



Evaluation of precooling methods for shelf-life enhancement of pear (*Pyrus* spp.) fruits under ambient storage

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In India, pear (*Pyrus* spp.) occupies a prominent position globally and is grown successfully under temperate and subtropical regions. In Punjab, the annual production of 79,500 MT has been realized from 3440 ha area under cultivation (Anonymous 2020). The pear fruit attains harvest maturity during the month of July which coincides with monsoon season, extreme humid and high temperature conditions that interferes with quality attributes and its post-harvest shelf-life. Being a climacteric fruit, pear experience rapid deterioration of fruit quality within 6 to 9 days after fruit harvest and also possess poor storage shelf-life (Kaur *et al.* 2021). It is well established fact that precooling method plays a significant role in enhancing shelf-life of freshly harvested fruits by removing the field heat (Duan *et al.* 2020). It is also considered as the significant method in the supply chain of horticultural crops. Therefore, our attention is focused to evaluate the different methods of precooling to extend the shelf-life of oriental pear under sub tropics of India and to maintain overall fruit quality attributes under ambient marketing conditions.

The study was carried out at Punjab Agricultural University, Ludhiana, Punjab during 2021–22. The pear plants of cultivar Patharnakh were selected at Fruit Research Farm of Punjab Agricultural University, Ludhiana, Punjab. The fresh fruits with fruit firmness of 17.39 lb force, total soluble solids 10.73 °B, acidity 0.49%, total sugars 6.66%, vitamin C (11.20 mg/100 g fw) and total phenols (46.11 mg GAE/100 g fw) were harvested during second week of July at physiological maturity stage. The fruit were subjected to 3 methods of precooling, viz. Hydro-cooling (HC), Forced Air Cooling (FAC) and Evaporative Cooling (EC). In HC method, fruits were precooled with the sprinkle of chilled water maintained at 5.0°C in an insulated and temperature controlled hydrocooler. In FAC method, plastic crates were used for packing the fruits and placed inside the cold

room. The cold air was pushed at an air speed of 3.0–3.5 m/s through the vents of plastic crates holding pear fruits.

In EC method, pear fruits were exposed to cold air produced from the dessert cooler. In all the precooling methods, fruit pulp temperature was regularly estimated with the pulp thermometer till the temperature became constant. The precooled and the non-precooled fruits of pear were packed in corrugated fibre board boxes (CFB) of 2 kg capacity and dimensions of 340 mm × 220 mm × 100 mm with 5.0% perforation. Fruits were stored at ambient conditions of 28–32°C and 70–80% RH. The quality attributes of fruits were determined at significant intervals of 5 days till 20 days of storage.

The Physiological loss in weight (PLW) was estimated on the initial and final fruit weight basis and expressed in per cent (%). A Penetrometer (Model FT-327, USA) was used to measure the fruit firmness and the resultant values were expressed in lb force. The sensory quality of fruits was evaluated by the panel of ten judges using ‘Hedonic scale’ (1–9). Total soluble solids (TSS) of fruit juice was determined by Hand refractometer (Erma, Japan) and the results were expressed in ‘°B’ after room temperature correction at 20°C. Juice titratable acidity and total sugars content were determined as per the methods followed by Kaur *et al.* (2021) and total phenols by the procedure suggested by Shaver *et al.* (2011). Vitamin C was determined by the method described by Ranganna (1999). The experiment was laid out in completely randomized block design (CRBD) consisted of 4 treatments and 4 storage intervals each with 3 replications per treatment. There were 48 boxes of 2 kg capacity pear fruit. The data were studied for the variance by using the package of SAS (V 9.3), SAS Institute Inc., and Cary, NC, USA.

The PLW of pear fruits increased during storage irrespective of precooling treatments (Table 1). The lowest PLW of 3.61% in fruits was recorded in FAC followed by HC method. However, higher PLW to the tune of 6.35% was observed in the control. Makwana *et al.* (2014) observed that precooling plays a positive role in diminishing the

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Table 1 Effect of precooling methods on physical attributes of pear fruits stored under ambient conditions

