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Colour changes during storage of apple cv. Red delicious- influence of harvest dates, precooling, calcium chloride and waxing

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Abstract

Colour is an important quality parameter which determines consumer acceptability of fruits like apple. It depends on many harvesting and postharvest factors. Present study was carried out to determine the influence of harvest dates, precooling, calcium chloride, wax coating and storage conditions on colour of apple cv Red delicious. It was evaluated by sensory analysis, L^*, a^*, b^* values using chromometer and anthocyanin content. Fruits from three harvest dates (H_1, H_2 and H_3) were subjected to various treatments. The treatments included T_1 (shade cooling), T_2 (Hydrocooling), T_3 (Hydrocooling + calcium chloride), T_4 (Hydrocooling + wax) and T_5 (Hydrocooling + calcium chloride + wax). Samples were stored under ambient and refrigerated condition for 100 days to monitor colour changes. There was colour degradation as indicated by increase in L^* and b^* values and decrease in a^* values during storage. In general T_5 (Hydrocooling + $CaCl_2$ + wax) showed lowest changes in all the studied parameters and T_1 (shadecooling) showed highest changes under both the storage conditions. Among the treatments T_5 (hydrocooling + $CaCl_2$ + wax) proved best to retain the maximum anthocyanin while as among harvest dates (H_3) late harvested apple retained the maximum anthocyanin content. After 100 days of storage apples harvested at (H_2) remained the best with respect to sensory color scores. Among different treatments T_1 recorded the minimum

Introduction

Apple (*Malus domestica* Borkh.) is one of the most important tree fruit of the world belongs to the family Rosaceae and sub-family Pomoidae. Apple is a typical temperate tree fruit with more than 80 per cent of the world's supply being produced in Europe. In India commercial cultivation of apple is largely confined to the state of Jammu and Kashmir, Himachal Pradesh and Uttrakhand which together accounts for about 2.5 per cent of world production (Ahsan *et al*., 2008; Wani *et al*., 2009).

Harvesting time is an important determinant for storage life. Fruits harvested at advanced maturity are more prone to mechanical injury, have short storage life and greater susceptibility to pathogens and physiological disorders (Juan *et al*., 1999). In addition, careless harvesting characterised by immature and over mature fruit, is another serious cause of postharvest losses (Ingle *et al*., 2000). Being a climacteric fruit, apple can be harvested at physiological maturity and stored to catch good price in the market (Roth *et al*., 2005; Sayin *et al*., 2010). In general, apple fruit harvested at immature stage have poor colour and flavour and more susceptible to physiological disorders such as bitter pit and superficial scale (Kvikliene *et al*., 2008). By contrast fruits harvested over mature tend to be soft and easily damaged during postharvest operations. Such fruits are more susceptible to diseases and physiological disorders as well as quality deterioration during or after storage (Ingle *et al*., 2000).

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 is reduced considerably. This also decreases the ripening rate, diminishes water loss and decay, thus helps preserving quality and prolongs shelf-life of the fruit (Ferreira *et al*., 1994).

Several physiological disorders and diseases of apple fruit during storage are related to the calcium content of fruit (Huder, 1981). Calcium deficiency results in economic losses in fruit (Dyson and Digby, 1975). It helps in regulation of metabolism in apple

