr>
<tr>
<td>Control</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>14</td>
</tr>
<tr>
<td>0.00w</td>
<td>8.33r</td>
<td>16.67m</td>
</tr>
<tr>
<td>1% CaCl2</td>
<td>3.54t</td>
<td>13.56n</td>
</tr>
<tr>
<td>2% CaCl2</td>
<td>5.32s</td>
<td>11.60o</td>
</tr>
<tr>
<td>0.5% Chitosan</td>
<td>3.14tu</td>
<td>11.34o</td>
</tr>
<tr>
<td>1% Chitosan</td>
<td>3.56t</td>
<td>10.75op</td>
</tr>
<tr>
<td>1% CaCl2 + 0.5% chitosan</td>
<td>2.67tuv</td>
<td>10.44opq</td>
</tr>
<tr>
<td>1% CaCl2 + 1% chitosan</td>
<td>1.43w</td>
<td>9.32pq</td>
</tr>
<tr>
<td>2% CaCl2 + 0.5% chitosan</td>
<td>1.87uv</td>
<td>10.11opq</td>
</tr>
<tr>
<td>2% CaCl2 + 1% chitosan</td>
<td>1.21w</td>
<td>9.23qr</td>
</tr>
<tr>
<td>Mean</td>
<td>0.00E</td>
<td>3.45D</td>
</tr>
</tbody>
</table>

Fruit firmness is one of the most crucial factors in determining the post-harvest quality and physiology of fruits (Kirmani et al., 2013). Data presented in Table 3 show that fruit firmness has significantly decreased as the storage period increased, reaching its lowest values at the end of storage period, regardless of the pre-harvest treatments. All treatments recorded significantly high firmness than control fruits; however, in both seasons, 2% CaCl2 + 1% chitosan showed, at each period, with few exceptions, the highest values of peach firmness. It should be noted that all the treatments had an effect in preserving fruit firmness as, at the end of the storage period, the lowest firmness value was obtained by the untreated fruits.

Pre-harvest beneficial effect of chitosan on fruit firmness could be due to the formation of a chitosan film on fruit which can act as a barrier for O2 uptake, thereby slowing the metabolic activity and consequently the ripening process (Reddy et al., 2000). Generally, the loss of pectic substances in the middle lamellae of the cell wall is perhaps the key step in ripening process that leads to the loss of cell integrity or firmness (Solomos; Latsis, 1973). The desired effect of calcium in maintaining fruit firmness may be due to the calcium binding to free carboxyl groups of polygalacturonate polymer, stabilizing and strengthening the cell wall, which in turn may strengthen the tissue becoming more resistant to hydrolytic enzyme activity, where calcium inhibits the polygalacturonase activity in cell walls (Buescher; Hobson, 1982). Results here regarding the role of CaCl2 in the reduction of fruit softening are in correlation with those obtained on plums (Kirmiani et al., 2013) and strawberry (Muñoz et al., 2008). All these reports show that the effect of calcium on firmness loss following the pre-harvest application of CaCl2 is due to a reduction in the activity of polygalacturonase enzyme in the cell wall. In addition, Reddy et al. (2000) reported that the beneficial effect of pre-harvest chitosan sprays on flesh firmness of untreated plums could be due to the formation of a chitosan film on fruit which can act as a barrier for O2 uptake, thereby slowing the metabolic activity and consequently the ripening process. It should be noted that chitosan treatments delayed the loss of firmness. In conclusion, the lowest firmness value as obtained by the untreated fruits.
Table 3: Effect of some pre-harvest treatments on firmness (kg/cm²) of 'Early Swelling' peach fruits stored at 0±1 °C during 2014 and 2015 seasons. Different letters indicate significantly different values by ANOVA followed by Duncan test at P≤0.05 (small letters refer to values recorded in each season, capital letters refer to mean values).

