Indian Journal of Agricultural Sciences **91** (3): 445–9, March 2021/Article
https://doi.org/10.56093/ijas.v91i3.112531

Effect of evaporative cooling on peel browning and quality of litchi (*Litchi chinensis*)

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Received: 06 October 2020; Accepted: 02 November 2020

ABSTRACT

The present study was carried out during 2016–18 at Punjab Agricultural University Ludhiana to examine the effect of evaporative cooling (EC) on peel browning and postharvest quality of litchi fruit during cold storage. The litchi fruits cv. Dehradun were harvested at the physiological maturity and subjected to EC treatments for 2 h, 4 h and 6 h. The fruits without EC were kept as a control. Thereafter, fruits were packed in corrugated fiberboard boxes and stored in a walk-in-cold room maintained at 2-3°C temperature and 90-95% relative humidity. The fruit samples were analyzed at weekly interval till four weeks for various physiological attributes, biochemical traits and enzymatic activities. The application of evaporative cooling for 6 h maintained lower physiological weight loss (6.38%), retained higher firmness (106.1g force),TSS (16.96°B), acidity (0.26%), anthocyanins (0.19 ΔA/g FW) and total phenols (218.43 mg/100g) during storage. The browning index of fruits was observed to be 3 (1/4-1/2 surface area brown up to 14 days of storage) with 4 and 6 h exposure to EC. The fruits subjected to EC for 6 h also maintained the lower activities of polyphenol oxidase (PPO) and peroxidase (POD) activity as compared to control. The study exhibited the expediency of EC treatment (6 h) to maintain the acceptable peel colour and prolong the storage life of fruits for 14 days as compared to 7 days in case of control.

Keywords: Browning, Evaporative cooling, Polyphenol oxidase, Peroxidase activity, Quality

Litchi is a prominent fruit of India, known for its pleasant flavour, attractive colour and nutritious value. It occupies an area of 92 thousand ha with the production of 6 lakh MT with a productivity of 6.2 MT/ha (Anonymous 2018). It is a nutritious fruit containing vitamin C, proteins and a fair amount of calcium, phosphorus, iron and vitamin A & B. It is also a great source of dietary fibres, proanthocyanidins and polyphenolics, which boosts the immune system (Deerasamee and Chaisawadi 2014). However, peel browning normally starts within 24-48 h of harvest, is the major hurdle influencing its visual acceptance, leading to decline in its commercial value (Xiao *et al*. 2019). Browning is thought to be due to breakdown in cellular compartmentation of enzymes and substrates which in turn cause oxidation of phenolics, producing brown by-products (Jiang *et al.* 2004). The harvesting of litchi coincides with the extreme high temperature and pre-monsoon rains leading to huge postharvest losses. Moreover, short span of harvesting period (2-4 weeks) further aggravates the problem. Pre-cooling is the most vital technique to remove the field heat from freshly harvested produce. This process slows down the metabolism and reduces deterioration (Ferreira *et al*. 2006).Among various pre-cooling methods, evaporative cooling is a simple, easy-to-operate and cost-effective. It is an affordable technique and can be executed by the farmers at their farms. The objective of this study was to examine the efficacy of evaporative cooling to diminish the pericarp browning and maintain the postharvest quality of litchi fruits during storage.

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MATERIALS AND METHODS

Fifteen uniform litchi plants of cv. Dehradun were selected at Fruit Research Station, Gangian, Punjab during 2016–18. The litchi fruits were harvested at the physiological mature stage from all the four directions of the plant. Thereafter, small bunches of half kilogram fruits were prepared and packed in plastic crates and transported in an air-conditioned van to the Punjab Horticultural Post Harvest Technology Centre P.A.U. Ludhiana.

Method of evaporative cooling: Evaporative cooling works on the principle of conversion of liquid water into vapour using the thermal energy in the air, resulting in a lower air temperature. The litchi fruits packed in plastic crates were put before the dessert cooler and cool humidified air was allowed to pass through the vents of plastic crates inside the enclosed chamber. The fruits were given EC treatments for 2, 4 and 6 h respectively. The pulp temperature of the produce was monitored regularly with the help of a

digital thermometer till the requisite period. After treatment, fruits were stored in walk-in-cold rooms for four weeks during which observations on various physiochemical parameters and enzymatic activity of stored fruits were recorded at weekly interval.