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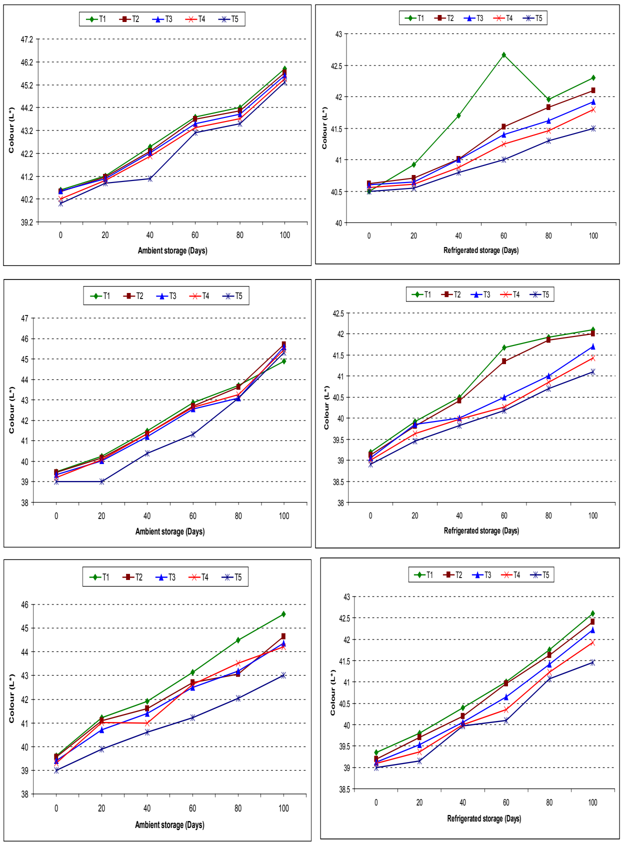
fruit and adequate concentrations maintain fruit flesh firmness and minimize the incidence of physiological disorders like water core, bitter pit and internal breakdown (Bangerth *et al*., 1972). The increase in calcium generally delays the ripening of the fruit and maintains their quality during prolonged storage. The application of calcium also reduces the incidence of storage decay (Conway, 1982).

Coating apples prior to storage seems an excellent fit for "Red Delicious" because it imparts high gloss, hides bruises and forms a modified atmosphere condition that tend to preserve firmness and prolong shelf-life. The inhibition of biochemical processes, which cause the aging of apples and shortening of their storage, may be achieved with the help of natural and artificially made chemical substances, which are used for after harvest treatment for fruits (Alleyne and Hagenmaier, 2000; Bai *et al*., 2002).

Colour changes are the most obvious signal for fruit ripening. During ripening, apple fruit generally shows a rapid loss of green colour which results from the degradation of chlorophyll structures (Tromp, 2005). The yellow to red colour of apple fruit, which is due to anthocyanins and carotenoids in the peel, becomes visible with chlorophyll decline (Kingston, 1992; Tromp, 2005). Apple fruits are kept in cold storage after harvest to preserve their quality. Low temperature plays main role in slowing the degradation of apple fruit quality during storage. Therefore, keeping in the view the above facts, the present investigation was aimed to maintain colour of apple by working out appropriate harvesting date, pre-cooling and various postharvest treatments.

Materials and Methods

Apple cv. "Red Delicious" of uniform shape, size and firm texture was procured from the apple orchards at three different dates with an interval of seven days. After harvest, these were manually sorted by discarding deformed, bruised, punctured and stemless fruits. One lot of fruits was separated and kept under shade for 12 hours for cooling which served as control T_1 (shade-cooling). The remaining fruits were given different treatments; T_2 (hydrocooling), T_3 (hydrocooling + $CaCl_2$), T_4 (hydrocooling + 6% paraffin wax) and T_5 (hydrocooling + 3% $CaCl_2$ + 6% paraffin wax). After treatment, samples were kept separately under two storage conditions viz., ambient (Temperature 18±2ºC, RH 75±5%) and refrigerated (Temperature 2±1ºC, RH 85±5%) for monitoring colour changes during storage periods. Fruits were evaluated after every 20 days (0, 20, 40, 60, 80 and 100 days) in case of both storage conditions with five replications.



T_1 = Shade cooling (Control); T_2 = Hydro cooling; T_3 = Hydro cooling + $CaCl_2$; T_4 = Hydro cooling + wax; T_5 = Hydro cooling + $CaCl_2$ + wax

Figure 1. Effect of harvest dates, post harvest treatments and storage conditions on Colour (L^* value) of apple

Determination of colour (L^*, a^*, b^* values)

Fruit surface colour was determined with a chromometer (Model CR-2000, Minolta, Osaka, Japan), equipped with an 8-mm measuring head and a c illumination (6774 K). The meter was calibrated using the manufacturer's standard white plate. Colour changes were quantified in the L^*, a^*, b^* colour space. L^*, refers to lightness of the colour of the sample fruit and ranges from black = 0 to white = 100. A negative value of a^* indicates a green colour where the positive value indicates red-purple colour. A positive value of b^* indicates a yellow colour and the negative value a blue colour.