<table>
<thead>
<tr>
<th>Treatment</th>
<th>2014 season</th>
<th>Mean</th>
<th>2015 season</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Storage period (days)</td>
<td></td>
<td>Storage period (days)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0 7 14 21 28 35</td>
<td>Mean</td>
<td>0 7 14 21 28 35</td>
<td>Mean</td>
</tr>
<tr>
<td>Control</td>
<td>1.10b-h 1.03f-l 0.870-v 0.72x 0.59y 0.49y</td>
<td>0.80C</td>
<td>1.15abc 1.00d-j 0.89i-q 0.84l-u 0.75r-v 0.57w</td>
<td>0.87B</td>
</tr>
<tr>
<td>1% CaCl₂</td>
<td>1.23a 1.07c-j 0.96q 0.91t 0.86p-w 0.82s-x</td>
<td>0.98B</td>
<td>1.10a-e 1.03b-i 0.95f-m 0.90i-q 0.84m-u 0.79p-v</td>
<td>0.94A</td>
</tr>
<tr>
<td>2% CaCl₂</td>
<td>1.20ab 1.04e-k 1.02g-m 0.97i-p 0.90n-t 0.75 wax</td>
<td>0.98B</td>
<td>1.16ab 1.10a-e 1.00e-k 0.88s-j 0.79o-v 0.69w</td>
<td>0.94A</td>
</tr>
<tr>
<td>0.5% Chitosan</td>
<td>1.18abc 1.09b-i 1.00h-n 0.93k-s 0.85r-w 0.71x</td>
<td>0.69B</td>
<td>1.18a 1.08-a-f 0.94f-o 0.85k-t 0.78q-v 0.71uw</td>
<td>0.92AB</td>
</tr>
<tr>
<td>1% Chitosan</td>
<td>1.15a-e 1.06d-j 1.01h-n 0.94k-r 0.88o-u 0.80x</td>
<td>0.79B</td>
<td>1.14a-d 1.05a-h 0.94f-n 0.89i-r 0.80n-v 0.72tuv</td>
<td>0.92AB</td>
</tr>
<tr>
<td>1% CaCl₂ + 0.5% chitosan</td>
<td>1.20ab 1.14a-f 1.06d-j 0.98i-o 0.91m-t 0.77u-x</td>
<td>1.01AB</td>
<td>1.13a-e 1.05a-g 0.98e-l 0.91h-q 0.84m-u 0.75s-v</td>
<td>0.94A</td>
</tr>
<tr>
<td>1% CaCl₂ + 1% chitosan</td>
<td>1.23a 1.13a-g 1.03f-k 0.94k-r 0.87o-v 0.84r-w</td>
<td>1.01AB</td>
<td>1.16ab 1.10a-e 1.01c-j 0.91q-i 0.81n-v</td>
<td>0.72tu</td>
</tr>
<tr>
<td>2% CaCl₂ + 0.5% chitosan</td>
<td>1.24ab 1.18abc 1.06d-j 0.98i-p 0.86q-w 0.76wxx</td>
<td>1.01AB</td>
<td>1.17ab 1.06a-g 1.00d-j 0.93g-p 0.83m-u</td>
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</tr>
<tr>
<td>2% CaCl₂ + 1% chitosan</td>
<td>1.25a 1.16a-d 1.08c-i 1.02g-m 0.94k-r 0.87o-v</td>
<td>1.05A</td>
<td>1.18a 1.10a-e 1.01c-j 0.90i-q 0.82m-v</td>
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</tr>
<tr>
<td>Mean</td>
<td>1.20AB 1.10B 1.01C 0.93D 0.85E 0.76F</td>
<td>1.15A</td>
<td>1.06B 0.97C 0.89D 0.81E 0.71F</td>
<td></td>
</tr>
</tbody>
</table>

The application of chitosan or CaCl₂ at different concentrations had a high effect on post-harvest shelf-life of 'Early Swelling' peach fruits (Table 5). Both treatments, CaCl₂, and chitosan, significantly reduced the color change rate of mango fruits during their storage, compared to untreated fruits.
Table 4: Effect of some pre-harvest treatments on hue angle (h°) of ‘Early Swelling’ peach fruits stored at 0±1 ºC during 2014 and 2015 seasons. Different letters indicate significantly different values by ANOVA followed by Duncan test at P≤0.05 (small letters refer to values recorded in each season, capital letters refer to mean values).

