Effects of Post-harvest Pre-cooling Processes and Cyclical Heat Treatment on the Physico-chemical Properties of " Red Haven Peaches" and "Shahmiveh Pears" During Cold Storage

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Abstract

The effects of different post-harvest hydrocooling solutions along with conventional cold storage and cyclical heat treatment on the physico-chemical properties and sensory characteristics of Persian "Red Haven" peaches and "Shahmiveh" pears were studied. Peaches and pears were harvested at 24^oC and at 26^oC respectively and immediately pre-cooled with: 20^oC ambient air, 14^oC raw water, plain ice water, ice water + 2% (W/W) $CaCl_2$, and ice water + 2% (W/W) $CaCl_2$ + 100ppm chlorine respectively for a holding time of 24h, 45, 30, 30 and 30 min until their final temperatures reached to 20^oC, 15^oC, 4^oC, 4^oC and 4^oC. Pre-cooled fruits were transferred to cold storage at 2^oC and 85%RH respectively for 4 and 10 weeks. All the peaches were brought out of the cold storage once a week for about 10 hours and held at 20^oC ambient temperature to prevent possible chilling injuries. Periodical measurements of physico-chemical parameters of fruits during storage and their sensory evaluation after storage showed that in most of the cases peaches and pears pre-cooled with different ice water solutions had significantly higher firmness, pectin content, organoleptic scores and lower weight loss than air-cooled samples. Addition of $CaCl_2$ to ice water along with cyclical heat treatment during storage increased the firmness (up to 50%) and lowered the pectin hydrolysis and weight loss of peaches up to respectively 25% and 50%. Similarly, addition of $CaCl_2$ to ice water increased the firmness (up to 60%) and lowered the pectin hydrolysis and weight loss of pears up to respectively 30% and 40%. Sensory analysis also showed that peaches and pears precooled with ice water containing $CaCl_2$ had significantly higher firmness and more attractive appearance, color and flavor than air cooled samples.

Keywords: hydrocooling, ice water cooling, firmness, pectin, cyclical heat treatment, weight loss, and fruits.

Introduction

In order to reduce post-harvest losses and meet market requirements of perishable horticultural produce, its preservation in the fresh state is of commercial importance (Puttaraju and Reddy 1997). Fast pre-cooling of agricultural produce after harvest (especially for those that have high respiration rates and /or a high surface to volume ratio), reduces the rate of quality loss and extends shelf life (Jeong et al. 1996).

Pre-cooling by removing field heat from freshly harvested fruits reduces microbial activity and respiration rates. Furthermore, the respiratory activity and senescence of fruit as well as ethylene production are temperature dependent. Due to the pre-cooling treatments, metabolic activity and consequently respiration rate and ethylene production of the fruits were reduced considerably. This also decreases the ripening rate, diminishes water loss and decay, and thus, helps preserving quality and prolongs shelf life of the fruits (Ferreira et al. 1994 and Reina et al. 1995). The process of heat removal from fresh produce can be achieved by several different methods, such as natural air cooling, forced air cooling, hydrocooling, ice cooling and vacuum cooling, each one differing in heat removal efficiency and processing cost.

One of the suitable methods for pre-cooling of harvested peaches is using forced air cooling process followed by anti-bacterial oil coating and finally water cooling (Smith 1982). Although this method has been very effective, its processing cost is much higher than using ice water directly for pre-cooling. In the forced air-cooling method, there is a high possibility of surface water evaporation and weight losses of produce, particularly, when the fruits are subjected to high air velocity.

Hydrocooling is a procedure in which, fruits are either sprayed with or immersed in cold water to reduce their temperature. Likewise many other perishable fruits, pears and peaches need to be precooled immediately after harvest and efficient hydrocooling with accurate cooling time is strongly recommended (Becker and Fricke 2002). In hydrocooling treatment, water is not lost from produce surfaces, but rather absorbed by them (Bartz 1988). Additional useful effects of the hydrocooling process include cleaning products (by removing chemical residues and debris), delaying fruit decay, and reducing surface scald, bronzing, and pitting (Sharp and Gould 1994). The rate of pre-cooling of the fruits immediately after harvest is a determining factor for their quality and durability in storage (Tonini et al. 1979).

Hydrocooling is a less expensive cooling method than the forced air cooling method, because water is more efficient than air in transferring the heat. This process removes field heat from produce up to 15 times more rapidly than the forced air cooling method (Ferreira et al. 1994). The heat transfer coefficient of hydrocooling is much higher than that of air cooling with natural convection methods. Nevertheless the heat transfer coefficients for hydrocooling and forced air cooling are comparable, if the air speed is high (Berinyuy, 1989).

In most instances, the water used for hydrocooling treatment is recycled (perhaps for several days) and becomes contaminated with spoilage microorganisms. These microorganisms contaminate subsequently cooled produce through natural openings and mechanical injuries created during harvesting. It is necessary to treat water with antifungal and antibacterial agents to avoid microbial build-up during hydrocooling. Chlorine solution in form of sodium, potassium, or calcium hypo-chlorite has been used to eliminate microorganisms for many years. To control *Rhizopus*, the responsible microorganism for sour rot in peaches, the best option is to use chlorine as the cheapest and most effective chemical compounds (Hopfinger 1989). While there is a belief that using chlorine in hydrocooling process leads to skin discoloration of peaches, researchers (Crisosto et al. 1993) repeatedly stated that chlorine concentration of water below 300 ppm is not a factor of color change as long as fruits skins have not been removed. On the other hand peach skin discoloration may originate from the hydrocooler. As Hopfinger (1989) reported, this disorder caused by the acidic pH (around 4.8) and presence of iron (about 80 ppm) in water. He used calcium hypochlorite at a concentration of 120 ppm and significantly reduced discoloration. Addition of calcium hypochloride not only increased the pH, but also decreased the solubility of iron in cooling water and caused to bind with it and precipitate (Hopfinger 1989). Furthermore, Crisosto (2002) reported that exposing fruit to clean water with high pH during hydrocooling dose not induce inking and discoloration. On the other hand dipping pears in $CaCl_2$ solution protected its original firmness: delayed its ripening process up to 40% of the time needed for untreated fruit (control) to ripe and produced fruit with acceptable sensory properties (Wills et al. 1982).