Determination of anthocyanin content

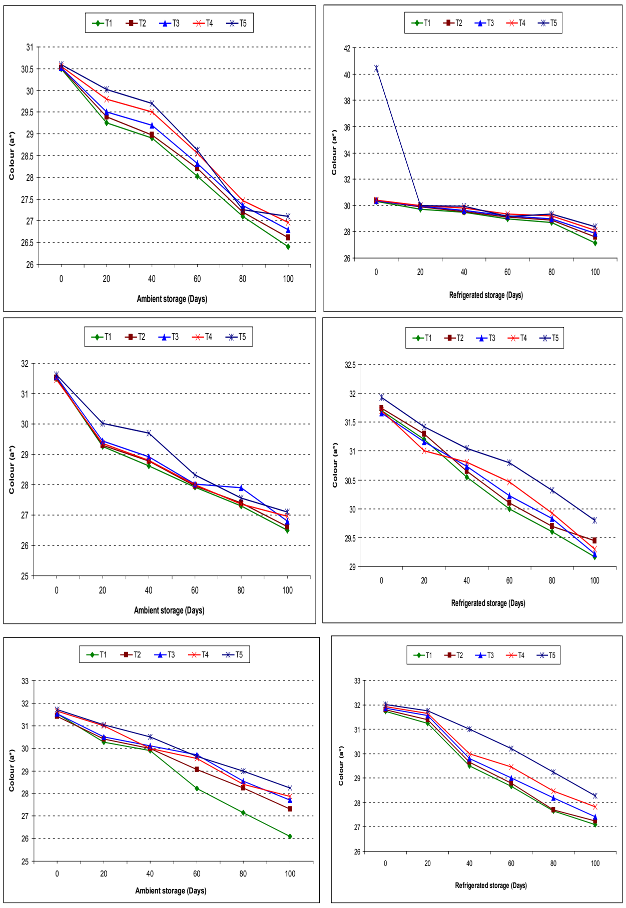
The anthocyanin content was estimated by blending a known weight of fruit with a known volume of ethanolic HCl (95% ethanol and 1.5 N HCl in the ratio of 85:15, v/v) in a blender and stored overnight under refrigeration at 4°C. The mixture was filtered and residue was washed repeatedly till a known volume was obtained. A small aliquot was diluted with ethanolic HCl to yield optical density

Table 1. Effect of harvest dates, post harvest treatments and storage conditions on sensory colour of apple

