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Effect of precooling on quality of pear fruits during storage

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ABSTRACT

The study was planned to evaluate the effect of precooling methods such as hydrocooling (HC), forced air cooling (FAC) and evaporative cooling (EC) on postharvest quality of pear fruit under cold storage conditions. The pear fruit were harvested at the physiological mature stage, sorted, graded, and packed in plastic crates. The fruit were subjected to HC, FAC and EC treatments to remove the field heat. In all the precooling methods, a digital thermometer was used to monitor the temperature of fruit pulp until a steady temperature (5.2°C) was achieved. After giving the precooling treatments the fruits were packed in corrugated fibre board boxes and stored in cold room (0-1 °C and 90-95% relative humidity). The stored samples were evaluated periodically at 15 days intervals up to 75 days for physico-chemical quality attributes. The results of the study indicated that FAC maintained lower physiological weight loss (3.51 %) and decay (3%), retained higher firmness (13.67 lb force), organoleptic score (7.52 out of 9), TSS (12.52 °B), total sugars (8.05%), acidity (0.27%) and total phenols (39.28 mg GAE/100g) during storage as compared to control. The HC treatment was almost similar to FAC in maintaining the quality of pear fruits. These two methods were convincingly better than EC and control. The results demonstrated the effectiveness of FAC and HC to prolong the storage life of pear fruits for 60 days as compared to only 45 days in case of control fruits.

Key words: *Pyrus pyrifolia*, hydro-cooling, evaporative cooling, forced air cooling, storage, quality

INTRODUCTION

Pear is an important fruit of India, occupying an area of about 42,000 hectares and producing 3.06 lakh MT fruits annually (Anonymous, 1). In Punjab province of North-West India, the area under pear cultivation is 3440 ha with a production of 79.5 thousand MT, mainly dominated by low chill cultivar 'Patharnakh'. Pear fruit is a good source of carbohydrate, dietary fibre, protein, vitamins and minerals.

The harvesting period of pear in Punjab coincides with relatively high temperature and monsoon rains which interfere with its postharvest shelf life and quality leading to huge postharvest losses. Therefore, our attention is focused on enhancing storage life as well as maintaining the overall quality of pear fruits grown in Punjab for a longer period of time.

Precooling is the key element in the postharvest operations of horticultural commodities which helps in removing the field heat, slowing down the physiological and biochemical activities and thus, meeting consumer demands for high-quality fresh produce (Duan *et al*., 5; Lufu *et al*., 8). It is essential to precool the perishable horticultural produce with high respiration rate to its lowest safe temperature.

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Application of different methods of pre-cooling viz, HC, FAC and EC were selected to investigate the effectiveness of these methods on postharvest shelf life of pear fruits under cold storage conditions.

MATERIALS AND METHODS

The present study was conducted at Punjab Agricultural University, Ludhiana. Healthy pear plants of cultivar 'Patharnakh' having uniform height and spread were selected at the experimental orchard. The fruit were harvested at proper maturity (TSS: 10.73 °B, firmness: 17.39 lb force) as indicated by the mature green stage during the second week of July (2021-22). Fruits that were uniform in size, shape, and free of pathogen infection were selected for the experiment. The freshly harvested fruits were immediately transported in an airconditioned vehicle to the postharvest laboratory. The fruits were divided into three different lots and were given precooling treatments viz HC, FAC, and EC

Field heat is indicated by the temperature difference between the initial temperature of harvested crop and its desired storage temperature. In order to optimize the precooling time, the pear fruits were subjected to different precooling treatments for varied periods of time until 7/8th of cooling was achieved. Produce is usually precooled to 7/8th of the temperature difference (Brosnan

and Sun, 3) which is calculated as per following formula:

$$T_{7/8}\,(°C) = T_{initial} - [(7/8) \times (T_{initial} - T_{storage\ temperature})]$$

$$T_{7/8}\,(°C) = 34.9 - [(7/8) \times (34.9\text{-}1)] = 5.2\,°C$$

For HC and FAC treatment, the fruits were pre-cooled from initial temperature ranging from 34.9 °C (temperature of fruit after harvest) to a final steady temperature of 5.2 °C (7/8th precooling temperature after calculation from the above formula) of fruit pulp. For EC, however, a desert cooler was used for carrying out precooling of fruit, and the prevailing room temperature was taken into consideration to achieve the final constant temperature of the core.