Calcium in form of pectic substances is found primarily in the middle lamella and in the primary cell walls of plant tissues. It acts as cementing or cell binding materials. Calcium has an important role in stability of cell wall structure, especially in fruits that are stored for relatively long time such as pears (Pooviah 1988). Gradual infiltration of calcium to cell wall results in increasing level of this ion in the cell wall and thus stabilizes it and protects the fruit against fungal and microbial contamination (Pooviah et al. 1991). Furthermore, postharvest treatment of "Passe-Crassane" pear cultivar with 2% (w/v) of $CaCl_2$ solution followed by cold storage (2^oC & 90%RH) and ripening after storage for one week at 20^oC not only prevented cellular wall and membrane degradation, but also decreased ethylene production and delayed its ripening process (Lara and Vendrell 1998). It was also found that firmness of "Red Delicious" apple is directly related to the calcium concentration in post-harvest hydrocooling treatment (Conway and Sams 1984).

The peaches unlike pears are very sensitive to chilling injuries during storage. A cyclical heat treatment or intermittent warming has been recommended to prevent any possible internal breakdown and damage. According to (Anderson 1979) peaches and nectarines that are warmed (2 days at about 18.3^oC) during low temperature storage of 0^oC have less internal breakdown, lower respiration rates and higher acidity than un-warmed fruits. This technique has been used as a method to prevent and alleviate chilling injuries in peaches during continuous cold storage at $1\text{-}2^oC$ (Ben-Arie et al. 1970, Lill et al. 1989, Marcellin and Ulrich 1983, Artes et al. 1996, Fernandez-Trujillo et al. 2000).

"Red Haven" and "Shahmiveh" are the two main varieties of Persian peaches and pears grown in the vast horticultural areas of Iran. The Persian "Red Haven" peaches have mostly a combined yellow red skin color, yellow pulp and the stone is easily separated from the meat. It has a semi hard texture and good handling properties. After ripening, it is very tasty and attractive. In terms of shape and size, the "Shahmiveh" pear is very similar to "Williams' Bon Chr'etein" or "Barlett" variety (Hedrick 1995), with a crisp texture, very good taste and sweet-smelling flavor. Commercially, these peaches and pears are harvested in July and August respectively and in a relatively short time.

Although hydrocooling process has been practiced for different varieties of Asian (mainly Chinese and Japanese), European and American varieties of peaches and pears, but this process has not been practiced for these two Persian varieties of peaches and pears. In fact the proposed varieties of peaches and pears are pre-cooled mainly with natural air convection method after harvest, and also their shelf life did not effectively extend during conventional cold storage. On the other hand, the cyclic heat treatment has not been studied for this variety of peaches.

The objectives of this study were to investigate the effects of post-harvest hydrocooling and specifically ice water cooling along with $CaCl_2$ on the physico-chemical properties (firmness, pH, total soluble solids, acidity, reducing sugar, and total pectin) and sensory characteristics of "Shahmiveh" pears during cold storage, and combination of these processes with cyclic heat treatment on "Red Haven" peaches.

Materials and Methods

Persian "Red Haven" peaches and "Shahmiveh" pears were harvested early morning from the Karaj Research Garden in July and August respectfully. After harvest each fruit was immediately sorted for size, color and absence of defects and randomly held in 15 groups (5 treatments x 3 replicates) each containing 32 pieces. In order to see the effects of fast heat removal, cell stability of calcium and chlorine sanitation on the quality criteria and during cold storage, five separate treatments of natural air, raw water, plain ice water, ice water + CaCl2, and addition of chlorine to ice water + CaCl2 were chosen and used for postharvet cooling of "Red Haven" peaches and "Shahmiveh" pears. Fruits were rapidly subjected to five pre-cooling treatments. The detail of different experiments has been mentioned in Table 1. The fruits were submerged in raw or ice water tanks along with agitation and the center temperature of some of peaches and pears were measured every 5 min. The rate of decreasing temperature in the center of peaches was faster than pears (mainly because of diameter difference), however both groups of fruits reached to 1^{o}C after 30 min.

Table 1. Pre-cooling treatments for "Red Haven" Peaches and **"**Shahmiveh" Pears respectively harvested at 24°C and 26^{o}C.