Harvest dates	Storage / Treatment	Ambient storage (Days) 0	20	40	60	80	100	Mean	Refrigerated storage (Days) 0	20	40	60	80	100	Mean
H_1	T_1	4.88	4.88	4.88	4.78	4.68	4.48	**4.66**	4.88	4.88	4.88	4.88	4.78	4.68	**4.83**
	T_2	4.88	4.88	4.88	4.78	4.68	4.48	**4.68**	4.88	4.88	4.88	4.88	4.78	4.68	**4.83**
	T_3	4.88	4.88	4.88	4.88	4.78	4.58	**4.71**	4.88	4.88	4.88	4.88	4.88	4.78	**4.83**
	T_4	4.88	4.88	4.88	4.78	4.68	4.48	**4.76**	4.88	4.88	4.88	4.88	4.78	4.68	**4.86**
	T_5	4.88	4.88	4.88	4.88	4.78	4.68	**4.83**	4.88	4.88	4.88	4.88	4.88	4.78	**4.86**
	Sub Mean	**4.88**	**4.88**	**4.88**	**4.82**	**4.72**	**4.54**	**4.79**	**4.88**	**4.88**	**4.88**	**4.88**	**4.82**	**4.72**	**4.84**
H_2	T_1	4.99	4.99	4.99	4.89	4.79	4.69	**4.67**	4.99	4.99	4.99	4.99	4.89	4.79	**4.94**
	T_2	4.99	4.99	4.99	4.89	4.79	4.69	**4.69**	4.99	4.99	4.99	4.99	4.89	4.79	**4.94**
	T_3	4.99	4.99	4.99	4.99	4.89	4.79	**4.74**	4.99	4.99	4.99	4.99	4.89	4.89	**4.95**
	T_4	4.99	4.99	4.99	4.89	4.79	4.69	**4.89**	4.99	4.99	4.99	4.99	4.89	4.79	**4.94**
	T_5	4.99	4.99	4.99	4.99	4.89	4.79	**4.94**	4.99	4.99	4.99	4.99	4.89	4.89	**4.95**
	Sub Mean	**4.99**	**4.99**	**4.99**	**4.93**	**4.83**	**4.73**	**4.91**	**4.99**	**4.99**	**4.99**	**4.99**	**4.89**	**4.83**	**4.94**
H_3	T_1	4.99	4.99	4.99	4.89	4.79	4.69	**4.68**	4.99	4.99	4.99	4.99	4.89	4.79	**4.94**
	T_2	4.99	4.99	4.99	4.89	4.79	4.69	**4.70**	4.99	4.99	4.99	4.99	4.89	4.79	**4.94**
	T_3	4.99	4.99	4.99	4.99	4.89	4.79	**4.89**	4.99	4.99	4.99	4.99	4.89	4.89	**4.96**
	T_4	4.99	4.99	4.99	4.89	4.79	4.69	**4.92**	4.99	4.99	4.99	4.99	4.89	4.79	**4.94**
	T_5	4.99	4.99	4.99	4.99	4.89	4.79	**4.94**	4.99	4.99	4.99	4.99	4.89	4.89	**4.96**
	Sub Mean	**4.99**	**4.99**	**4.99**	**4.93**	**4.83**	**4.73**	**4.91**	**4.99**	**4.99**	**4.99**	**4.99**	**4.89**	**4.83**	**4.95**
	Grand Mean	**4.95**	**4.95**	**4.95**	**4.89**	**4.79**	**4.67**	**4.87**	**4.95**	**4.95**	**4.95**	**4.95**	**4.87**	**4.79**	**4.91**

CD (p=0.05)	Ambient storage	Refrigerated storage
Harvest (H) =	0.108	0.077
Treatment (T) =	0.102	0.092
H x T =	0.107	0.095
Storage (S) =	0.087	0.081
H x S =	NS	NS
H x S x T =	NS	NS

T_1 = Shade cooling (Control); T_2 = Hydro cooling; T_3 = Hydro cooling + $CaCl_2$; T_4 = Hydro cooling + wax; T_5 = Hydro cooling + $CaCl_2$



T_1 = Shade cooling (Control); T_2 = Hydro cooling; T_3 = Hydro cooling + $CaCl_2$; T_4 = Hydro cooling + wax; T_5 = Hydro cooling + $CaCl_2$ + wax

Figure 2.Effect of harvest dates, post harvest treatments and storage conditions on Colour (a* value) of apple

(OD) checked at 530 nm measurements within the optical range of spectrophotometer.

Sensory evaluation

Sensory colour of apple samples was evaluated by semi-trained panel of 10 members (Ranganna, 1986). The panellist were provided with coded samples of apple and were requested to note their sensory responses on 5-point hedonic scale (5: Excellent, 4: Very Good, 3: Good, 2: Fair, 1: Poor).

