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Hydrocooling delays pericarp browning, enzymatic activities and maintains quality of litchi fruits under cold chain conditions

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ABSTRACT

The role of hydrocooling on storage life of litchi (*Litchi chinensis* Sonn.) cultivar 'Dehradun' was investigated. The bunches of litchi fruits cv. Dehradun were harvested at the physiological mature stage *i.e.* when fruit attained full rosy red colour. Thereafter, small bunches of about half kilogrammes fruits were prepared and subjected to hydrocooling treatments for 10, 20 and 30 min. The temperature of water was maintained at 4°C with auto-cut refrigeration system. The fruits without hydrocooling were kept as control treatment. The temperature of cooling media and fruit pulp was regularly monitored with digital thermometer. Immediately after giving hydrocooling treatments, fruits were air-dried to remove the surface moisture and thereafter packed in corrugated fibre board boxes and stored in walk-in-cold room maintained at temperature 2-3°C and 90-95% relative humidity. The stored samples were evaluated periodically at weekly interval till four weeks various physiological, biochemical parameters and enzymatic activity. The results of the study indicated that litchi fruits hydrocooled for 30 min. maintained lower physiological weight loss (3.88%), browning index 3 (¼ to ½ browning), retained higher organoleptic score (7.15 out of 9), TSS (19.14°B), acidity (0.32%), total anthocyanins (0.31 ΔA/g FW) and total phenols (246.33 mg/100 g) during storage. The fruits subjected to hydrocooling for 30 min. also maintained the lowest activity of PPO activity as compared to control and other treatments. The study demonstrates the effectiveness of hydrocooling treatment in prolonging the storage life of litchi fruits for 21 days as compared to 7 days in case of control fruits.

Key words: *Litchi chinensis*, shelf life, polyphenol oxidase activity.

INTRODUCTION

Litchi (*Litchi chinensis* Sonn.) is an important subtropical fruit of India, occupies an area of 92 thousand ha with the production of 6 lakh MT and productivity of 6.2 MT/ha (Anon, 1). However, litchi is highly perishable fruit and turns brown within 24-48 hours of harvest, thus fetch lower price in the market. The post-harvest pericarp browning is considered to be due to rapid degradation of anthocyanins owing to polyphenol oxidase enzyme activity (Nokthai *et al.,* 8). The pre-cooling treatment is eco-friendly, safe and economical, has been largely researched to compensate the chemicals treatments (Sivakumar *et al*., 11). Pre-cooling minimizes the microbial activity, metabolic activity, respiration rate and ethylene production, thereby preserves the quality and extends the shelf life of harvested produce (Ferreira *et al*., 3). Among various pre-cooling methods, hydrocooling is a simple low-cost approach to quickly lower temperature of the produce and thereby remove the field heat rapidly. The objective of this study was to explore the efficacy of hydrocooling in reducing the pericarp browning and maintaining the quality of litchi fruits during storage.

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MATERIALS AND METHODS

The bunches of litchi fruits cv. Dehradun were harvested from all the four directions of the plant at the physiological mature stage *i.e*., when fruit attained full rosy red colour. Thereafter, small bunches of half kilogrammes fruits were prepared and packed in plastic crates and immediately transported in air-conditioned van to the Punjab Horticultural Post Harvest Technology Centre (PHPTC), PAU, Ludhiana. The bruised and sun-burned fruits were sorted out and only healthy fruits with respect to uniform size and colour were selected for the experiments. The laboratory scale hydrocooler was used for hydrocooling of litchi fruits. The hydrocooler consisted of insulated water tank (50l capacity), insulated cabinet for loading of produce, water recirculating pump and refrigeration unit. The temperature of water is maintained at 4°C. The litchi fruits packed in plastic crated were loaded in the hydrocooler and cold water was sprinkled over the fruits as per treatments for 10, 20 and 30 min. separately. The pulp temperature of the produce was monitored regularly with the help of pulp thermometer till the requisite time period. Thereafter, the treated as well as control fruits were packed in corrugated fibre board boxes (2 kg) and kept in walk-in-cold room maintained at 2-3°C and

90-95% RH for 28 days. The various physio-chemical parameters and enzymatic activity of stored fruits were recorded at weekly interval for four weeks.