Treatment codes	Cooling Medium	Medium Temperature	Cooling Time	Fruits Final Temperatures
ANC	Air-cooling with Natural Convection	10°C at night 20°C at day	24 h	18°C
HRW	Hydrocooling with Raw Water	14 °C	45 min	15°C
HIW	Hydrocooling with Ice Water	Closed to 0°C	30 min	4°C
HIWC	Hydrocooling with Ice Water + CaCl2 (2%w/w)	Closed to 0°C	30 min	4°C
HIWCC	Hydrocooling with Ice Water + CaCl2 (2%w/w) + Chlorine (100ppm)	Closed to 0°C	30 min	4°C

All the fruits were then transferred to a cold storage room at 2^{o}C and 85% RH and stored for up to 4 weeks for peaches and 10 weeks for pears. All the peaches were brought out of the cold storage once a week for about 10 hours and held at 20^{o}C ambient temperature to prevent possible chilling injuries. Samples were taken every week (8 fruit) for peaches and every 2 weeks (6 fruit) for pears. According to the standard systems of Association of Official Analytical Chemists (AOAC), reducing sugar and total pectin content of each sample respectively were measured by sugar inversion or method of 22.097 and alcohol precipitation or methods of 22.008 and 22.067 (AOAC 1975). The three parameters of pH, total acidity (TA), and total soluble solids (TSS) of each sample, respectively were measured by different methods of 32.018 for pH of acidified food, 22.058 for titratable acidity of fruit products, and 22.024 for reducing sugar by refractive system (AOAC 1984). The weight loss was measured by classical and conventional method. The Mitcham et. al (1996) method was adopted to measure the firmness of each sample. In this method a hand Effe-gi penetrometer (Effe-gi, 48011, Afolnsine, Italy) with a maximum capacity of 15 kg/cm^{2} and a plunger of 8 mm diameter was used to record the fruit's firmness at three symmetric equatorial points of each fruit.

A panel of 10 judges at final sampling did organoleptic evaluation of the produce. This panel was selected from twenty graduate students and staff in Food Technology Department of Tehran University. According to Kramer and Twigg (1966) their ability to distinguish the differences in appearance, color, firmness and flavor between different treatments and replicates (at least more than 70% of the times) was assessed by using the triangle test (as an attribute test) and basic hedonic scale (as a variable test). Additionally, the panelists were trained with a wide range of peaches and pears from underripe (fresh) to overripe (stored at room temperature) to have a better filling for different levels of organoleptic attributes. Kramer and Twigg (1966) and Brovelli et al. (1999) recommended a ballot of scoring test (for sensory evaluation of fruit in a multiple comparison method) which detects sensory parameters more efficiently and provide more descriptive information was developed for this experiment (Table 2). Four different properties including appearance, color, firmness and flavor were chosen and a 100-point scale (ranging from 0 for very bad to 100 for very good) was used for the sensory analysis of the samples. While each property was judged at different levels of acceptability, it was also scored by each panelist. Collected data were analyzed in a completely randomized block design with judges as blocks.

The performed experimental treatments were based on a completely randomized design. The data were statistically evaluated by an analysis of variance with Duncan's multiple range tests for mean separation.

Table2. Descriptive and scoring levels of four Organoleptic properties used for sensory evaluation of “Red Haven” peaches and “Shahmiveh” pears.

Appearance	Color	Firmness	Flavor	Scores
Extremely unpleasant appearance	Extremely unpleasant color	Extremely soft	Extremely unpleasant flavor	0-20
Unpleasant	Unpleasant color	Soft	Unpleasant flavor	20-40
Neither like nor dislike appearance	Neither like nor dislike color	Neither soft nor firm	Neither like Nor dislike flavor	40-60
Pleasant	pleasant color	firm	Pleasant flavor	60-80
Extremely pleasant	Extremely Pleasant color	Extremely Firm	Extremely Pleasant flavor	80-100

Results and Discussion

The final center temperature of peaches and pears were very close to 4^{o}C after 30 min. The horizontal axis is the cooling time in minutes and the vertical axis is the decimal temperature difference (DTD) a dimensionless number and it was calculated by using Equation (1), where T= Target temperature, P= Produce temperature, W= cooling media temperature.

$$DTD = \frac{T - W}{P - W} \qquad (1)$$

According to this equation the DTD for peaches and pears respectively were about 0.17 and 0.16. The corresponding cooling times from E line appropriate for these two fruits were close to 50 min. The lower cooling medium temperature (0^{o}C versus 1.7^{o}C), higher agitation rate and consequently higher heat transfer coefficient caused that the actual cooling times for peaches and pears diminished to 30 min.

A – Greens, B -- Beans, peas, asparagus, C -- Small cucumbers, radishes, beets (<3.8 cm or 1.5" diameter.), D -- Small apples and peaches, slicing cucumbers, E -- Sweet corn, apples, and peaches, F -- Large apples and peaches (> 7.5 cm or 3" diameter.), and G -- Cantaloupes, large eggplant.

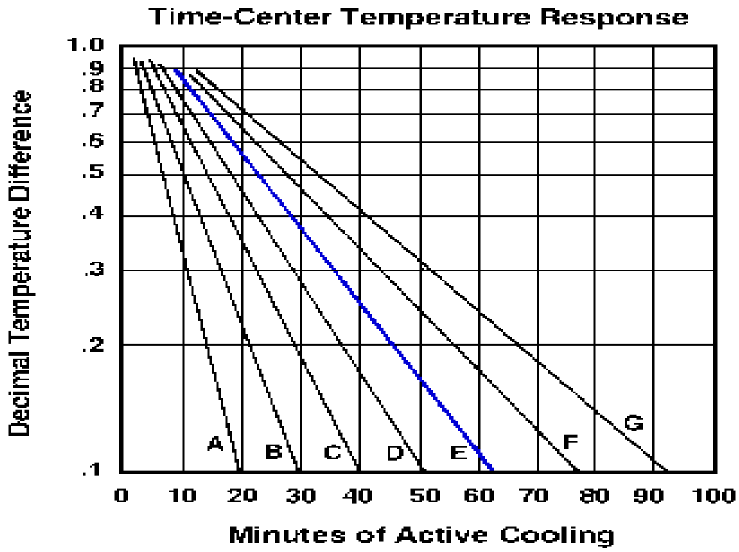


Figure 1. Time-temperature response of various fruits and vegetables immersed in agitated chilled water at 1.7^oC (Boyette et al. 1992).