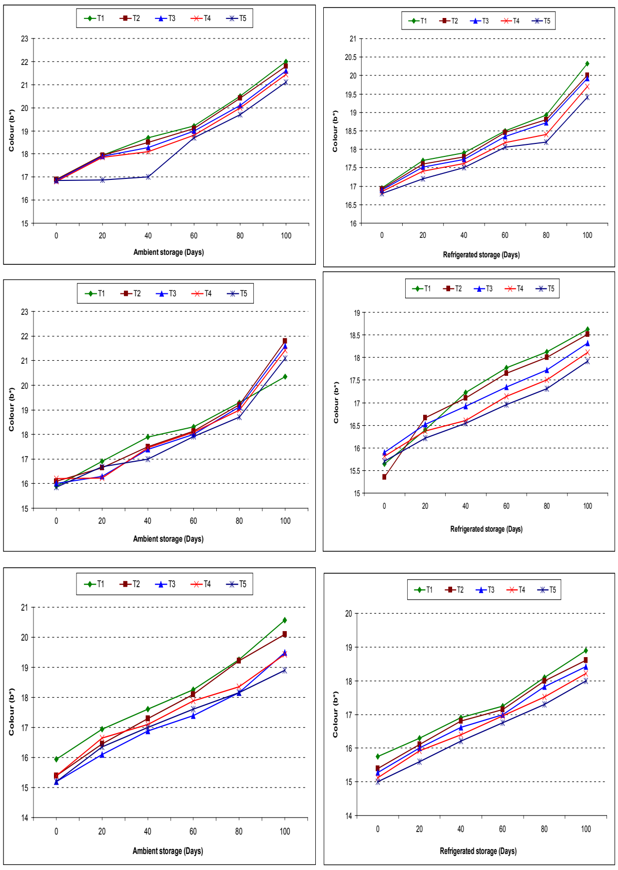
Statistical analysis

The data was statistically analysed through R-Software using Completely Randomized Design (CRD) in factorial experiment.

Results and Discussion

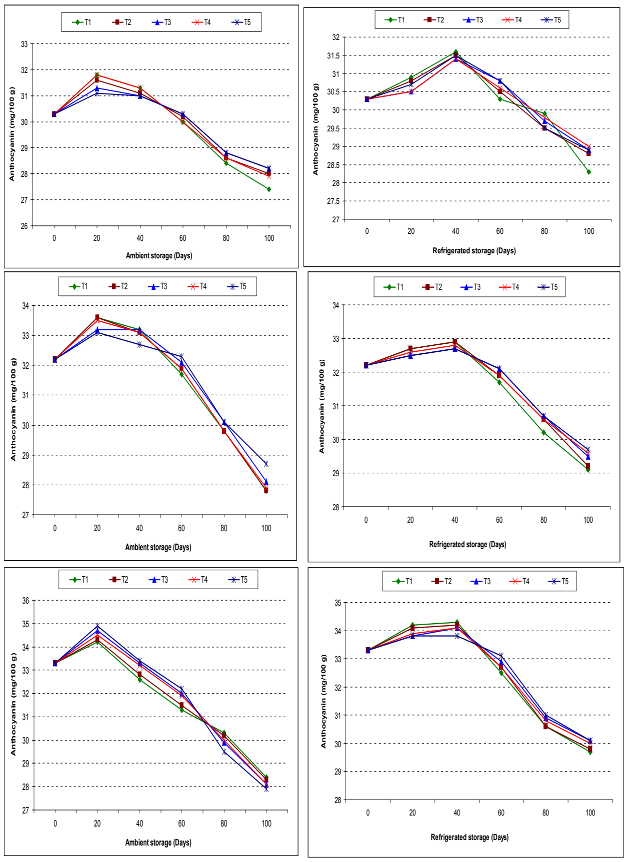
Colour (L^*, a^*, b^* values)