The physiological loss in weight (PLW) of fruit was calculated on initial weight basis and expressed in percent. Fruit firmness was measured using texture analyzer (Model TA-XT2i, Stable Microsystems Ltd. UK). A cylindrical probe of 5 mm, with a load cell of 25 kg and test speed of 0.5 mm/s was used. Corresponding maximum force in grams was recorded as the firmness of test sample. Browning index of fruit was assessed in a 0-4 scale (Ramma, 9), where 0 is no browning (excellent quality), 1 is slight browning, 2 is <1/4 surface area brown, 3 is 1/4 to 1/2 surface area brown, 4 is >1/2 to ¾ surface area brown (poor quality). The overall organoleptic rating of the fruits was done by a panel of ten judges on the basis of a 9-point Hedonic scale. The total soluble solids (TSS) of the fruit juice were determined using a hand refractometer and expressed as percent TSS after making the temperature correction at 20ºC. The titratable acidity was estimated as per standard procedures (Ranganna, 10). The anthocyanins content in the pericarp and total phenols were estimated as per method proposed by Zheng and Tian (15).

Polyphenol oxidase assay was determined as per Zauberman *et al*. (13) method. Fresh pericarp sample (0.1 g) was homogenized in a pestle mortar using 2 ml of ice cold 0.05 M sodium phosphate buffer (pH 6.5) containing 1% polyvinylpyrrolidone (PVP). Homogenized material was centrifuged at 10,000 rpm at 4°C for 20 min. and the resulting supernatant was used for the assay of PPO enzyme. To determine PPO enzyme activities, 3.5 ml of 0.05 M sodium phosphate buffer (pH 6.5) was taken in a cuvette to which 0.1 ml of enzyme extract was added. The reaction was initiated by the addition of 0.5 ml of 0.1 M catechol. The absorbance was read at 410 nm for 3 min. at the interval of 1 min. against the buffer. The activity of polyphenol oxidase was expressed as units/min/g of fresh weight.

The experiments consisted of 4 treatments and 4 storage intervals and were laid out in completely randomized design with three replications for each treatment. The experiments were conducted for two years during 2016-17 and 2017-18. The data were pooled and analyzed for variance by using the SAS (V 9.3, SAS Institute Inc., Cary, NC, USA) package.

RESULTS AND DISCUSSION

The PLW of litchi fruits increased during storage irrespective of different treatments (Table 1). The lowest average PLW (3.88%) of fruits was recorded in HC (30 min) followed by HC 20 min. On the other hand, the highest PLW (7.05%) was observed in control fruits. During different storage intervals the HC (30 min.) recorded the minimum weight loss of litchi fruits which ranged between 1.29 to 6.71% from 7 to 28 days of cold storage, respectively as compared to control, where PLW ranged from 4.80 to 9.28 % during same storage intervals. It has been pointed out that losses of less than 5 per cent in weight do not detract materially and are of little economic significance in majority of horticultural crops. However, the weight loss above 5% is generally considered to cause a noticeable loss of quality and value. Keeping in view this value it may be depicted that HC (30 min.) treated fruits can be stored for 3 weeks as compared to 7 days in case of control. Makwana *et al*. (6) observed that precooling play a positive role in diminishing the respiration and other metabolic activities of fruits, thus lowered the weight loss, spoilage and increased the shelf- life of mango fruits.

Table 1. Effects of hydrocooling on physiological loss weight (%) and firmness (g force) of litchi fruits stored at 2-3°C and 90-95% RH.

	Storage interval (days)									
	PLW (%)					Firmness (g force)				
Treatment	7	14	21	28	Mean	7	14	21	28	Mean
HC10 min.	1.67	3.44	6.13	7.63	4.72	130.5	124.0	107.5	96.0	114.5
HC 20 min.	1.54	2.82	5.33	7.24	4.23	134.0	128.5	115.0	103.0	120.1
HC 30 min.	1.29	2.59	4.91	6.71	3.88	136.5	134.0	124.0	110.5	126.3
Control	4.80	6.60	7.50	9.28	7.05	118.0	106.5	90.5	79.0	97.4
Mean	2.33	3.86	5.97	7.72		129.75	123.25	109.25	97.13	
LSD (P≤ 0.05): Treatment = 0.20						LSD(P≤ 0.05): Treatment = 2.30				
Storage = 0.13						Storage = 1.40				
Treatment × Storage = 0.41						Treatment × Storage = 4.70				

The firmness, in general followed a declining drift corresponding with advancement in storage period. The maximum firmness (126.3 g force) of fruits was observed in HC (30 min.), whereas the minimum firmness was noticed in control fruits (97.4 g force) (Table 1). The hydrocooling (30 min.) treatment maintained the higher firmness throughout the storage periods of 28 days, which ranged between 136.5 to 110.5 g force as compared to control fruits, which experienced the faster loss of firmness and ranged from 118.0 to 79.0 g force during storage. The loss of firmness of litchi fruits may be attributed to water loss and degradation of pectic substances. Hydrocooling has been reported to reduce respiration and leads to delay in softening of fruits during storage (Ferreira *et al*., 3).