The results of physico-chemical experiments have been summarized in Table 3. The average firmness of peaches precooled with HIWC (ice water and $CaCl_2$) was about 7.38 kg force/cm^2. Considering 8 mm diameter of penetrometer, this force corresponds to 37 N force, which is very comparable to 43 N the firmness of fresh Red Haven peaches reported by Byrne et. al (1991). In other words, this treatment could save the original firmness of fresh peaches with the minimum loss. The average firmness values of peaches in HIW, HIWC and HIWCC treatments respectively were 32, 47 and 44% higher than ANC samples over 4 weeks of cold storage. These results agreed with previous work (Divakar et al, 1981). The firmness of peaches gradually decreased with increasing storage time. Although the firmness in all of the treatments was similar after 4 weeks of storage, the ice water cooling treatments of peaches maintained higher firmness for more than 2 weeks during storage time than air-cooling with natural convection (ANC) and hydrocooling with raw water (HRW) methods (Fig.2).These results were also compatible with Park's (2002) report on precooling and storage of nectarine. The author pointed out that hydrocooling of nectarine increases flesh firmness of non-packaged fruits for a limited time during cold storage.

Among the ice water pre-cooled treatments and for three weeks of cold storage, peaches pre-cooled with $CaCl_2$ solutions (HIWC and HIWCC treatments) had significantly higher firmness than non calcium treated (Table 2). This result also agreed with the research of Ochei and Basiouny (1993). They reported that postharvest application CaCl2 on peaches followed by storage at 3^oC over a period of 7 weeks increased fruit firmness and delayed their ripening.

Researchers (Valero et al. 2002) believe that Ca treatment of some nectarine fruits have effects on conjugated forms of putrescine (conjugated-soluble and cell wall-bound), which are related to fruit firmness. They reported that the Ca treatment of plum after harvest and before storage at 2^oC for 28 days showed a noticeable increase in the above-mentioned compounds and caused higher firmness in comparison with the non-treated samples.

Pectin content of peaches decreased gradually during the storage period (Fig.3). Measurements of remaining pectin at the each week of storage duration showed, that ice water cooling with calcium treatment (HIWC) had the highest amount (about 25% compared with ANC treatment).

Table 3. Effects of different pre-cooling treatments on the average of physicochemical parameters during storage including firmness (kg/cm^2), pH, total soluble solids (Brix), acidity (malic acid% for peach and citric acid% for pear), reducing sugar content (g/ml)X100, total pectin (TP%), and weight loss (WL%).

T x	**Fir** y	**PH** y	**TSS** y	**Ac**	**TP** y	**Sugar**	**WL** y
ANC Peach	5.00 a*	3.63a	15.33	0.139	7.3 a	3.18	2.2 b
HRW Peach	5.35 ab	3.63 a	15.13	0.150	7.4 a	3.35	1.9 ab
HIW Peach	6.65 b	3.58 a	15.10	0.165	8.2 ab	3.77	2.4 b
HIWC Peach	7.38 c	3.48 b	15.25	0.149	9.2 b	3.13	1.2 a
HIWCC Peach	7.20 c	3.56 ab	15.19	0.165	7.2 a	3.19	2.0 b
ANC Pear	9.41 a	4.33 ab	13.63 a	0.230	2.2 a	4.77 ab	3.0 b
HRW Pear	9.78 ab	4.23 a	13.14ab	0.226	2.5 ab	4.88 a	2.6 ab
HIW Pear	10.78 b	4.32 ab	13.17ab	0.235	3.2 b	4.74 ab	2.5 ab
HIWC Pear	11.44c	4.28ab	12.97b	0.221	3.4 b	4.69 b	1.9 a
HIWCC Pear	11.30 c	4.38b	13.29ab	0.214	3.4 b	4.70 b	1.9 a

x=Treatment codes for peaches and pears in Table 2. The physiological values are means of four and five measurements (each one with three replicates) respectively for peaches and pear, y=Separated means in columns by Duncan's multiple range test, *Means with same subscripts in a column are not significantly different (P<0.05).

The most probable way for softening texture is the analyses of available pectin in cell walls of fruits and vegetables. The formation of water-soluble pectin as a result of pectin degradation, loosening of cell walls and separation of cells were determined during ripening of freestone peaches (Pressey et al. 1971 and Pressey 1976). In this process protopectin with the aid of enzymes (such as polygalacturonase) degrades to soluble pectin gradually (Smith et al. 1997). There is a strong relation between pectin degradation and fruit firmness. For example, in nectarines as fruit firmness decreased, the soluble pectin concentration increased to the same extent in both treatments at the expense of insoluble pectin (Von Mollendorff et al. 1993).

Fig.2 Firmness changes of "Red Haven" peaches precooled with different postharvest treatments and stored at 2C along with cyclical heat treatment