Treatment	Storage period (days)				
	5	10	15	20	Mean
<i>PLW (%)</i>					
HC	1.60 ^h	2.70 ^g	4.80 ^f	6.60 ^c	3.93 ^C
FAC	1.20 ^h	2.45 ^g	4.50 ^f	6.30 ^c	3.61 ^D
EC	2.50 ^g	5.10 ^{ef}	6.20 ^{cd}	7.70 ^b	5.38 ^B
Control	3.10 ^g	5.51 ^{de}	7.60 ^b	9.20 ^a	6.35 ^A
Mean	2.10 ^D	3.94 ^C	5.78 ^B	7.45 ^A	
<i>Firmness (lb force)</i>					
HC	15.00 ^b	13.60 ^e	12.40 ^g	8.60 ^k	12.40 ^B
FAC	15.60 ^a	14.00 ^d	13.00 ^f	9.40 ^j	13.00 ^A
EC	14.60 ^c	12.80 ^f	11.00 ^h	7.20 ^l	11.40 ^C
Control	14.00 ^d	12.50 ^g	10.40 ⁱ	6.00 ^m	10.73 ^D
Mean	14.80 ^A	13.23 ^B	11.70 ^C	7.80 ^D	
<i>Organoleptic Quality (1-9)</i>					
HC	7.30 ^b	7.80 ^{ab}	7.20 ^{bc}	6.00 ^e	7.08 ^A
FAC	7.50 ^{ab}	8.10 ^a	7.30 ^b	6.50 ^{cde}	7.35 ^A
EC	7.20 ^{bc}	7.70 ^{ab}	6.40 ^{de}	5.00 ^f	6.58 ^B
Control	7.10 ^{bcd}	7.50 ^{ab}	6.00 ^e	4.70 ^f	6.33 ^B
Mean	7.28 ^B	7.78 ^A	6.73 ^C	5.55 ^D	
<i>Spoilage (%)</i>					
HC	0.00 ^e	2.00 ^{de}	5.00 ^{cde}	12.00 ^{bc}	4.75 ^C
FAC	0.00 ^e	0.00 ^e	2.00 ^{de}	5.00 ^{cde}	1.75 ^D
EC	0.00 ^e	3.00 ^{de}	12.00 ^{bc}	20.00 ^a	8.75 ^B
Control	5.00 ^{cde}	8.00 ^{cd}	18.00 ^{ab}	25.00 ^a	14.00 ^A
Mean	1.25 ^C	3.25 ^C	9.25 ^B	15.50 ^A	

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.

respiration and other metabolic activities of fruits; and minimized the fruit weight loss of mango fruits. The fruit firmness deteriorated with the advancement of storage period (Table 1). It was the highest (13.0 lb force) in FAC followed by HC (12.40 lb force) treatment; whereas, minimum (10.73 lb force) was noticed in the control fruits. FAC has been reported to reduce the softening of fruits during storage due to delayed metabolic activities of fruits as a result of precooling (Shilpa *et al.* 2022).

The highest overall sensory score of 7.30 was recorded in fruits subjected to FAC treatment and had more acceptable rating up to 15 days of storage, after that the decline in values was observed (Table 1). The control fruits retained Hedonic scoring of 7.5 up to 10 days of storage and thereafter, a sudden decline was also registered. Liang *et al.* (2013) reported an improvement in the organoleptic sensory quality characters of pre-cooled litchi fruits. The highest decay incidence of about 14.0% was registered in the control and the least (1.75%) in FAC method. In the

control, decay incidence was increased substantially from 5.0–25.0% from 5 days to 20 days of storage. Li *et al.* (2019) reported that FAC significantly decreased the disease incidence of mangoes.

The FAC treated fruits showed a gradual improvement in TSS and total sugars content till 15 days of storage and thereafter, a declining trend was noticed (Table 2). On the contrary, TSS and total sugars of fruit juice was decreased throughout the storage period in the untreated control fruits. The fruits subjected to FAC treatment recorded the higher mean TSS of 12.73 °B and total sugars (7.50 %) content, whereas, control fruits exhibited the lowest values of 11.38

Table 2 Effect of precooling methods on chemical attributes of pear fruits stored under ambient conditions