The PLW of fruit was calculated on the 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 a 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 2003), 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 3/4 surface area brown (poor quality). The colour of fruit was measured with colour difference meter (Colour Flex, Hunter Lab, USA) and expressed as *L*, a*, b** coordinates**.** The instrument was calibrated with a standard white ceramic tile and black tile before recording the observations. The hunter scale varies from 100 for perfect white and 0 for black. The chromaticity dimension *a** depicts redness with +ive, greenness when – ive, and *b** measures yellowness when +ive and blueness when –ive. The total soluble solids (TSS) of the fruit juice were determined using a hand-held refractometer and expressed as percent TSS after making the temperature correction at 20ºC. The titratable acidity was estimated by titrating the known quantity of fruit juice against N/10 standard alkali and results were expressed in per cent citric acid. The anthocyanins content in the pericarp and total phenols were estimated as per the method proposed by Zheng and Tian (2006) and Shaver *et al*. (2011). Polyphenol oxidase (PPO) and peroxidase (POD) assay was determined as per the method suggested by Zauberman *et al*. (1991).

The experiments consisted of 4 treatments and 4 storage intervals and laid out in a completely randomized design with three replications comprised of 10 Kg fruits in each replication. The experiments were conducted for two years during 2016–17 and 2017–18. The data were pooled and analyzed for the variance by using the SAS (V 9.3, SAS Institute Inc., and Cary, NC, USA) package.

RESULTS AND DISCUSSION

Physiological loss in weight: PLW was significantly affected by EC (Table 1). The minimum PLW (6.38%) was

Table 1 Effect of evaporative cooling on PLW, firmness, browning index and peel colour of litchi stored at 2-3°C temperature and 90-95% RH

Treatment	Storage interval (days)				
	7	14	21	28	Mean
PLW (%)					
Evaporative cooling (EC) 2 Hours	3.72^{h}	6.42^{e}	8.18^{c}	8.86^{b}	6.79^{b}
Evaporative cooling (EC) 4 Hours	3.45^{hi}	6.40^{e}	7.43^{d}	9.00^{ab}	6.51^{c}
Evaporative cooling (EC) 6 Hours	3.31^{i}	6.00^{f}	7.45^{d}	8.75^{b}	6.38^{c}
Control	4.80^{g}	6.60^{e}	7.50^{d}	9.28^{a}	7.05^{a}
Mean	3.82^{d}	6.30^{c}	7.64^{b}	8.97^{a}	
Firmness (g force)					
Evaporative cooling (EC) 2 Hours	121.5^{ab}	109.5^{de}	91.0^{g}	76.5^{j}	98.9^{c}
Evaporative cooling (EC) 4 Hours	124.5^{a}	112.0^{d}	94.5^{fg}	82.0^{hi}	103.2^{a}
Evaporative cooling (EC) 6 Hours	125.5^{a}	118.5^{cd}	95.5^{fg}	85.0^{h}	106.1^{b}
Control	118.0^{bc}	106.5^{e}	90.5^{g}	79.0^{i}	97.4^{c}
Mean	122.4^{a}	111.6^{b}	92.9^{c}	80.6^{d}	
Browning index (0-4 scale)					
Evaporative cooling (EC) 2 Hours	2.0	4.0	4.0	4.0	
Evaporative cooling (EC) 4 Hours	2.0	3.0	4.0	4.0	
Evaporative cooling (EC) 6 Hours	2.0	3.0	4.0	4.0	
Control	3.0	4.0	4.0	4.0	
Peel Colour					
Evaporative cooling (EC) 2 Hours	19.69^{ab}	16.69^{bc}	9.76^{d}	8.69^{d}	13.71^{ab}
Evaporative cooling (EC) 4 Hours	20.86^{a}	17.70^{bc}	10.41^{d}	9.27^{d}	14.56^{a}
Evaporative cooling (EC) 6 Hours	21.07^{a}	17.54^{bc}	10.70^{d}	9.83^{d}	14.78^{a}
Control	18.22^{ab}	14.78^{c}	9.08^{d}	7.73^{d}	12.45^{b}
Mean	19.96^{a}	16.68^{b}	9.99^{c}	8.88^{c}	