During the experiment period fruit colour L^*, a^*, b^* values changed as per the harvest dates and differed significantly at each harvest date (Figure 1-3). Early harvested apples H_1 recorded the maximum L^* and b^* values (40.60 and 16.90) and the minimum values for a^* (30.50). After the storage period of 100 days fruits harvested at late maturity H_2 received the minimum values for L^* and b^* whereas maximum values for a^* was recorded by fruits harvested at late stage of maturity (H_3). The reason behind the higher a* values in harvest date third (H_3) might be the full pigment development upto late stages of maturity. These results are in agreement with Kvikliene *et al.* (2008). Among the treatments, T_5 (Hydrocooling + $CaCl_2$ + wax) recorded the minimum values of L^* and b* whereas it received maximum values for a^*. The reason behind the higher a* values recorded by T5 might be protective effect of $CaCl_2$ and wax on degradation of pigments. These results are in conformation with Bai *et al.* (2003). As it is evident from Figure 1-3, there was continuous increase in L^* and b^* values and decrease in a^* values during the storage period irrespective of treatment and harvest dates. The reason behind this increase in L^* and b^* values and decrease in a^* values might be the pigment



T_1 = Shade cooling (Control); T_2 = Hydro cooling; T_3 = Hydro cooling + $CaCl_2$; T_4 = Hydro cooling + wax; T_5 = Hydro cooling + $CaCl_2$ + wax

Figure 3. Effect of harvest dates, post harvest treatments and storage conditions on Colour (b^* value) of apple



T_1 = Shade cooling (Control); T_2 = Hydro cooling; T_3 = Hydro cooling + $CaCl_2$; T_4 = Hydro cooling + wax; T_5 = Hydro cooling + $CaCl_2$ + wax

Figure 4. Effect of harvest dates, post harvest treatments and storage conditions on anthocyanin content (mg/100 g) of apple

degradation during the storage. These results are in accordance with Henriquez *et al.* (2010). Colour changes were more pronounced in ambient storage than in refrigerated storage. This is because all the degradation reactions including those responsible for colour get slowed down under low temperature conditions.

Anthocyanin content (mg/100 g)

Anthocyanin content changed according to harvest dates and varied significantly with each harvest date. Late harvested fruits H_3 showed highest anthocyanin content (33.30mg/100g) while early harvested (H_1) showed minimum anthocyanin content (30.30 mg/100 g). After the 100 days of storage (H_3) late harvested apple retained the maximum anthocyanin content than H_1 and H_2. The reason behind the highest anthocyanin in late harvested apples might be due to full colour development by associated enzymes (PAL) and the lowest anthocyanin in H_1 early harvested apple might be due to more chlorophyll than anthocyanin. Among the treatments T_5 (hydrocooling + $CaCl_2$ + wax) proved best to retain the maximum anthocyanin than other treatments. The reason behind this is the protective effect of precooling, $CaCl_2$ and wax on overall degradation of fruit (Wijewardane and Guleria, 2009). As it is clear from the Figure 4 that there was continuous decrease in anthocyanin content in all harvest dates as well as treatments. This may be due to the progressive senescence of fruit tissue which involves the degradation of pigments (Wijewardane and Guleria, 2013). Low temperature slows down anthocyanin degradation which resulted in more pronounced decrease in anthocyanin content in ambient storage than in refrigerated storage.

Sensory evaluation

During the period of study, colour scores changed according to harvest dates and differed significantly at different dates (Table 1). Late (H_3) and mid (H_2) harvested fruits got more colour score (4.99) than H_1 (4.88). The reason behind may be the synthesis of anthocyanins up to the later stages of maturity. However, after 100 days of storage, apples harvested at H_2 remained the best with respect to color scores.

Among different treatments T_1 recorded the minimum values for colour whereas T_5 (Hydrocooling + $CaCl_2$ + Wax) received the higher values. This might be due to negative effect of hydrocooling, $CaCl_2$ and wax coating on senescence of fruit. Coating materials have been reported to maintain the skin colour (Habibunisa *et al*., 1988). As it is clear from the Table 1 that with the prolonged storage there is considerable decrease in colour. These results are in conformation with Mir *et al*. (2004).

Conclusion

The results revealed significant effect of various studied factors on colour changes during storage. There was colour degradation as indicated by increase in L^* and b^* values and decrease in a^* values during storage. In general T_5 (Hydrocooling + $CaCl_2$ + wax) recorded minimum changes in all the studied parameters and T_1 (shadecooling) recorded maximum under both the storage conditions.

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