Treatment	Storage period (days)				
	5	10	15	20	Mean
<i>TSS (° B)</i>					
HC	11.80 ^g	12.20 ^e	13.50 ^b	11.20 ^h	12.18 ^B
FAC	12.20 ^e	12.90 ^{cd}	13.80 ^a	12.00 ^f	12.73 ^A
EC	13.00 ^c	13.60 ^b	11.80 ^g	9.80 ⁱ	12.05 ^C
Control	13.00 ^c	12.80 ^d	10.40 ⁱ	9.30 ^k	11.38 ^D
Mean	12.50 ^B	12.88 ^A	12.38 ^C	10.58 ^D	
<i>Total Sugars (%)</i>					
HC	6.60 ^{fg}	7.30 ^d	8.20 ^b	6.20 ^h	7.08 ^B
FAC	6.80 ^{ef}	7.60 ^c	8.60 ^a	7.00 ^e	7.50 ^A
EC	7.30 ^d	7.70 ^c	6.40 ^{gh}	5.60 ⁱ	6.75 ^C
Control	7.00 ^e	6.30 ^h	5.20 ^j	4.50 ^k	5.75 ^D
Mean	6.93 ^C	7.23 ^A	7.10 ^B	5.83 ^D	
<i>Titrateable Acidity (% malic acid)</i>					
HC	0.35 ^{ab}	0.28 ^d	0.22 ^e	0.17 ^{figh}	0.26 ^B
FAC	0.38 ^a	0.33 ^{bc}	0.29 ^{cd}	0.21 ^{ef}	0.30 ^A
EC	0.30 ^{cd}	0.21 ^{efg}	0.20 ^{efg}	0.15 ^h	0.21 ^C
Control	0.28 ^d	0.20 ^{efg}	0.16 ^{gh}	0.13 ^h	0.19 ^D
Mean	0.33 ^A	0.25 ^B	0.22 ^C	0.17 ^D	
<i>Vitamin C (mg/100 g fw)</i>					
HC	10.30 ^a	8.50 ^d	7.00 ^f	6.30 ^g	8.03 ^B
FAC	10.50 ^a	9.00 ^c	7.40 ^e	6.70 ^f	8.40 ^A
EC	9.70 ^b	7.60 ^e	5.20 ^h	4.60 ⁱ	6.78 ^C
Control	9.00 ^c	6.00 ^g	4.80 ⁱ	4.00 ^j	5.95 ^D
Mean	9.88 ^A	7.78 ^B	6.10 ^C	5.40 ^D	
<i>Total Phenols (mg GAE/100 g fw)</i>					
HC	42.50 ^c	39.00 ^{ef}	35.60 ^h	30.00 ^j	36.78 ^B
FAC	45.00 ^a	43.60 ^b	40.10 ^d	37.50 ^g	41.55 ^A
EC	40.25 ^d	38.50 ^f	33.40 ⁱ	25.00 ^l	34.29 ^C
Control	39.60 ^{de}	33.00 ⁱ	27.00 ^k	20.50 ^m	30.03 ^D
Mean	41.84 ^A	38.53 ^B	34.03 ^C	28.25 ^D	

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.

°B and 5.75 %, respectively. FAC method has been reported to reduce the respiration rate and slow down the conversion of starch into different proportion of sugars concentrations, thus maintaining higher TSS and total sugars in the fruits (Nampan *et al.* 2006). Overall, in all the treatments, decrease in titratable acidity was observed in pear fruits during storage (Table 2) being the highest (0.30%) in FAC and the lowest (0.19%) in the control. The maintenance of higher acidity in FAC pear fruits may be due to slower degradation of organic acids and decreased in rate of respiration (Liang *et al.* 2013).

The ascorbic acid content in pear fruit reduced with the prolongation in storage days (Table 2). However, the lowest value among precooling treatments was gradually observed in EC and the highest (8.40 mg/100 g) in FAC. Conversely, it was declined at substantially faster rate and the lowest (5.95 mg/ 100 g) was noticed in untreated fruits. Sun *et al.* (2018) also reported the maintenance of higher ascorbic acid in pre-cooled peach fruits during storage.

Total phenolic content decreased significantly during storage being maximum in fruits subjected to FAC treatment (41.55 mg GAE/100 g) and minimum (30.03 mg GAE/100 g) in the control. Phenolic compounds converted to α -quinones and; thereafter, polymerized to brown pigments might be the reason of decrease in level of total phenols during storage. Hong *et al.* (2018) reported that precooling was effective in maintaining higher total phenolic compound in strawberries. Kaur *et al.* (2021) also reported that fruit weight, firmness, and sugar content were reduced significantly during ambient temperature storage of Patharnakh and Punjab Beauty pear cultivars. It is intended that precooling of pear fruits with forced air-cooling (FAC) method significantly enhanced the shelf-life for about 15 days under ambient storage at temperature of 28–32°C and RH 70–80% with acceptable fruit quality attributes.

SUMMARY

Patharnakh pear fruits were freshly harvested at the physiological maturity during second week of July and subjected to different precooling treatments, viz. Hydrocooling (HC), Forced Air Cooling (FAC) and Evaporative Cooling (EC). The effect of these methods on fruit shelf-life and quality attributes under ambient conditions was investigated during the year 2021–22 at Punjab Horticultural Post harvest Technology Centre, Punjab Agricultural University, Ludhiana, Punjab. In all treatments, temperature of fruit pulp was regularly checked with digital pulp thermometer until a constant temperature was accomplished. Thereafter, the fruits were packed in corrugated fibre board boxes of 2 kg capacity and stored at ambient conditions (28–32°C and 70–80% relative humidity). The stored samples were assessed, periodically, at

5 days interval till 20 days for physiological and biochemical parameters. The results of the study revealed that FAC maintained lower physiological weight loss, spoilage and retained higher fruit firmness, sensory quality score, juice TSS, total sugars, acidity, vitamin C and total phenolic content during storage compared to the control. This method is an effective approach for maintaining the post-harvest shelf-life of perishable pear fruits for about 15 days in comparison to 10 days in the untreated control fruits.

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