Firmness at harvest: 140.5 g force and the peel colour at harvest (a*): 33.08.

recorded in fruits treated with EC (6 h), followed by EC (4 h) whereas, the maximum PLW was recorded in control fruits (7.05%). The weight loss of fruits during storage is a natural phenomenon which occurs due to respiratory and transpiration of water through pericarp. Brecht *et al*. (2003) demonstrated that by reducing the temperature of fruits immediately after harvest resulted in reducing the weight loss in fruits.

Fruit firmness: The firmness of litchi fruits declined with the advancement of storage intervals (Table 1). The maximum firmness (106.1 g force) of fruits was observed in EC (6 h), whereas the minimum firmness was noticed in control fruits (97.4 g force) The EC (6 h) treatment maintained the higher firmness throughout the storage periods of 28 days which ranged between 125.5 to 85.0 g force as compared to control fruits which experienced the faster loss of firmness and it ranged from 118.0 to 79.0 g force during storage. The reduction in fruit firmness has been attributed to the changes in cellular substances, such as pectin, cellulose, and other polysaccharides, and this effect is generally associated with fruit ripening (Joo *et al*. 2011). The maintenance of higher fruit firmness in EC (6 h) may be attributed to lower water loss observed in litchi fruits.

Browning index: BI of litchi fruits increased gradually within 2 weeks of storage in treated fruits and thereafter it increased rapidly with increase in storage period (Table 1). However, EC (6 h) recorded the lowest BI score 2 (<1/4 surface area brown) to 3 (¼ to ½ surface area brown) from 7th to 14th days of storage resulting in maintaining the acceptability of litchi fruits for two weeks and thereafter the browning was increased swiftly. In contrast, the control fruits registered acceptable BI score 3 (1/4th to ½ surface area brown) up to 7 days of storage thereafter BI increased at a faster rate, resulting in rejection of fruits. Browning in litchi is considered to occur through polyphenol oxidase and peroxidase activities which are responsible for the degradation of the anthocyanins pigments (Huang *et al*. 2006). Evaporative cooling might have helped in rehydration of litchi pericarp, therefore it reduced the physiological reactions in the fruit and delayed the occurrence of browning in EC treated fruits.

Peel Colour: The colour of litchi fruits showed an

Table 2 Effect of evaporative cooling on physicochemical parameters of litchi cv. Dehradun stored at 2-3°C temperature and 90-95% RH

Treatment	Storage interval (days)				
	7	14	21	28	Mean
Total Soluble Solids (°B)					
Evaporative cooling (EC) 2 Hours	17.35^{abc}	17.20^{bc}	16.55^{ef}	15.20^{hi}	16.58^{c}
Evaporative cooling (EC) 4 Hours	17.50^{ab}	17.30^{abc}	16.80^{de}	15.50^{gh}	16.78^{b}
Evaporative cooling (EC) 6 Hours	17.65^{a}	17.45^{ab}	17.00^{cd}	15.75^{g}	16.96^{a}
Control	17.55^{ab}	17.25^{bc}	16.25^{f}	15.05^{i}	16.53^{c}
Mean	17.51^{a}	17.30^{b}	16.65^{c}	15.38^{d}	
Titratable acidity (%)					
Evaporative cooling (EC) 2 Hours	0.26^{abc}	0.24^{bcd}	0.22^{cde}	0.20^{de}	0.23^{b}
Evaporative cooling (EC) 4 Hours	0.28^{ab}	0.26^{abc}	0.24^{bc}	0.22^{cde}	0.25^{ab}
Evaporative cooling (EC) 6 Hours	0.29^{a}	0.27^{abc}	0.26^{abc}	0.23^{cde}	0.26^{a}
Control	0.27^{abc}	0.18^{ef}	0.15^{fg}	0.11^{g}	0.18^{c}
Mean	0.28^{a}	0.24^{b}	0.22^{b}	0.19^{c}	
Total Phenols mg/100g					
Evaporative cooling (EC) 2 Hours	226.9^{ab}	216.4^{cd}	203.2^{efg}	192.9^{hi}	209.8^{bc}
Evaporative cooling (EC) 4 Hours	231.4^{ab}	220.8^{bc}	211.2^{de}	198.6^{fg}	215.5^{ab}
Evaporative cooling (EC) 6 Hours	233.6^{a}	225.1^{b}	212.7^{de}	202.4^{fg}	218.4^{a}
Control	228.6^{ab}	220.9^{bc}	205.5^{ef}	195.4^{gh}	212.6^{ab}
Mean	230.1^{a}	220.79^{b}	208.13^{c}	197.29^{d}	
Anthocyanins (ΔA/gFW)					
Evaporative cooling (EC) 2 Hours	0.20^{bc}	0.18^{cd}	0.15^{de}	0.11^{fg}	0.17^{b}
Evaporative cooling (EC) 4 Hours	0.23^{a}	0.18^{cd}	0.16^{de}	0.13^{ef}	0.17^{b}
Evaporative cooling (EC) 6 Hours	0.23^{a}	0.21^{ab}	0.18^{cd}	0.14^{ef}	0.19^{a}
Control	0.22^{ab}	0.18^{cd}	0.14^{ef}	0.11^{fg}	0.16^{bc}
Mean	0.22^{a}	0.19^{b}	0.16^{c}	0.12^{d}	