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<tr>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Storage period (days)</td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>59.88a-e 56.64af</td>
<td>56.64C</td>
</tr>
<tr>
<td>1% CaCl₂</td>
<td>61.21ab 55.47d-g</td>
<td>56.64C</td>
</tr>
<tr>
<td>2% CaCl₂</td>
<td>60.55a-d 55.67c-g</td>
<td>56.64C</td>
</tr>
<tr>
<td>0.5% Chitosan</td>
<td>59.04a-e 56.19g</td>
<td>56.64C</td>
</tr>
<tr>
<td>1% Chitosan</td>
<td>59.22a-e 55.07efg</td>
<td>56.64C</td>
</tr>
<tr>
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<tr>
<td>1% Chitosan</td>
<td>59.22a-e 55.07efg</td>
<td>56.64C</td>
</tr>
<tr>
<td>1% CaCl₂ + 0.5% chitosan</td>
<td>61.42a 56.64af</td>
<td>56.64C</td>
</tr>
<tr>
<td>1% CaCl₂ + 1% chitosan</td>
<td>60.40a-d 56.12cg</td>
<td>56.64C</td>
</tr>
<tr>
<td>0.5% Chitosan</td>
<td>59.22a-e 55.07efg</td>
<td>56.64C</td>
</tr>
<tr>
<td>1% Chitosan</td>
<td>59.22a-e 55.07efg</td>
<td>56.64C</td>
</tr>
<tr>
<td>Control</td>
<td>59.22a-e 55.07efg</td>
<td>56.64C</td>
</tr>
<tr>
<td>1% CaCl₂</td>
<td>61.21ab 55.47d-g</td>
<td>56.64C</td>
</tr>
<tr>
<td>2% CaCl₂</td>
<td>60.55a-d 55.67c-g</td>
<td>56.64C</td>
</tr>
<tr>
<td>0.5% Chitosan</td>
<td>59.04a-e 56.19g</td>
<td>56.64C</td>
</tr>
<tr>
<td>1% Chitosan</td>
<td>59.22a-e 55.07efg</td>
<td>56.64C</td>
</tr>
<tr>
<td>1% CaCl₂ + 0.5% chitosan</td>
<td>61.42a 56.64af</td>
<td>56.64C</td>
</tr>
<tr>
<td>1% CaCl₂ + 1% chitosan</td>
<td>60.40a-d 56.12cg</td>
<td>56.64C</td>
</tr>
<tr>
<td>0.5% Chitosan</td>
<td>59.22a-e 55.07efg</td>
<td>56.64C</td>
</tr>
<tr>
<td>1% Chitosan</td>
<td>59.22a-e 55.07efg</td>
<td>56.64C</td>
</tr>
<tr>
<td>Control</td>
<td>59.22a-e 55.07efg</td>
<td>56.64C</td>
</tr>
<tr>
<td>1% CaCl₂</td>
<td>61.21ab 55.47d-g</td>
<td>56.64C</td>
</tr>
<tr>
<td>2% CaCl₂</td>
<td>60.55a-d 55.67c-g</td>
<td>56.64C</td>
</tr>
<tr>
<td>0.5% Chitosan</td>
<td>59.04a-e 56.19g</td>
<td>56.64C</td>
</tr>
<tr>
<td>1% Chitosan</td>
<td>59.22a-e 55.07efg</td>
<td>56.64C</td>
</tr>
<tr>
<td>1% CaCl₂ + 0.5% chitosan</td>
<td>61.42a 56.64af</td>
<td>56.64C</td>
</tr>
<tr>
<td>1% CaCl₂ + 1% chitosan</td>
<td>60.40a-d 56.12cg</td>
<td>56.64C</td>
</tr>
<tr>
<td>0.5% Chitosan</td>
<td>59.22a-e 55.07efg</td>
<td>56.64C</td>
</tr>
<tr>
<td>1% Chitosan</td>
<td>59.22a-e 55.07efg</td>
<td>56.64C</td>
</tr>
</tbody>
</table>