A FAC unit having internal dimensions of 8' × 8' × 8' (L × B × H) with temperature adjustment provision of cooling air at 5 °C and humidity maintained between 85 - 95% was used. Pear fruits in crates were kept in front of pressure blower and cold air at high velocity was circulated around the fruits. The cold air was pushed at an air speed of 3 – 3.5 m/s through the plastic crates containing pear fruits until the pulp temperature reached 5.2 °C.

The laboratory scale hydro-cooler consisted of an insulated water tank (200 litre capacity) and insulated stainless steel cabinet for loading produce in plastic crates, a water re-circulating pump, and a refrigeration unit to maintain the temperature. The temperature of the water was adjustable at 5 °C. The pear fruits packed in plastic crates were loaded in the hydrocooler and cold water was sprinkled on the fruits until the pulp temperature of fruit reached 5.2 °C.

The evaporative cooling system consisted of a window-mounted electric desert cooler, fitted with pump to circulate water over the khas-khas pads and a centrifugal fan to draw air through the pads. The desert cooler consisted of a tank with a capacity of 70 liters, a 0.19 kW motor, and air velocity of 4000 CMH. Air was pushed at an air speed of 3-3.5 m/s through the plastic crates containing pear fruits until the pulp temperature reached constant (29 °C).

The precooled as well as control (non-precooled) fruits were packed in corrugated fibre board boxes of 2 kg capacity (340 mm × 220 mm × 100 mm), and stored in the cold room. The physico-chemical parameters of these stored fruits were assessed up to a period of 75 days at an interval of 15 days.

The weight loss of pear was estimated on the initial weight basis and depicted as a percentage loss. Fruit firmness was measured using a 'Penetrometer' (Model FT -327) after removing about one square cm peel on both sides of the fruit. The force required to push the plunger (8 mm diameter) into pear flesh was recorded and measured in lb force. The organoleptic quality of the fruits was carried out by ten semi-trained personnel as per the standard Hedonic Scale (Sivakumar and Korstan, 16). A hand refractometer (Erma, Japan) was used to estimate the total soluble solids (TSS) of fruit and expressed as °B after temperature modification at 20 ºC. The total sugars were estimated as per standard procedures (AOAC, 2), by titrating the clarified fruit juice against Fehling solution after inversion and results were expressed in per cent (%). The titratable acidity and vitamin C were estimated as per standard procedures (Ranganna, 11) and expressed as % malic acid and mg/ 100g, respectively. The total phenolic content was calculated as per the procedure suggested by Shaver *et al.* (13).

The experiment comprised four treatments with three replications per treatment and five storage intervals each, laid out in completely randomized design. There were 120 boxes of pear fruit and each box was of two kg capacity. The data were analyzed for the variance by using the SAS (V 9.3, SAS Institute Inc., and Cary, NC, USA) package.

RESULTS AND DISCUSSION

The data on optimization of time for achieving the 7/8th temperature of pear fruits with HC, FAC and EC method are presented in Fig. 1. The data exhibited that there was faster decline in temperature of the pear with HC as compared to FAC and EC. HC took 130 minutes and FAC took 360 minutes to precool the pear fruits from 34.9 °C to 5.2 °C. However, the EC could not achieve the desired

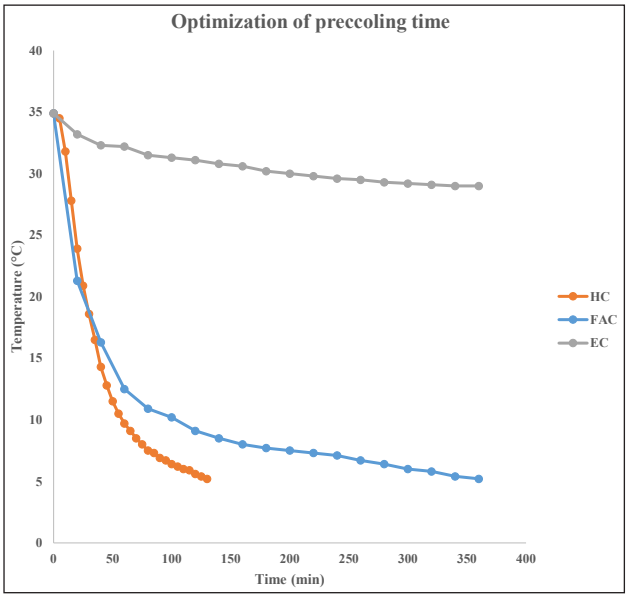

Fig. 1. Optimization of precooling time of pear fruits using hydrocooling, forced air cooling and evaporative cooling methods

temperature to precool the pear fruit. In the present study we have observed that hydrocooling has proved to be a rapid cooling method as compared to forced air cooling and evaporative cooling. This may be due to the thermal conductivity of water which is very high compared to air. This was in line with the research done by Ravindra and Goswami (12), where it was reported that water removes heat much faster than air.