The highest organoleptic quality score was recorded in fruits given hydrocooling treatment for 30 min. (7.05) and were found highly acceptable up to 21 days of storage, after that slight decline in sensory scores was recorded (Table 2). Whereas, the control fruits were acceptable only up to 7 days (7.30) of storage and thereafter sudden decline in organoleptic quality score was observed. The decrease in organoleptic quality of litchi fruit during storage might be due to susceptibility of litchi pericarp to browning and loss of other flavouring compounds due to degradative process. Makwana *et al.* (6) observed the highest sensory scores in mango when treated with precooling before storage.

The browning of litchi pericarp increased during storage (Table 2). However, the HC (30 min.) recorded the lowest BI score 1 (slight browning) to 3 (1/4th to ½ surface area brown) from 7th to 21st days of storage resulting in maintaining the acceptability of fruits upto three weeks and thereafter the browning of pericarp aggravated rapidly (Table 2). In contrast, non-hydrocooled control fruits registered the acceptable BI score 3 (1/4th to ½ surface area brown) on 7th day of storage and thereafter the pericarp browning increased at a faster rate leading to rejection of fruits. Hydrocooling has been reported to play an important role in slowing down the browning incidence and retained the fruit quality in horticultural commodities (Sivakumar *et al.*, 11). Browning severity correlated well with weight loss and decreased in hydrocooled fruits of rambutan (Nampan *et al.,* 7).

The TSS content increased slowly and steadily up to 21 days of storage in HC (30 min.) treated fruits and then declined gradually (Table 3). On the other hands, the control fruits showed a continuous decline in TSS content throughout the storage period. The HC (30 min.) recorded the highest TSS (19.14□B) and was statistically significant from all the treatments, whereas control fruits exhibited the lowest TSS value (16.53□B). The maintenance of higher total soluble solids in hydrocooled litchi fruits may be due to the positive role of hydrocooling in delaying the respiration rate of fruits resulting in delayed conversion of starch into sugars. Hydrocooling technique decelerates the respiration rates and retained the better quality in fruits (Nampan *et al.,* 7).

In general, a decline in titratable acidity of litchi fruits during storage was noticed in all the treatments (Table 3). The highest mean acidity (0.32%) was observed in HC (30 min) and was significantly at par with HC for 20 min. (0.31%), whereas, the lowest acidity was noticed in the control fruits (0.18%) treatments. The maintenance of higher acidity in hydrocooled litchi fruits may be due to slower degradation of organic acids owing to decreased respiration rate resulted from hydrocooling treatments (Liang *et al.,* 5).

The anthocyanins in litchi pericarp were found to decline during storage (Table 4). However, the decrease was gradual in hydrocooled fruits and

Table 2. Effects of hydrocooling on organoleptic quality and browning index (0-4 scale) of litchi fruits stored at 2-3°C and 90-95% RH.

	Storage interval (days)								
	Organoleptic quality (9 point hedonic scale)					Browning index (0-4 scale)			
Treatment	7	14	21	28	Mean	7	14	21	28
HC 10 min.	7.25	6.55	6.04	5.15	6.25	1	2	4	4
HC 20 min.	7.75	7.40	7.10	5.30	6.89	1	2	3	4
HC 30 min.	8.05	7.65	7.30	5.60	7.15	1	2	3	4
Control	7.30	5.30	4.80	4.65	5.51	3	4	4	4
Mean	7.59	6.73	6.31	5.18					
LSD (P≤ 0.05): Treatment = 0.14 Storage = 0.09 Treatment × Storage = 0.28									

Table 3. Effects of hydrocooling on total soluble solids (°B) and titratable acidity (%) of litchi fruits stored at 2-3°C and 90-95% RH.

Treatment	Storage interval (days)									
	Total soluble solids (°B)					Titratable acidity (%)				
	7	14	21	28	Mean	7	14	21	28	Mean
HC 10 min.	18.05	18.80	18.60	17.45	18.23	0.33	0.29	0.26	0.21	0.27
HC 20 min.	18.45	18.95	19.30	17.90	18.65	0.34	0.32	0.30	0.28	0.31
HC 30 min.	19.00	19.50	19.80	18.25	19.14	0.35	0.34	0.32	0.30	0.32
Control	17.55	17.25	16.25	15.05	16.53	0.27	0.18	0.15	0.11	0.18
Mean	18.26	18.63	18.49	17.16		0.32	0.28	0.26	0.23	
LSD (P≤ 0.05):	Treatment = 0.20					LSD (P≤ 0.05): Treatment = 0.02				
	Storage = 0.13					Storage = 0.01				
	Treatment × Storage = 0.41					Treatment × Storage = NS				

highest average total anthocyanins in litchi pericarp were found in HC 30 min. (0.31 ΔA/g FW). On the other hand, in control fruits the level of anthocyanins decreased at a very fast rate leading to the browning of pericarp after 7 days and also registered lowest mean value of total anthocyanins (0.16 ΔA/g FW). It has been reported that anthocyanins are readily discolourized by PPO enzyme activity in presence of a better substrate such as catechol (Zhang *et al.,* 14). Wijewardane and Guleria (12) reported continuous decrease of anthocyanins content of apple with the advancement of storage periods and also documented that precooling was effective for reduction in losses of pigment.

