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RESEARCH ARTICLE

Effect of harvest maturity and postharvest treatments on some chemical parameters of apple cv. Red delicious

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Abstract

Harvesting time is an important determinant for storage life of Apple. Fruits harvested at advanced maturity are more prone to mechanical injury, increased enzyme activity, short storage life and greater susceptibility to pathogens and physiological disorders. 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 asses various quality changes. Chemical parameters, exhibit both increasing and decreasing trend. There was a decrease in acidity while TSS and total sugar content increased during storage of 100 days. Changes were more pronounced in ambient storage than refrigerated.

Introduction

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). 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).

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). Keeping in the view significance of this fruit in the economy of the region, the present investigation was aimed to improve shelf life and quality of apple by working out appropriate harvesting date, pre-cooling and various postharvest treatments with an objective to study the changes in biochemical attributes of treated apple during storage.

2. Material 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 %) storage 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.

Total soluble solids (°Brix)

Total soluble contents were determined by a hand refractometer (model Atago N, Japan) having range of 0-32 per cent and the values obtained in per cent were correlated at 20ºC. The fruits for the test were divided into 3 replicates each consisting of 5 fruits and were subjected to juice extraction using an Omni juice extractor, followed by filtration through muslin cloth. Two to three drops of the filtered juice were put on the refractometer lens for TSS measurement and expressed as °Brix.

Titrable acidity (%)

Titrable acidity was determined by taking a known weight of fruit juice and making a known volume of it by adding distilled water. Then a known volume of this liquid was treated against 0.1 N sodium hydroxide using phenolpthalin as an indicator. Titrable acidity was expressed as percentage malic acid as per equation.

$$\text{Titrable acidity} = \frac{\text{Titre x Normality of alkali x Vol. make up x Equivalent weight of acid}}{\text{Vol. of sample taken for estimation} \times \text{Weight or volume of sample taken x 1000}} \times 100$$

Total sugars (%)

Total and reducing sugars were estimated by taking 5 g of sample with 100 ml distilled water, boiled for 1 hour in 150 ml beaker. Loss of water during boiling was made up by addition of distilled water. The solution was heated, transferred to a 250 ml volumetric flask and neutralized using sodium hydroxide. To it 2 ml of 45 per cent lead acetate was added, shaken well and left undisturbed for 10 minutes. Then it was de leaded with 2 ml of potassium oxalate and volume made up to 250 ml. The solution was filtered and marked as solution (1).

For estimation of total sugars, 50 ml of solution (1) was inverted in 200 ml of flask by adding 5 g of citric acid to it and then boiled for 15 to 20 minutes and cooled, neutralized with 1N sodium hydroxide till pink colour appeared using phenopthalein indicator volume was made upto 250 ml and solution designated as solution II. 5 ml of each Fehlings solution (A) and (B) were taken in a titration flask containing 25 ml of distilled water titrated against solution (II) for estimation of total sugars, till red colour was observed. After this 2 drops of methylene blue (indicator) were added and titration was continued till brick red precipitate was observed. During the entire period, the flask was kept on burner to keep the contents hot. Percentage total sugars were calculated using the followed equation

$$\text{Total sugars (\%)} = \frac{\text{0.05 x volume made}}{\text{Titrate volume x weight of sample}} \times 100$$

Statistical analysis

The data was statistically analysed through R-Software using Completely Randomized Design (CRD) in factorial experiment (Gomez and Gomez, 1984).

3. Results and discussion

Total Soluble Solids (^{o}Brix)

Total soluble solids of apple and other fruits is a major quality parameter (Weibel *et al.*, 2004;Peck *et al.*,2006).During storage study period TSS changed according to harvest dates and differed significantly at different dates (Table-1). Later harvested (H_3) fruits had higher TSS content (14.84^{o}Brix) than H_2 (14.38^{o}Brix) and H_1 (14.17^{o}Brix). After 100 days of storage apples harvested at H_2 were of best quality. Later harvested fruits had shown higher TSS both at harvesting time and at the end of storage period too (Yong *et al.*, 1998). The higher values of TSS in early harvested fruits (H_1) may be due to concentration effects as there is more moisture loss during early harvested fruits because of immature cuticle formation. Moreover,in early harvested fruits the enzyme activity is predominantly more especially PME which results in more degradation and hence increase in TSS.