The TSS at harvest: 17.70 °B, TA at harvest: 0.36 percent, TP at harvest: 267.87 mg/100 g FW and the anthocyanins at harvest: 0.41 ΔA/gFW.

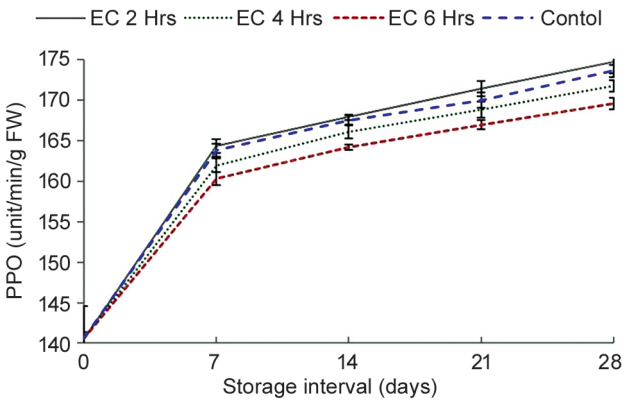

Fig 1 Effect of evaporative cooling on polyphenol oxidase activity (unit/min/g FW) of litchi cv. Dehradun stored at 2-3°C temperature and 90-95% RH.

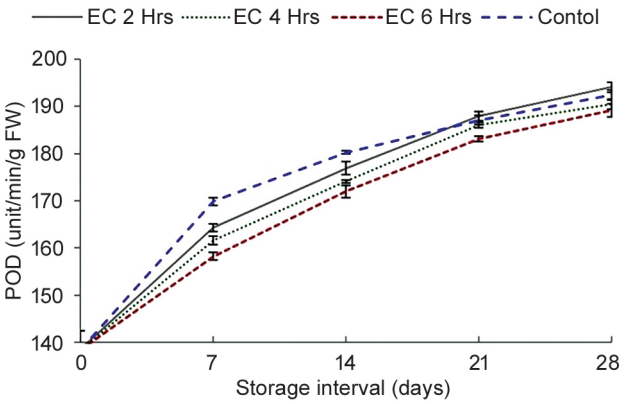

Fig 2 Effect of evaporative cooling on peroxidase enzyme activity (unit/min/g FW) of litchi cv. Dehradun stored at 2-3°C temperature and 90-95% RH.

inverse relationship with the advancement of storage period (Table 1). It declined continuously from 7th day to 28th day of storage. The freshly harvested ripe fruit of litchi had an attractive pink colour but once harvested, this changed quickly to a dull brown unattractive colour. However, all the fruits of EC treatments (6 h) were in good conditions up to 14 days as compared to control. The maximum Hunter colour value a* (14.78) was recorded in EC (6 h) closely followed by EC (4 h) whereas the rate of colour loss was fast in control fruits (no precooling) and exhibited minimum colour value a* (12.45). Pericarp browning is the most important postharvest problem associated with litchi because it significantly reduces consumer preference and appeal. You *et al.* (2014) documented that the precooling can maintain pericarp moisture content and decrease pericarp browning index of fruit.