The PLW of pear fruits increased during the storage period in all the treatments (Table 1). The lowest average PLW (3.51 %) of fruits was recorded in FAC followed by HC (3.73%). While, the maximum PLW (5.50 %) was noticed in control. The FAC recorded the minimum weight loss of pear fruits which ranged between 0.60 - 6.75 % from 15 to 75 days of cold storage in comparison to control, where PLW varied from 1.25 to 9.10 % during same storage intervals. It has been reported that weight loss ≤ 6% is considered safe to maintain the market acceptability of pear fruits (Singh *et al*., 15). Keeping in view this value, it may be inferred that FAC-treated fruits can be stored for 60 days as compared to 45 days in case of control. Shilpa *et al*. (14) observed that forced air precooling played a positive role in diminishing the respiration and other metabolic activities of fruits thus lowering the weight loss and increasing the shelf life of litchi fruits.

Table 1. Effect of different pre cooling methods on PLW, firmness, spoilage and organoleptic quality of pear fruits stored at 0-1°C.

Treatment	Storage period (days)					
	15	30	45	60	75	Mean
			PLW (%)			
HC	0.80^{ijk}	1.70^{h}	3.95^{f}	5.30^{de}	6.90^{c}	3.73^{C}
FAC	0.60^{k}	1.40^{hi}	3.70^{f}	5.10^{e}	6.75^{c}	3.51^{D}
EC	1.10^{ijk}	2.30^{g}	5.20^{e}	7.00^{c}	8.70^{a}	4.86^{B}
Control	1.25^{hij}	3.43^{f}	5.80^{d}	7.90^{b}	9.10^{a}	5.50^{A}
Mean	0.94^{E}	2.21^{D}	4.66^{C}	6.33^{B}	7.86^{A}	
			Firmness (lb force)			
HC	15.70^{b}	15.00^{c}	13.80^{ef}	12.20^{i}	9.60^{l}	13.26^{B}
FAC	16.00^{a}	15.60^{b}	14.00^{e}	12.60^{h}	10.15^{k}	13.67^{A}
EC	14.40^{d}	13.70^{f}	12.40^{hi}	10.00^{k}	8.20^{n}	11.74^{C}
Control	13.80^{ef}	13.00^{g}	11.50^{j}	9.20^{m}	7.00^{o}	10.90^{D}
Mean	14.98^{A}	14.33^{B}	12.93^{C}	11.00^{D}	8.74^{E}	
			Oganoleptic Quality (1-9)			
HC	7.40^{cde}	7.90^{abcd}	8.20^{ab}	7.10^{e}	5.80^{fg}	7.28^{A}
FAC	7.80^{abcde}	8.00^{abc}	8.50^{a}	7.20^{de}	6.10^{f}	7.52^{A}
EC	7.30^{cde}	7.50^{bcde}	7.80^{abcde}	6.20^{f}	5.10^{gh}	6.78^{B}
Control	7.20^{de}	7.45^{bcde}	7.70^{bcde}	5.90^{f}	5.00^{h}	6.65^{B}
Mean	7.43^{B}	7.71^{B}	8.05^{A}	6.60^{C}	5.50^{D}	
			Spoilage (%)			
HC	0.00^{f}	0.00^{f}	3.00^{ef}	5.00^{def}	13.00^{bc}	4.20^{C}
FAC	0.00^{f}	0.00^{f}	0.00^{f}	3.00^{ef}	12.00^{bcd}	3.00^{C}
EC	0.00^{f}	2.00^{ef}	5.00^{def}	12.00^{bcd}	18.00^{ab}	7.40^{B}
Control	0.00^{f}	5.00^{def}	9.00^{cde}	15.00^{abc}	22.00^{a}	10.20^{A}
Mean	0.00^{D}	1.75^{CD}	4.25^{C}	8.75^{B}	16.25^{A}	

HC – Hydrocooling, FAC – Forced Air Cooling, EC – Evaporative Cooling. Means with different alphabet superscripts in the same column differ significantly (P≤0.05) in that particular interval.