Table 5: Effect of some pre-harvest treatments on shelf life (days) of ‘Early Swelling’ peach fruits after 35 days of cold storage at 0±1 ºC during 2014 and 2015 seasons. Different letters indicate significantly different values by ANOVA followed by Duncan test at P≤0.05.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Shelf life (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2014 season</td>
</tr>
<tr>
<td>Control</td>
<td>2.00D</td>
</tr>
<tr>
<td>1% CaCl₂</td>
<td>2.33CD</td>
</tr>
<tr>
<td>2% CaCl₂</td>
<td>2.33CD</td>
</tr>
<tr>
<td>0.5% Chitosan</td>
<td>2.33CD</td>
</tr>
<tr>
<td>1% Chitosan</td>
<td>2.33CD</td>
</tr>
<tr>
<td>1% CaCl₂ + 0.5% chitosan</td>
<td>2.33CD</td>
</tr>
<tr>
<td>1% CaCl₂ + 1% chitosan</td>
<td>2.33CD</td>
</tr>
<tr>
<td>0.5% Chitosan</td>
<td>2.33CD</td>
</tr>
<tr>
<td>1% Chitosan</td>
<td>2.33CD</td>
</tr>
<tr>
<td>Control</td>
<td>2.00D</td>
</tr>
<tr>
<td>1% CaCl₂</td>
<td>2.33CD</td>
</tr>
<tr>
<td>2% CaCl₂</td>
<td>2.33CD</td>
</tr>
<tr>
<td>0.5% Chitosan</td>
<td>2.33CD</td>
</tr>
<tr>
<td>1% Chitosan</td>
<td>2.33CD</td>
</tr>
<tr>
<td>1% CaCl₂ + 0.5% chitosan</td>
<td>2.33CD</td>
</tr>
<tr>
<td>1% CaCl₂ + 1% chitosan</td>
<td>2.33CD</td>
</tr>
<tr>
<td>0.5% Chitosan</td>
<td>2.33CD</td>
</tr>
<tr>
<td>1% Chitosan</td>
<td>2.33CD</td>
</tr>
<tr>
<td>Control</td>
<td>2.00D</td>
</tr>
<tr>
<td>1% CaCl₂</td>
<td>2.33CD</td>
</tr>
<tr>
<td>2% CaCl₂</td>
<td>2.33CD</td>
</tr>
<tr>
<td>0.5% Chitosan</td>
<td>2.33CD</td>
</tr>
<tr>
<td>1% Chitosan</td>
<td>2.33CD</td>
</tr>
<tr>
<td>1% CaCl₂ + 0.5% chitosan</td>
<td>2.33CD</td>
</tr>
<tr>
<td>1% CaCl₂ + 1% chitosan</td>
<td>2.33CD</td>
</tr>
<tr>
<td>0.5% Chitosan</td>
<td>2.33CD</td>
</tr>
<tr>
<td>1% Chitosan</td>
<td>2.33CD</td>
</tr>
</tbody>
</table>

Total soluble solid (TSS) percentage showed a steady increase in firmness, commensurate with the advance in the storage period (Table 6), this was regardless of treatments. In both seasons, untreated fruits recorded low TSS percentages (43.92% in 2014 and 43.20% in 2015). These beneficial effects may due to the reduction of fruit respiration metabolism (El-Ghapprah; Ponnampalam; Boulet, 1991; Hagenmaier, 2005), and increased the shelf life of fruits (Maftoonazad; Ramaswamy, 2005). In addition, chitosan acts as an effective preservative for the increase of shelf life of peach fruits (El-Badawy, 2012) and mango (Chauhan; Agrawal; Raje, 2014).
Table 6: Effect of some pre-harvest treatments on total soluble solid (%) of ‘Early Swelling’ peach fruits stored at 0±1 ºC during 2014 and 2015 seasons. Different letters indicate significantly different values by ANOVA followed by Duncan test at P≤0.05 (small letters refer to values recorded in each season, capital letters refer to mean values).

<table>
<thead>
<tr>
<th>Treatment</th>
<th>2014 season</th>
<th>Mean</th>
<th>2015 season</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Storage period (days)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0 7 14 21 28 35</td>
<td>14.96A</td>
<td>15.10A</td>
<td>16.30E</td>
</tr>
<tr>
<td>Control</td>
<td></td>
<td>12.63p-u 13.17n-t</td>
<td>14.10h-q 15.53b-i</td>
<td>15.53b-i</td>
</tr>
<tr>
<td>1% CaCl₂</td>
<td></td>
<td>12.93o-t 13.53s-k</td>
<td>14.30g-o 15.00d-I</td>
<td>15.87b-f</td>
</tr>
<tr>
<td>2% CaCl₂</td>
<td></td>
<td>12.77o-t 13.33m-t</td>
<td>14.03i-q 16.00f-k</td>
<td>16.30A</td>
</tr>
<tr>
<td>0.5% Chitosan</td>
<td></td>
<td>12.77o-u 13.60k-o</td>
<td>14.83e-m15.77b-g</td>
<td>16.40d-a</td>
</tr>
<tr>
<td>1% Chitosan</td>
<td></td>
<td>12.80o-u 13.30m-t</td>
<td>13.90j-r 14.60f-n</td>
<td>15.77b-g</td>
</tr>
<tr>
<td>1% CaCl₂ + 0.5% chitosan</td>
<td></td>
<td>12.00o-stu 13.47l-s</td>
<td>14.10h-q 17.35m-5b-j</td>
<td>15.87b-f</td>
</tr>
<tr>
<td>1% CaCl₂ + 1% chitosan</td>
<td></td>
<td>12.57q-u 13.07n-t</td>
<td>13.57k-r 14.27g-o</td>
<td>16.50a-d</td>
</tr>
<tr>
<td>2% CaCl₂ + 0.5% chitosan</td>
<td></td>
<td>11.87tu 12.47r-u</td>
<td>13.70k-r 14.83e-m15.47b-i</td>
<td>16.20h-j</td>
</tr>
<tr>
<td>2% CaCl₂ + 1% chitosan</td>
<td></td>
<td>11.40u 13.07n-t</td>
<td>13.57k-r 14.17h-p</td>
<td>14.83e-m15.90b-f</td>
</tr>
</tbody>
</table>