Among different treatments, T_1 (Control) recorded maximum TSS at all harvesting stages while as minimum TSS was recorded incase of T5 (Hydrocooling+ $CaCl_2$ +Wax). This might be due to the fact that both $CaCl_2$ and Wax had negative effect on moisture loss which results in lower TSS due to dilutions of solids. Similar results regarding effect of $CaCl_2$ and Wax were reported by Badshah *et al.*(1994) and Hussain (2001) Furthermore, $CaCl_2$ (3%) forms a thin layer on surface of fruits which delays degradation process and also reduces evaporation from fruits (Hayat *et al.*, 2003). Wax coating results in decrease in moisture loss. As it is evident from Table 10 that with prolonged storage there is increase in TSS. This increase in TSS might be due to hydrolysis of polysaccharide during storage which resulted in increase in TSS (Hayat *et al.*, 2003; Mir *et al.*, 2004). Refrigerated storage resulted in lesser increase in TSS than ambient.

Acidity (%)

Apple cultivars have been shown to have significant differences in acidity (Ali *et al.*,2004).During storage study period total acidity changed according to harvest dates and differed significantly at different dates (Table-2). Early harvested (H_1) fruits had higher acidity (0.363%) than H_2 (0.351%) and H_3 (0.330%). After 100 days of storage apples harvested at H_2 were of best quality. Early harvested fruits had shown higher acidity at harvesting time but lowerat the end of storage period (Yong *et al*., 1998).

The lower values of acidity in late harvested fruits (H_3) may be due to the breakdown of organic acids as a main respiratory substrate. Among different treatments,T_1 (Control) recorded minimum acidity at all harvesting stages. While maximum acidity was recorded incase of T_5 (hydrocooling+ $CaCl_2$ + wax). This might be because of the fact that hydrocooling, $CaCl_2$ and wax reduces the respiration rate which results in maintained acidity over a long period. Similar results regarding effect of $CaCl_2$ and wax were reported by Hussain (2001). Furthermore, as per the data given in Table 3 ($CaCl_2$) delays degradation process and wax coating results in decrease in respiration rate. As it is evident from Table 11 that with prolonged storage there is decrease in acidity. This decrease in acidity might be due to oxidation of organic acids during storage which resulted in decrease in acidity (Drake and Spayed, 1983). Decrease in acidity was more pronounced in ambient storage than in refrigerated storage.

Total sugars (%)

The sugars content, sucrose, glucose, fructose, and sorbitol, in fruit flesh contribute to the fruit sweetness, and is one of the major characteristics of fruit quality and market value. The apple fruit accumulate starch at the early stages of maturation that is later on hydrolyzed to sugars at edible maturity (Magein and Leurquin, 2000). The starch to sugars conversion continue during storage (Beaudry *et al.*, 1989), resulting in increased total sugars with storage duration (Crouch, 2003). Results obtained during storage study period showed that fruit total sugars changed according to harvest dates and differed significantly at different dates (Table-3). Later harvested (H_3) fruits showed higher sugar content (18.60%) than H_2 (19.40%) and H_1 (.19.70%). After 100 days of storage apples harvested at H_2 were of best quality.

The lower values of total sugars in early harvested fruits (H_1) may be due to the higher starch content in early harvested fruits. Moreover, in early harvested fruits the starch degrading enzyme activity is low especially amylases which results in degradation of starch in to simple sugars.

Among different treatments, T_1 (Control) recorded maximum total sugars at all harvesting stages. Minimum total sugars was recorded in case of T_5 (Hydrocooling+ $CaCl_2$ +Wax). This might be due to the fact that hydrocooling, $CaCl_2$ and wax reduces enzyme activity which helps in maintaining the starch. Similar results regarding effect of $CaCl_2$ and wax were reported by Wijewardane *et al.* (2009). Furthermore, $CaCl_2$ forms a thin layer on surface of fruits which delays degradation process and also reduces evaporation from fruits (Hayat *et al.*, 2003). Wax coating results in decrease in moisture loss thus prevents concentration effect. As it is evident from

Table 3 that with prolonged storage there is increase in total sugars. This increase in total sugars might be due to hydrolysis of starch and other higher polysaccrides during storage which resulted in higher total sugars (Brummell *et al.*, 2001; Mir *et al.*, 2004). When differnr srorge conditions are evaluated, ambient storage caused a greater increase in total sugars than in refrigerated storage.