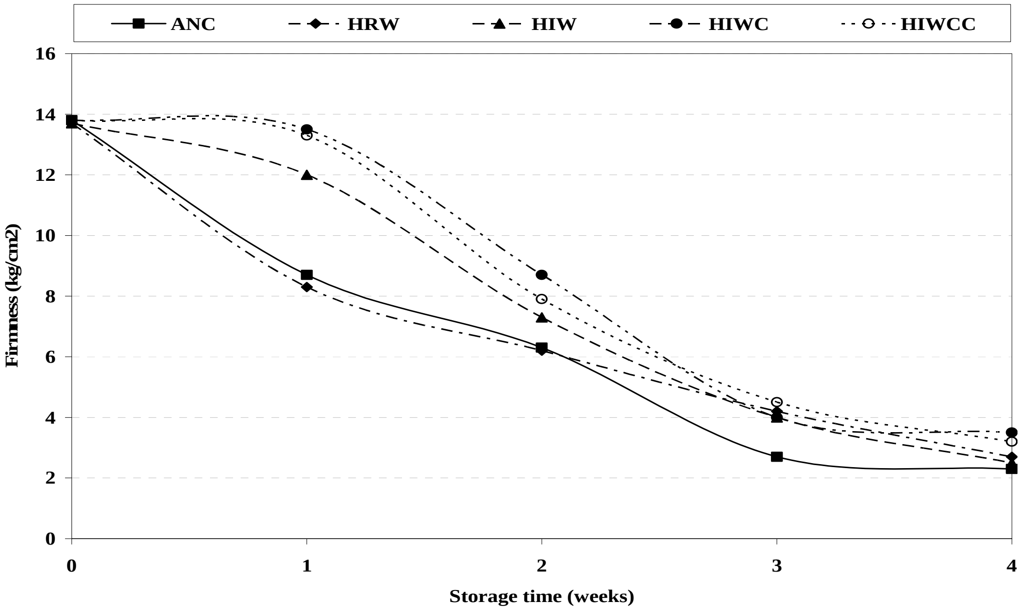
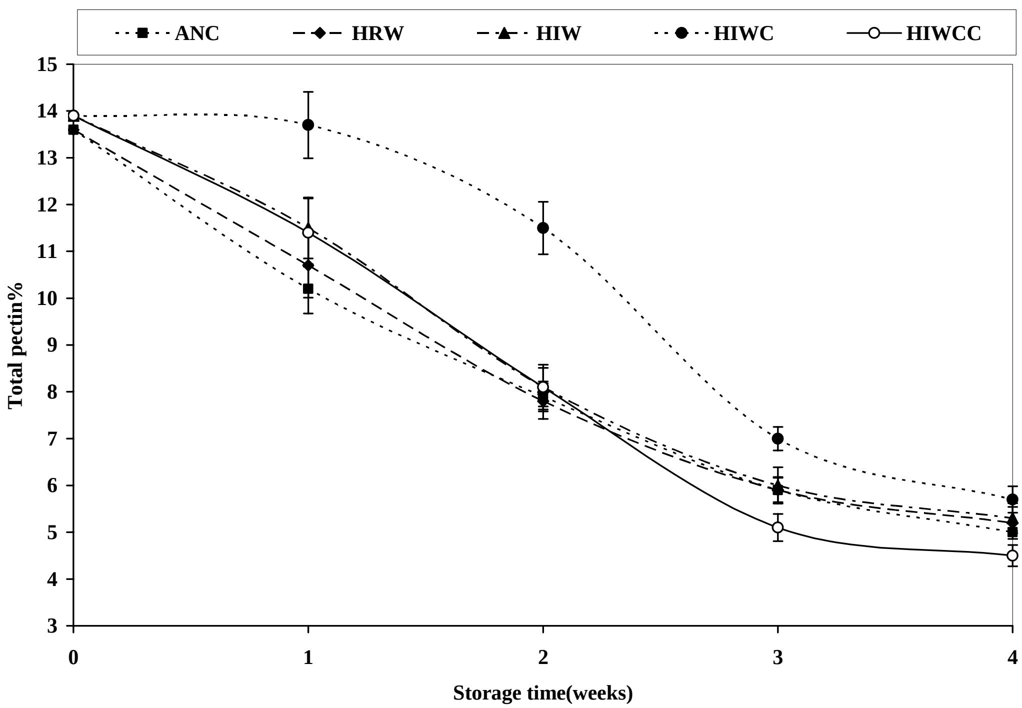


Fig.3 Changes in total pectin% of "Red Haven" peaches precooled with different postharvest treatments and stored at 2C along with cyclical heat treatment.



Chatjigakis et al. (1998) studied the spectroscopy of peach cell walls and revealed the existence of the esterified and non-es-terified carboxyl groups of the pectin molecules. He found that degree of esterification [(number of esterified carboxylic groups/number of total carboxylic groups)] or (D.E.) of peach pectin remained practically constant up to 35 days storage at $0^{o}C$. Further on, he pointed the changes in pectin esterification of peaches during storage correlated well to fruit firmness. The agreement of the obtained data and above-mentioned researchers' results showed that there is a physiological relation between the firmness and pectin content of peaches pre-cooled with ice water.

The TSS, reducing sugar content and TA were not affected by various pre-cooling treatments and no significant differences was observed among different treatments, but the pH's of HIWC treatment was significantly lower than ANC, HRW and HIW treatments.

Bal and Cholan (1981) and Albert et al. (1976) found that with increasing ripeness of peaches, the texture softened and the TSS increased with a corresponding decrease in acidity. Later on Robertson and Meredith (1988) reported that in ripening of "Flordaking" peaches at $20^{o}C$, beside some changes in fruit color properties, the TSS/TA ratios increased. They marked the most significant changes due to ripening at room temperature were decrease in green color and softening of fruit flesh (decrease in firmness). On the other hand they reported that storage of peaches at $0^{o}C$ had no significant effect on increasing TA rather increased slightly their firmness after one week.

Based on the above-mentioned results, if peaches are picked in a firm stage, its ripening will result in an increase in soluble solids and decrease in acidity and firmness and the rate of physiological and biochemical changes during ripening are dependent on temperature. Hence, the lower rate of these changes in hydro-cooled fruits might be due to faster heat loss of produce after harvest. During this process, the rate of enzyme activities, starch hydrolysis, pectin break down, and the rate of decline in firmness leading to the release of calcium from the tissue may have also been affected. Ripening of pre-cooled peaches was delayed in treatments of HIW, HIWC and HIWCC as compared to ANC.