The highest TSS mean percentage, compared to all the other treatments, was obtained with the treatment of 2% CaCl₂ + 1% chitosan. Increased TSS percentages throughout the storage period are presumably due to increased activity of enzymes responsible for starch hydrolysis to soluble sugars and can be caused by the decline in the amount of carbohydrates, pectines, partial hydrolysis of proteins and decomposition of glucosides into subunits during respiration (Abbasi et al., 2009). Wongmetha and Ke (2012) reported that chitosan had no effect on TSS of mango fruits. A similar response was also showed in strawberry (Muñoz et al., 2008). Results of calcium as a pre-harvest treatment are in harmony with those mentioned by Montanaro et al. (2006) on kiwifruit, Bhat et al. (2012) on pear and El-Badawy (2012) on ‘Florida Prince’ peach.
Table 7: Effect of some pre-harvest treatments on titratable acidity (%) of 'Early Swelling' peach fruits stored at 0±1 ºC during 2014 and 2015 seasons. Different letters indicate significantly different values by ANOVA followed by Duncan test at P≤0.05 (small letters refer to values recorded in each season, capital letters refer to mean values).

<table>
<thead>
<tr>
<th>Treatment</th>
<th>2014 season Storage period (days)</th>
<th>Mean Storage period (days)</th>
<th>2015 season Storage period (days)</th>
<th>Mean Storage period (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 7 14 21 28 35</td>
<td>0 7 14 21 28 35</td>
<td></td>
<td>0 7 14 21 28 35</td>
</tr>
<tr>
<td>Control</td>
<td>0.360a-g 0.330d-l 0.290h-q 0.283i-r 0.260n-s 0.223rs 0.291C</td>
<td>0.360ef 0.330j 0.320k 0.293o 0.270r 0.260st 0.306E</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1% CaCl₂</td>
<td>0.380a-e 0.333c-k 0.306g-p 0.286h-q 0.250o-s 0.210s 0.294C</td>
<td>0.370d 0.353g 0.323k 0.293o 0.273r 0.243v 0.309D</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2% CaCl₂</td>
<td>0.380a-e 0.316e-n 0.306g-p 0.266l-s 0.243p-s 0.210s 0.287C</td>
<td>0.390b 0.347h 0.330j 0.307m 0.280q 0.250u 0.317C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.5% Chitosan</td>
<td>0.380a-e 0.326d-m 0.303g-p 0.286h-q 0.266l-s 0.246p-s 0.302BC</td>
<td>0.360ef 0.347h 0.323k 0.300n 0.273r 0.260st 0.311D</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1% Chitosan</td>
<td>0.380a-e 0.350a-h 0.323d-n 0.280j-r 0.260n-s 0.236qrs 0.305BC</td>
<td>0.390b 0.347h 0.330j 0.307m 0.280q 0.250u 0.317C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1% CaCl₂ + 0.5% chitosan</td>
<td>0.380a-e 0.356a-g 0.330d-l 0.326d-m 0.286h-q 0.263m-s 0.324AB</td>
<td>0.380c 0.363e 0.330j 0.310lm 0.287p 0.270r 0.323B</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1% CaCl₂ + 1% chitosan</td>
<td>0.393abc 0.380a-e 0.356a-g 0.333c-k 0.313f-o 0.283i-r 0.343A</td>
<td>0.380c 0.357fg 0.340i 0.313l 0.290op 0.273r 0.326AB</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2% CaCl₂ + 0.5% chitosan</td>
<td>0.406a 0.370a-f 0.346a-i 0.326d-m 0.300g-p 0.276k-r 0.338A</td>
<td>0.400a 0.357fg 0.340i 0.313l 0.280g 0.257t 0.324AB</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2% CaCl₂ + 1% chitosan</td>
<td>0.400ab 0.387a-d 0.343b-j 0.323d-n 0.307g-p 0.273k-r 0.340A</td>
<td>0.390b 0.360ef 0.337i 0.320k 0.290op 0.263s 0.327A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>0.384A 0.350B 0.323C 0.300C 0.276D 0.247E</td>
<td>0.380A 0.351B 0.330C 0.31D 0.280E 0.259F</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 8: Effect of some pre-harvest treatments on total phenols (%) of 'Early Swelling' peach fruits stored at 0±1 ºC during 2014 and 2015 seasons. Different letters indicate significantly different values by ANOVA followed by Duncan test at P≤0.05 (small letters refer to values recorded in each season, capital letters refer to mean values).