The firmness of fruit dropped gradually with progression in storage duration. The maximum mean firmness (13.67 lb force) of fruits was observed in FAC followed by HC (13.26 lb force), whereas the minimum firmness was noticed in control fruits (10.90 lb force) (Table 1). The finest eating quality of pear fruits is imparted at 12 lb force firmness (Mahajan *et al*., 9), making it an important parameter to judge the market quality of fruit. Considering this value as the permissible limit for firmness, it was observed that pear fruits treated with FAC or HC can be stored successfully for up to 60 days in cold storage. The loss of firmness of pear fruits may be attributed to water loss and degradation of pectic substances. FAC has been reported to reduce respiration and leads to delaying softening of fruits during storage (Ferreira *et al*., 6).

FAC-treated fruits registered the highest organoleptic quality score (7.20) and were found highly acceptable up to 60 days of storage, after which the decline in sensory scores was recorded (Table 2). The organoleptic quality of hydro-cooled fruit was also found acceptable up to 60 days of storage (7.10). The control fruits were acceptable only for up to 45 days (7.70) of storage and thereafter deterioration in quality was observed. Makwana *et al.* (10) observed the highest sensory scores in mango fruit that were precooled before storage.

The different precooling treatments showed a wide variation of spoilage percentage throughout the storage period. The maximum decay incidence (10.2%) was noticed in control treatment (no precooling) and was statistically significant from all other treatments. The minimum decay was recorded in FAC (3%) followed by HC (4.2 %). In control fruits, the level of decay incidence increased from 5 % during 30 days to 22 % after 75 days of storage. However, the level of decay was considerably low in FAC and varied between 0 to 12 % from 15 to 75 days of storage. The precooling treatments restricts the respiratory activities and ethylene production, thereby slowing down the decay incidence in

fruits (Ferreira *et al.,* 6). Wijewardane and Guleria (17) reported that precooling of apple fruits after harvesting helped in retaining better physio-chemical characteristics, in addition, significantly lowering disease incidence.

The TSS and total sugars content increased up to 60th day of storage in fruits which were given FAC and HC pre-treatment and then declined gradually (Table 2). Whereas, control fruits and EC showed an increase in TSS and total sugars content up to 30 days of storage and thereafter declined. The FAC recorded the highest average TSS (12.52 °B) and total sugars (8.05%), and was statistically significant from all the treatments, whereas control fruits exhibited the minimum mean TSS value (11.10 °B) and total sugars (6.91%) at the end of storage period. The maintenance of higher total soluble solids and total sugars in forced air-cooled pear fruits may be due to the positive role of FAC in delaying the respiration rate of fruits resulting in the delayed conversion of starch into sugars. FAC technique has been reported to maintain better quality in litchi fruits (Shilpa *et al.,* 14).

In context to titratable acidity, declining trend in the percent acidity was noticed in pear fruits during storage (Table 2). The highest mean acidity (0.29 %) was observed in HC and was significantly at par with FAC (0.27 %), whereas, the lowest acidity was noticed in the control fruits (0.18%) treatments. The maintenance of higher acidity in forced air-cooled pear fruits may be due to slower degradation of organic acids owing to decreased respiration rate (Liang *et al.,* 7).

The vitamin C content in pear were found to decline during storage (Table 2). However, the decrease was gradual in forced air-cooled fruits and the highest average ascorbic acid was found in FAC (8.38) at the end of the storage period. On the other hand, in control fruits, the level of ascorbic acid decreased at a very fast rate and also registered the lowest ascorbic acid content (6.84). The reduction in vitamin C content might be due to its oxidation into dehydro-ascorbic acid by oxidase enzyme. The present results are in conformity with the study of Makwana *et al*. (10) who reported a slower decline in vitamin C in precooled fruits of mango as compared to non-precooled fruits.

Total phenolic content in precooled as well as non-precooled fruits, showed a declining trend during storage (Table 2). However, the maximum total phenols were recorded in treatment FAC (39.28 mg GAE/100g) which was at par with HC (37.05 mg GAE/100g). Whereas, lowest total phenols were registered in control fruits (30.44 mg GAE/100g) at the end of the storage period. This was in accordance with the interpretations of Diaz *et al*. (4) who reported more phenolic content in precooled cherry than non-precooled ones.