During 4 weeks of storage the weight loss of peaches in HIWC treatment was about 45% less than the samples in ANC treatment (Fig. 4 and Table 3). Villanueva et al. (1999) reported 19.5% weight loss for "Flordaking" peach after storage at $5^{o}C$ and 85% RH for 4 weeks followed by six days warming at room temperature ($20^{o}C$). Cyclical heat treatment of peaches pre-cooled with different methods decreased their weight loss after storage. While the past experiences showed the peaches pre-cooled with natural air and stored at conventional storage (without cyclical heat treatment) had a weight loss of more than 10%, the weight loss of same fruit pre-cooled with HIWC treatment and stored at the same conditions along with cyclical heat treatment was less than 1.5%.

The penetration of Ca cation into the fruits skin during the hydrocooling process plays a major role in preventing action of pectin hydrolysis, softening (reduction of firmness) and moisture release of fruits. As a conclusion it can be inferred that firmness and weight loss of the peaches are closely associated (Pearson and Perring 1986).

Results of sensory evaluation showed that the panelists chose the appearance, color, firmness and flavor of peaches precooled with ice water pleasant (Table 4) and the statistical analysis showed that their average scores were significantly higher than the ones pre-cooled either by ANC or HRW treatments. Additionally, the average sensory scores (appearance, color, firmness and flavor) of peaches in HIWC were more than 50% higher than ANC treatments. Conversely the sensory results of peaches ,in HIWCC treatment did not show any noticeable discoloration and melting flesh after storage most probably because of adding $CaCl_2$ for pH adjustment and firming texture.

Fig.4 Weight loss% of "Red Haven " peaches precooled with different postharvest treatments and stored at 2C along with cyclical heat treatment

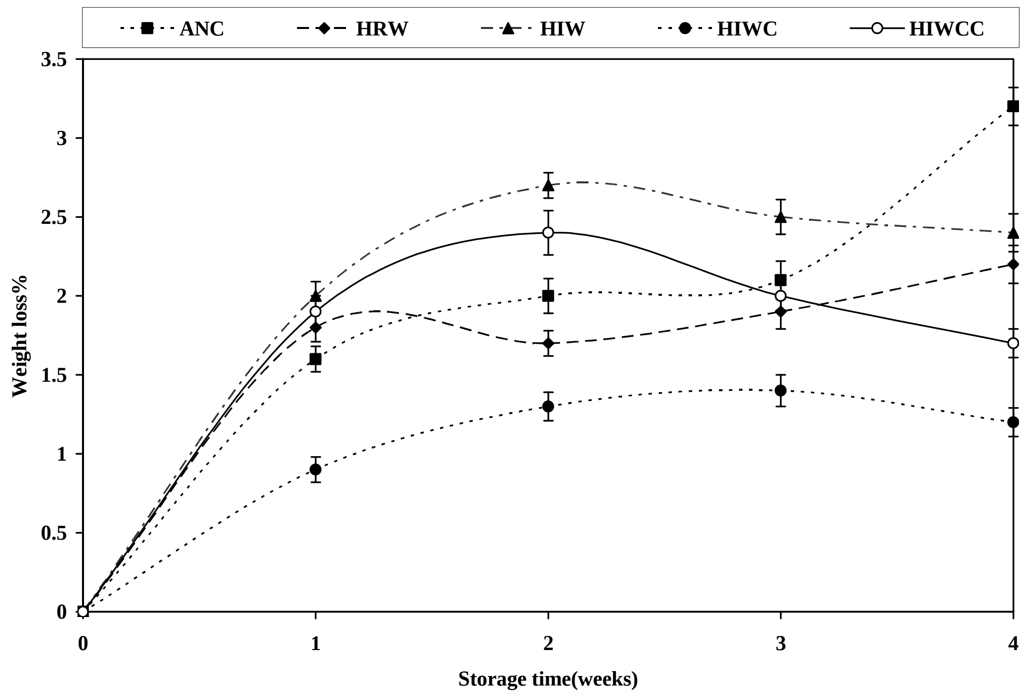


Fig.5 Firmness changes of "Shahmiveh" pears precooled with different postharvest treatments and stored at 2C