<table>
<thead>
<tr>
<th>Treatment</th>
<th>2014 season Storage period (days)</th>
<th>Mean Storage period (days)</th>
<th>2015 season Storage period (days)</th>
<th>Mean Storage period (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 7 14 21 28 35</td>
<td>0 7 14 21 28 35</td>
<td></td>
<td>0 7 14 21 28 35</td>
</tr>
<tr>
<td>Control</td>
<td>0.044b-g 0.051a-e 0.058ab 0.068a 0.055A</td>
<td>0.027h-k 0.032e-h 0.036de 0.048a 0.036A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1% CaCl₂</td>
<td>0.040c-g 0.043b-g 0.047b-g 0.054a-d 0.046AB</td>
<td>0.028h-l 0.031f-i 0.034efg 0.048a 0.035AB</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2% CaCl₂</td>
<td>0.039c-g 0.043b-g 0.046b-g 0.051a-e 0.045B</td>
<td>0.024fkm 0.029g-j 0.035def 0.045ab 0.033ABC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.5% Chitosan</td>
<td>0.039c-g 0.043b-g 0.046b-g 0.050b-f 0.045B</td>
<td>0.028i-m 0.030g-j 0.032e-h 0.041bc 0.032BC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1% Chitosan</td>
<td>0.037d-g 0.041c-g 0.045b-g 0.052a-d 0.044B</td>
<td>0.026i-m 0.028h-k 0.031f-i 0.039cd 0.031CD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1% CaCl₂ + 0.5% chitosan</td>
<td>0.030g 0.038d-g 0.047b-g 0.056abc 0.043B</td>
<td>0.026i-m 0.027h-l 0.029g-j 0.039cd 0.030CDE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1% CaCl₂ + 1% chitosan</td>
<td>0.032g 0.039d-g 0.046b-g 0.052a-d 0.042B</td>
<td>0.025j-m 0.025j-r 0.026i-m 0.035def 0.028EF</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2% CaCl₂ + 0.5% chitosan</td>
<td>0.035efg 0.039c-g 0.044b-g 0.053a-d 0.043B</td>
<td>0.025j-m 0.026i-m 0.027h-l 0.035def 0.029DE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2% CaCl₂ + 1% chitosan</td>
<td>0.033fg 0.037d-g 0.040c-g 0.050b-f 0.040B</td>
<td>0.022m 0.023lm 0.024km 0.033efg 0.025F</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>0.037C 0.042BC 0.047AB 0.054A</td>
<td>0.025C 0.028BC 0.030B 0.040A</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
CONCLUSIONS

The effect of pre-harvest application of calcium chloride, chitosan and their combinations on storability and quality attributes of ‘Early Swelling’ peach fruits was investigated in this study. CaCl₂ at 2% and chitosan at 1% concentrations proved to be effective in reducing weight loss (%), decay (%), and maintaining maximum firmness and lengthening shelf life. Fruit color (L*) was not affected by any of the treatments, while untreated fruits and calcium chloride alone with both the applied concentrations, were found to maintain higher total soluble solids (%), total phenolic content, and lower titratable acidity percentage (%).

REFERENCES