From the present investigations it can be concluded that pear fruit precooled with forced air cooling and hydrocooling can be successfully stored

Table 2. Effect of different pre cooling methods on TSS, total sugars, acidity, vitamin C and total phenols of pear fruits stored at 0-1°C.

Treatment	Storage period (days)					
	15	30	45	60	75	Mean
			TSS (°B)			
HC	11.40^{h}	12.00^{f}	12.60^{d}	13.50^{b}	11.50^{h}	12.20^{B}
FAC	11.70^{g}	12.20^{e}	13.00^{c}	13.70^{a}	12.00^{f}	12.52^{A}
EC	12.00^{f}	12.50^{d}	12.20^{e}	11.00^{i}	9.80^{k}	11.50^{C}
Control	12.30^{e}	13.00^{c}	11.40^{h}	10.20^{j}	8.60^{l}	11.10^{D}
Mean	11.85^{D}	12.43^{A}	12.30^{B}	12.10^{C}	10.48^{E}	
			Total Sugars (%)			
HC	7.26^{g}	7.57^{f}	8.20^{c}	8.50^{b}	7.00^{h}	7.71^{B}
FAC	7.50^{f}	7.86^{de}	8.50^{b}	8.80^{a}	7.60^{f}	8.05^{A}
EC	7.63^{ef}	8.00^{cd}	7.00^{h}	6.60^{i}	5.80^{jk}	7.01^{C}
Control	7.85^{de}	8.23^{c}	6.85^{h}	6.00^{j}	5.60^{k}	6.91^{D}
Mean	7.56^{BC}	7.92^{A}	7.64^{B}	7.48^{C}	6.50^{D}	
			Titratable acidity (% malic acid)			
HC	0.39^{a}	0.32^{cd}	0.29^{ef}	0.25^{fg}	0.20^{hij}	0.29^{A}
FAC	0.37^{ab}	0.35^{bc}	0.25^{fg}	0.22^{ghi}	0.18^{ijk}	0.27^{B}
EC	0.31^{de}	0.26^{f}	0.20^{hij}	0.17^{jkl}	0.15^{kl}	0.22^{C}
Control	0.30^{de}	0.22^{gh}	0.17^{jkl}	0.14^{l}	0.08^{m}	0.18^{D}
Mean	0.35^{A}	0.29^{B}	0.23^{C}	0.19^{D}	0.15^{E}	
			Vitamin C (mg/ 100g fw)			
HC	10.30^{b}	9.00^{de}	7.80^{g}	6.90^{i}	6.00^{k}	8.00^{B}
FAC	10.70^{a}	9.30^{cd}	8.00^{g}	7.40^{h}	6.50^{j}	8.38^{A}
EC	10.00^{b}	8.70^{ef}	7.30^{h}	6.60^{ij}	5.20^{l}	7.56^{C}
Control	9.50^{c}	8.50^{f}	6.50^{j}	5.20^{l}	4.50^{m}	6.84^{D}
Mean	10.13^{A}	8.88^{B}	7.40^{C}	6.53^{D}	5.55^{E}	
			Total Phenols (mg GAE/ 100g fw)			
HC	43.30^{b}	40.60^{e}	37.25^{g}	33.10^{k}	31.00^{m}	37.05^{B}
FAC	44.50^{a}	42.00^{c}	40.00^{f}	36.20^{h}	33.70^{j}	39.28^{A}
EC	41.20^{d}	37.00^{g}	32.50^{l}	28.75^{o}	23.00^{q}	32.49^{C}
Control	40.00^{f}	35.30^{i}	30.50^{n}	26.00^{p}	20.40^{r}	30.44^{D}
Mean	42.25^{A}	38.73^{B}	35.06^{C}	31.01^{D}	27.03^{E}	

HC – Hydrocooling, FAC – Forced Air Cooling, EC – Evaporative Cooling. Means with different alphabet superscripts in the same column differ significantly ($p \leq 0.05$) in that particular interval

with acceptable quality for 60 days at 0-1 °C and 90-95 % RH. Precooling is one of the techniques which should be applied widely throughout the supply chain of horticultural crops to attain its real potential.

AUTHORS' CONTRIBUTION

Conceptualization of research (KM, SKG); Designing of the experiments (KM, SKG, SRS);Contribution of experimental materials (SK, SRS); Execution of field/lab experiments and data collection (KM, SKG, SRS); Analysis of data and interpretation (KM, SKG, SK); Preparation of the manuscript (KM, SKG).

DECLARATION

The authors declare no conflict of interest.

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