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Table-1 : Effect of harvest dates, post harvest treatments and storage conditions on TSS content (^{o}Brix) of apple

Harvest dates	Storage / Treatment	Ambient storage (Days)							Refrigerated storage (Days)						
		0	20	40	60	80	100	Mean	0	20	40	60	80	100	Mean
H_1	T_1	14.17	15.17	15.97	16.87	17.77	18.37	**16.39**	14.17	14.67	15.07	15.47	16.07	16.50	**15.09**
	T_2	14.17	14.77	15.47	16.37	17.47	18.17	**16.07**	14.17	14.47	14.87	15.27	15.87	16.20	**14.93**
	T_3	14.17	14.67	15.17	16.17	17.27	17.77	**15.87**	14.17	14.27	14.57	14.97	15.37	15.60	**14.67**
	T_4	14.17	14.77	15.47	16.57	17.47	18.07	**16.09**	14.17	14.57	14.97	15.37	15.77	16.10	**14.97**
	T_5	14.17	14.47	15.27	16.07	16.77	17.47	**15.70**	14.17	14.27	14.47	14.77	15.07	16.02	**14.40**
	Sub Mean	**14.17**	**14.77**	**15.47**	**16.41**	**17.35**	**17.97**	**16.02**	**14.17**	**14.45**	**14.79**	**15.17**	**15.63**	**16.02**	**15.04**
H_2	T_1	14.38	14.98	15.58	16.38	17.28	18.18	**16.13**	14.38	14.88	15.18	15.38	15.88	16.30	**15.33**
	T_2	14.38	14.78	15.38	16.08	16.88	17.88	**15.90**	14.38	14.68	15.08	15.18	15.68	16.00	**15.17**
	T_3	14.38	14.48	14.98	15.28	16.48	17.38	**15.50**	14.38	14.48	14.88	15.08	15.38	15.60	**14.97**
	T_4	14.38	14.68	15.18	16.08	16.68	17.58	**15.76**	14.38	14.68	15.18	15.38	15.58	15.90	**15.18**
	T_5	14.38	14.58	14.58	15.38	16.18	16.98	**15.35**	14.38	14.78	14.98	15.18	15.38	15.40	**14.80**
	Sub Mean	**14.38**	**14.70**	**15.14**	**15.84**	**16.70**	**17.60**	**15.73**	**14.27**	**14.56**	**14.91**	**15.20**	**15.58**	**15.84**	**15.06**
H_3	T_1	14.84	15.74	16.54	17.34	18.14	18.84	**16.91**	14.84	15.34	15.94	16.34	17.14	17.40	**16.17**
	T_2	14.84	15.74	16.24	17.04	17.84	18.54	**16.71**	14.84	15.24	15.74	16.24	16.94	17.20	**16.03**
	T_3	14.84	15.34	16.04	16.54	17.14	17.64	**16.26**	14.84	15.04	15.34	15.74	16.24	16.30	**15.58**
	T_4	14.84	15.54	16.34	17.14	17.74	18.44	**16.67**	14.84	15.34	15.84	16.34	16.84	17.00	**16.03**
	T_5	14.84	15.24	15.84	16.54	17.04	17.44	**16.16**	14.84	15.04	15.24	15.54	15.94	16.10	**15.45**
	Sub Mean	**14.84**	**15.52**	**16.20**	**16.92**	**17.58**	**18.18**	**16.54**	**14.84**	**15.20**	**15.62**	**16.04**	**16.62**	**16.80**	**15.85**
	Grand Mean	**14.46**	**15.00**	**15.60**	**16.39**	**17.21**	**17.92**	**16.10**	**14.43**	**14.74**	**15.11**	**15.47**	**15.94**	**16.22**	**15.32**

CD ($p \leq 0.05$)			**CD ($p \leq 0.05$)**		
Harvest (H)	=	0.266	Harvest (H)	=	0.283
Treatment (T)	=	0.209	Treatment (T)	=	0.219
H x T	=	0.328	H x T	=	0.323
Storage (S)	=	0.312	Storage (S)	=	0.305
H x S	=	0.223	H x S	=	0.219
H x S x T	=	0.259	H x S x T	=	0.237

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

Table-2 : Effect of harvest dates, post harvest treatments and storage conditions on acidity (%) of apple