During storage a decline in total phenolic content of litchi fruits was noticed in all the treatments (Table 4). However, the maximum total phenols were recorded in HC 30 min. (246.3 mg/100 g), which was at par with HC 20 min (243.7 mg/100 g). The lowest total phenols were registered in control fruits (212.5 mg/100 g). During storage, decrease in level of total phenols might be due to conversion of phenolic compounds to *o*-quinones, which are then polymerized to brown pigments. Diaz *et al*. (2) reported that precooled cherry maintained higher phenolic content as compared to control.

The PPO activity in all the treatments increased from 7 to 21 days of storage and thereafter declined (Fig. 1). The highest PPO activity was recorded in control fruits (168.71 unit/min/g FW), whereas, the minimum PPO activity (148.08 unit/min/g FW) was observed in treatment HC (30 min.) followed by HC 20 min. (151.64 unit/min/g FW). This phenomenon may be explained by the fact that during the senescence of fruits, the consumption of phenols increases with the increase in PPO activity, and later on, PPO activity gradually decreased because of the lack of availability of phenolic substances. The changes of PPO activity in pericarp during storage are inconsistent in different reports. However, the most studies have proven the

Table 4: Effects of hydrocooling on anthocyanins (ΔA/gFW) and total phenols (mg/100g) of litchi fruits stored at 2-3°C and 90-95% RH.

Treatment	Storage interval (days)									
	Anthocyanins (ΔA/gFW)					Total phenols (mg/100g)				
	7	14	21	28	Mean	7	14	21	28	Mean
HC10 min.	0.30	0.26	0.22	0.19	0.24	252.3	243.0	235.0	220.5	237.7
HC 20 min.	0.34	0.29	0.25	0.21	0.27	258.0	248.5	239.7	228.9	243.7
HC 30 min.	0.39	0.34	0.29	0.24	0.31	260.4	252.9	239.6	232.2	246.3
Control	0.22	0.18	0.14	0.11	0.16	228.6	220.9	205.5	195.3	212.5
Mean	33.7	30.67	27.06	23.31		249.8	241.3	229.9	219.2	
LSD (P≤ 0.05):	Treatment = 0.02					LSD (P≤ 0.05): Treatment = 8.16				
	Storage = 0.02					Storage = 5.16				
	Treatment × Storage = NS					Treatment × Storage = NS				

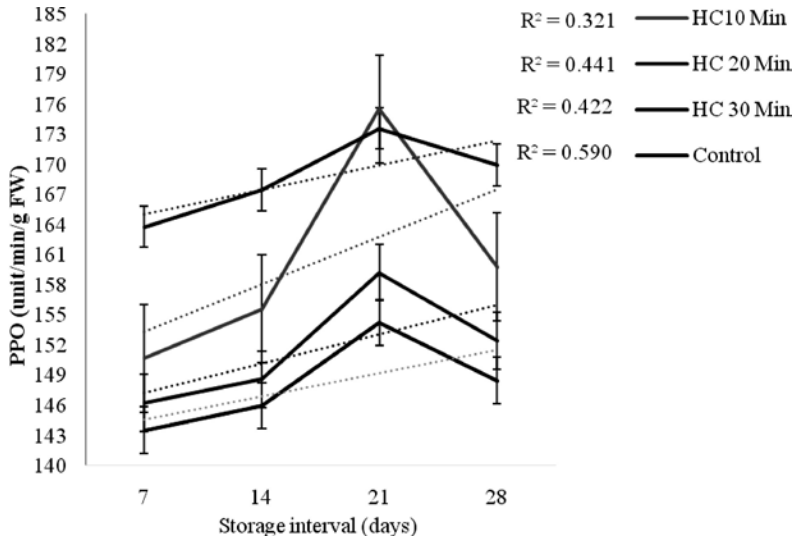

Fig. 1. Effects of hydrocooling on PPO (unit/min/g FW) of litchi cv. Dehradun stored at 2-3°C and 90-95% RH.

involvement of PPO in the enzymatic browning. The present study was in conformity with the findings of He *et al*., (4), who recorded the increase of PPO activity in litchi with storage and decreased after reaching a peak.

From the present investigations it can be concluded that litchi fruits hydrocooled for 30 min. can be successfully stored for 3 weeks in cold storage (2-3°C and 90-95% RH) with acceptable quality.

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