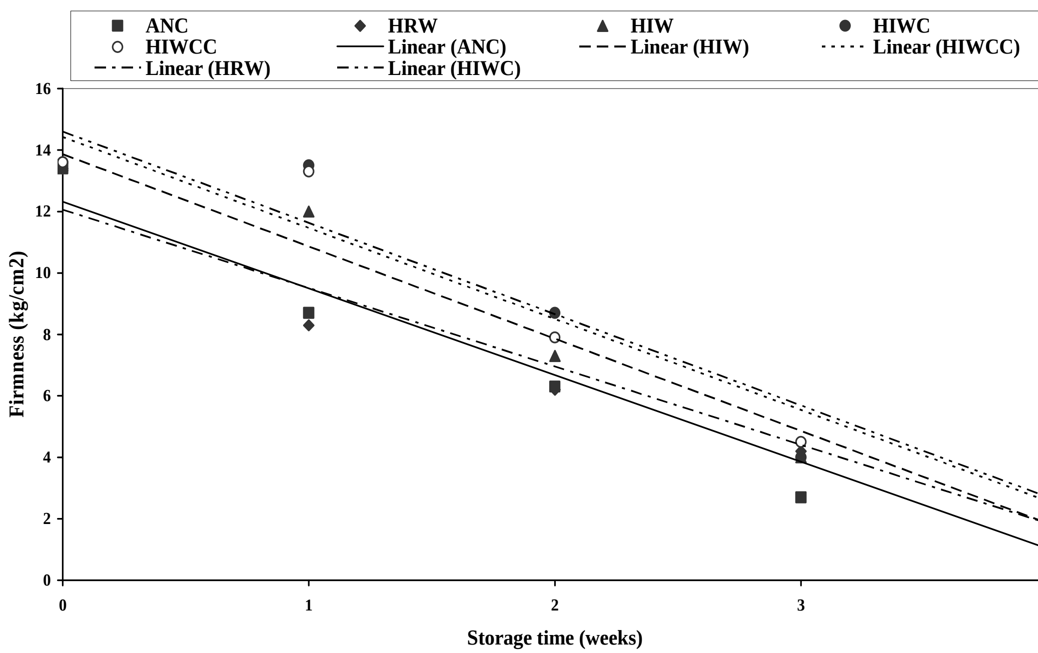


Table 4. Effects of different pre-cooling treatments on the average scores of sensory evaluation at the end of storage including appearance (Ap), color (Col), firmness (Fir) and flavor (Fla) in "Red Haven" peaches and "Shahmiveh" pears.

T **x**	**Ap** y	**Col** y	**Fir** y	**Fla** y
ANC Peach	46 [a]	47 [a]	45 [a]	47 [a]
HRW Peach	54[a]	59 [a]	59 [a]	59 [a]
HIW Peach	60 [ab]	71 [b]	65 [ab]	65 [ab]
HIWC Peach	71 [b]	73 [b]	72[b]	74 [b]
HIWCC Peach	65 [b]	65 [ab]	71[b]	69 [b]
ANC Pear	46 [a]	42 [a]	41 [a]	50 [a]
HRW Pear	57 [a]	68 [ab]	61 [a]	62 [a]
HIW Pear	62 [b]	72 [b]	66 [b]	66 [ab]
HIWC Pear	72 [b]	78 [b]	75 [b]	70 [b]
HIWCC Pear	60 [ab]	73 [b]	63[ab]	68 [b]

x=Treatment codes for peaches and pears as explained in Table 1. The physiological values are means of four and five measurements (each one with three replicates) respectively for peaches and pear,
y=Separated means in columns by Duncan's multiple range test, Means with same subscripts in a column are not significantly different ($P<0.05$).

The overall firmness of pears in HIW, HIWC and HIWCC treatments were higher than the ANC and HRW samples (Fig. 5). While there was a significant difference between the samples of ice water cooling treatments and others the average firmness of pears in HIW, HIWC and HIWCC respectively were 50%, 59%, and 57% higher than ANC (Table 3). These results were agreed with other researchers such as Lara and Vendrell (1998). Tonini et al. (1979) reported that hydrocooling process had the same positive effects on the firmness quality of other variety of pears. Increasing calcium concentration in d'Anjou pears reduced the incidence of cork spot and improved shelf life by increasing fruit firmness (Raese et. al, 1999).

Although pectin content of pears decreased from 6% to less 2% during the storage period (Fig.6), the pears precooled with HIW, HIWC and HIWCC treatments were higher than the ANC and HIW samples. Measurements of remaining pectin at the each week of storage duration showed,The weekly and cumulative weight losses of "Shahmiveh" pears in HIW, HIWC and HIWCC were lower than ANC and HRW treatments during the 10 weeks storage period (Figures 7 and 8). Furthermore, the average weight losses of "Shahmiveh" pears during the 10 weeks storage for HIWCC, HIWC and HIW treatments respectively were 36, 36 and 17 percent lower than ANC treatment (Table 3). These results are compatible with the reports of Randhawa et al. (1982). The weight loss of LeConte pear fruit dipped for 20 min in 4, 6 and 8% $CaCl_2$ solutions and stored for 55 days at conventional storage conditions (0-3.3^{o}C and 85-90% RH) respectively were about 5.4, 7.0 and 8.4%.

Tonini et al. (1979) showed that the weight loss of hard skin varieties of “William” pears reduced by 30% - 50% when it was immersed in a $CaCl_2$ solution for 10 minutes. Furthermore, the pH, titrateable acidity, and reducing sugar content of pears were not affected by the different pre-cooling treatments.

In the sensory evaluation experiment for pears again panelists classified the appearance, color, firmness and flavor of pears precooled with ice water as a pleasant fruit after storage and the data analysis showed that their average scores were significantly higher than ANC or HRW samples (Table 4). The average sensory scores (appearance, color, firmness and flavor) of pears in HIWC were about 60% higher than ANC treatments. These results are also compatible with Monzini and Gorini (1978). They showed that hydrocooling of William pears produced a fresher color (higher chlorophyll content in pulp) and better organoleptic properties (freshness, crispness juiciness and sweetness) than ANC samples.

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In the sensory evaluation experiment for pears again panelists classified the appearance, color, firmness and flavor of pears precooled with ice water as a pleasant fruit after storage and the data analysis showed that their average scores were significantly higher than ANC or HRW samples (Table 4). The average sensory scores (appearance, color, firmness and flavor) of pears in HIWC were about 60% higher than ANC treatments. These results are also compatible with Monzini and Gorini (1978). They showed that hydrocooling of William pears produced a fresher color (higher chlorophyll content in pulp) and better organoleptic properties (freshness, crispness juiciness and sweetness) than ANC samples.