Total soluble solids: The TSS content declined slowly and steadily during storage irrespective of treatments (Table 2). However, control fruits showed a faster and abrupt decline in TSS content throughout the storage period. The EC (6 h) recorded the highest TSS (16.96°B) whereas control fruits exhibited the lowest TSS value (16.53°B). The slower decline of TSS in EC might be due to slow hydrolysis of starch and sugars due restricted respiratory activities (Makwana *et al*. 2014).

Titratable acidity: In general, a decline in titratable acidity of litchi fruits during storage was observed in all the treatments (Table 2).The highest mean acidity (0.23%) was observed in EC (6 h) whereas the lowest acidity was recorded in the control fruits (0.18%). The EC (6 h) delayed the decline in titratable acidity, primarily due to slower conversion of acids to sugars and further utilization of acids during respiration. Precooling may reduce respiration and the consumption of respiratory substrates; thereby it might have delayed softening of fruits and reduced the content of titratable acids (Alique *et al*. 2006).

Total phenolic content: During storage, a decline in total phenolic content of litchi fruits was noticed in all the treatments (Table 2). However, the maximum phenolic content was recorded in treatment EC (6 h) (218.43 mg/100 g) which was at par with FC (4 h) (215.46 mg/100 g). The lowest phenolic content was observed in control fruits (212.59 mg/100 g). During storage, decrease in level of total phenols might be due to breakdown of cellular structure at senescence stage (Ghasemnezhad *et al.* 2013). Diaz *et al.* (2009) who reported that pre-cooled cherry maintained higher phenolic content as compared to control samples.

Anthocyanins: The anthocyanins in litchi pericarp were found to decline during storage (Table 2). However, the decrease was gradual in EC (6 h) fruits which recorded the highest anthocyanins (0.24 ΔA/g FW). On the other hand, in control fruits, the level of anthocyanins decreased at a very faster rate, leading to the browning of pericarp after 7 days which also registered the lowest mean value of total anthocyanins (0.16 ΔA/g FW). It is believed that anthocyanins polymerize during storage; additionally, oxidative reactions caused by enzymatic activity could have resulted in anthocyanins degradation (Reque *et al*., 2014). Wijewardane and Guleria (2013) reported that precooling was effective in delaying the degradation of anthocyanins in apple.

Polyphenol oxidase activity (PPO): The PPO activity in all the treatments increased from 7 days to 21 days of storage and thereafter it declined (Fig 1). The highest PPO activity was recorded in control fruits (168.71 unit/min/g FW) whereas the minimum PPO activity (165.25 unit/min/g FW) was observed in treatment EC (6 h). The browning in the pericarp is largely dependent on phenols and PPO activity. It is generally acknowledged that PPO is involved in enzymatic browning of harvested litchi fruits (Mishra *et al*. 2012). PPO catalyzes the oxidation of phenol to quinones and then condenses tannins to brown polymers (Wang *et al*. 2014). The lower PPO activity in evaporative cooled fruits might be due to the role of EC in delaying the senescence of fruits as a result of removal of field heat immediately after harvest.

Peroxidase activity (POD): The control fruits exhibited the maximum activity of POD (183.26 unit/min/g FW) which was statistically at par with treatment EC for 2 h (Fig 2). However, the minimum POD activity (175.60 unit/min/g

FW) was registered in EC (6 h) and was statistically at par with EC (4 h). POD is another group of oxidases involving in the enzymatic browning. The peroxidase is a heme-containing glycoprotein that can oxidize a large number of phenols and this type of oxidation was responsible for the browning of many fruits (Chisari *et al.* 2007). Liang *et al.* (2013) claimed that precooling swiftly reduce the POD activity in litchi pericarp.

The present study revealed that acceptable peel colour and postharvest quality of freshly harvested litchi fruit can be maintained with application of evaporative cooling for 6 h at farm level. This simple postharvest intervention can prolong the storage life of litchi fruits for two weeks at 2-3°C temperature and 90-95% RH.

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