Conclusions

Results of sensory evaluation showed that the organoleptic scores of all the ice water cooled pears were significantly higher than ANC samples. The overall objective results of this study showed that post-harvest ice water cooling of peaches and pears followed by cold storage had significantly ($P>0.005$) higher amount of firmness, pectin content, organoleptic scores (appearance, color, firmness and texture) and lower weight loss than air-cooled samples. While addition of $CaCl_2$ pronounced the effects of ice water postharvet cooling of peaches and pears, it respectively increased their firmness (50% and 59%), lowered their pectin hydrolysis (25% and 30%) and weight loss (45% and 36%). Furthermore 10 hours of weekly cyclical heat treatment of Persian “Red Haven” peaches at 20^{o}C ambient temperature and during the cold storage, preserved the most important quality criteria of fresh fruit after storage. It can be concluded that in comparison with ANC treatment, the experimental and sensory results of measuring firmness in peaches precooled with HIWC are pretty much comparable with each other. Inefficient heat removal in precooling process, lack of $CaCl_2$ in hydrocooler and increasing the chlorine concentration in cooling medium respectively in HRW, HIW and HIWCC treatments caused some discoloration development in peach skin during cold storage.This study showed the best treatment for preserving the quality“Red Haven” peaches after harvest is pre-cooling with ice water containing calcium chloride.

Fig.6 Total pectin% changes of "Shahmiveh" pears precooled with different postharvest treatments and stored at 2C.

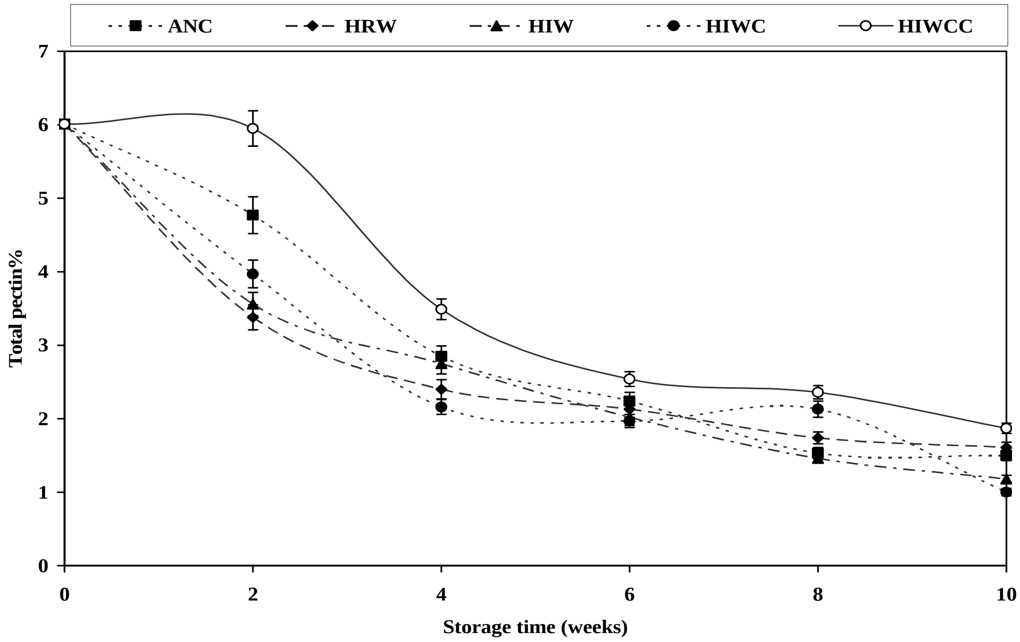
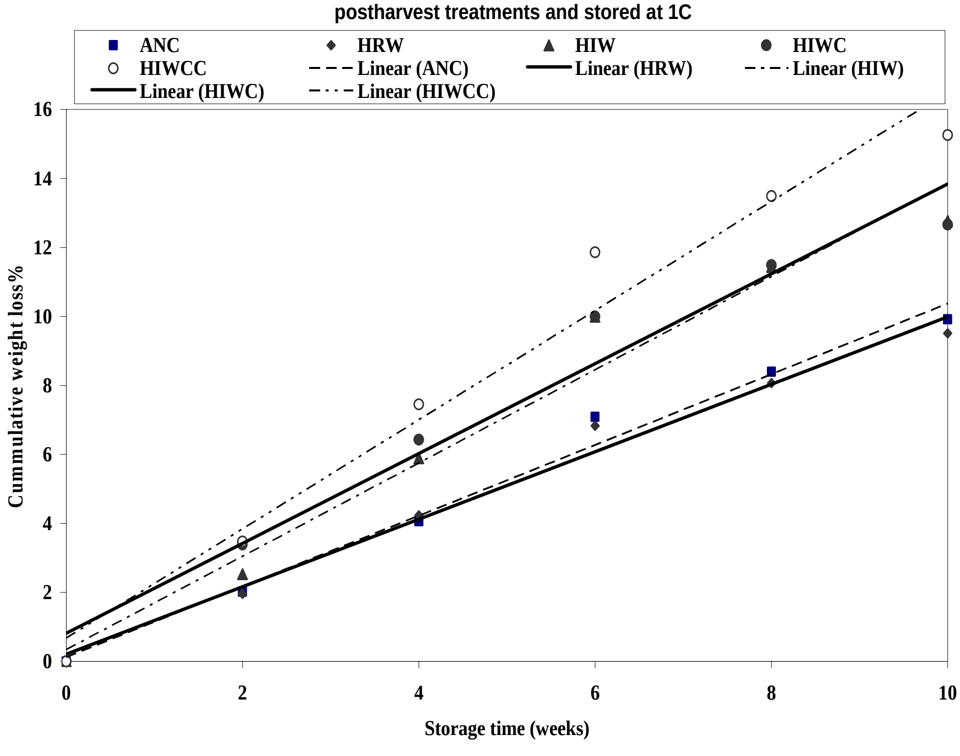


Fig.7 Cummulative weight loss% of "Shahmiveh" pears pre-cooled with different postharvest treatments and stored at 1C



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