Harvest dates	Storage / Treatment	Ambient storage (Days)							Refrigerated storage (Days)						
		0	20	40	60	80	100	Mean	0	20	40	60	80	100	Mean
H_1	T_1	0.363	0.347	0.314	0.277	0.248	0.216	**0.294**	0.364	0.349	0.338	0.316	0.304	0.274	**0.324**
	T_2	0.363	0.349	0.318	0.281	0.257	0.238	**0.301**	0.364	0.349	0.343	0.328	0.319	0.285	**0.331**
	T_3	0.363	0.359	0.341	0.312	0.288	0.262	**0.321**	0.364	0.354	0.349	0.340	0.323	0.315	**0.341**
	T_4	0.363	0.356	0.337	0.304	0.279	0.255	**0.316**	0.364	0.351	0.344	0.334	0.320	0.306	**0.337**
	T_5	0.363	0.357	0.344	0.338	0.317	0.292	**0.335**	0.364	0.354	0.351	0.343	0.331	0.321	**0.344**
	Sub Mean	**0.363**	**0.354**	**0.331**	**0.302**	**0.278**	**0.253**	**0.313**	**0.364**	**0.351**	**0.345**	**0.332**	**0.319**	**0.300**	**0.335**
H_2	T_1	0.351	0.335	0.320	0.288	0.267	0.227	**0.298**	0.351	0.343	0.335	0.296	0.283	0.277	**0.314**
	T_2	0.351	0.339	0.322	0.295	0.272	0.236	**0.303**	0.351	0.345	0.338	0.302	0.294	0.287	**0.320**
	T_3	0.351	0.345	0.340	0.315	0.292	0.265	**0.318**	0.351	0.347	0.343	0.335	0.327	0.320	**0.337**
	T_4	0.351	0.342	0.335	0.310	0.285	0.260	**0.314**	0.351	0.346	0.341	0.332	0.321	0.310	**0.334**
	T_5	0.350	0.347	0.342	0.320	0.305	0.298	**0.327**	0.350	0.348	0.345	0.339	0.332	0.327	**0.340**
	Sub Mean	**0.351**	**0.342**	**0.332**	**0.306**	**0.284**	**0.257**	**0.312**	**0.351**	**0.346**	**0.340**	**0.321**	**0.311**	**0.304**	**0.329**
H_3	T_1	0.330	0.316	0.275	0.254	0.225	0.200	**0.267**	0.330	0.320	0.310	0.273	0.256	0.229	**0.286**
	T_2	0.330	0.318	0.281	0.260	0.229	0.203	**0.270**	0.330	0.322	0.312	0.278	0.260	0.233	**0.289**
	T_3	0.330	0.319	0.383	0.262	0.232	0.205	**0.289**	0.330	0.325	0.316	0.284	0.267	0.238	**0.293**
	T_4	0.330	0.321	0.288	0.266	0.235	0.208	**0.275**	0.330	0.323	0.314	0.281	0.263	0.234	**0.291**
	T_5	0.330	0.322	0.391	0.270	0.239	0.217	**0.295**	0.330	0.325	0.318	0.387	0.269	0.241	**0.312**
	Sub Mean	**0.330**	**0.319**	**0.324**	**0.262**	**0.232**	**0.207**	**0.279**	**0.330**	**0.323**	**0.314**	**0.301**	**0.263**	**0.235**	**0.294**
	Grand Mean	**0.348**	**0.338**	**0.329**	**0.290**	**0.265**	**0.239**	**0.301**	**0.348**	**0.340**	**0.333**	**0.318**	**0.298**	**0.280**	**0.320**

	Ambient: CD ($p \leq 0.05$)	Refrigerated: CD ($p \leq 0.05$)
Harvest (H)	0.014	0.012
Treatment (T)	0.015	0.013
H x T	0.012	0.016
Storage (S)	0.011	0.010
H x S	0.016	0.014
H x S x T	0.015	0.012

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

Table-3 : Effect of harvest dates, post harvest treatments and storage conditions on total sugars (%) 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	9.40	10.50	11.40	12.30	13.20	14.00	**11.80**	9.40	9.70	10.00	10.40	10.80	11.10	**10.23**
	T_2	9.40	10.20	11.30	12.10	12.90	13.60	**11.58**	9.40	9.60	9.90	10.10	10.30	10.60	**9.98**
	T_3	9.40	10.00	10.90	11.60	12.50	13.00	**11.23**	9.40	9.60	9.70	9.90	10.20	10.30	**9.85**
	T_4	9.40	9.90	10.90	11.70	12.50	13.10	**11.25**	9.40	9.70	9.80	10.10	10.30	10.50	**9.97**
	T_5	9.40	9.70	10.30	11.00	11.80	12.40	**10.77**	9.40	9.50	9.70	9.80	9.90	10.00	**9.72**
	Sub Mean	**9.40**	**10.06**	**10.96**	**11.74**	**12.58**	**13.22**	**11.33**	**9.40**	**9.62**	**9.82**	**10.06**	**10.30**	**10.50**	**9.95**
H_2	T_1	9.82	11.12	12.52	13.32	14.02	14.62	**12.57**	9.82	10.02	10.42	10.92	11.22	11.52	**10.65**
	T_2	9.82	10.82	12.02	12.92	13.62	14.12	**12.22**	9.82	10.02	10.32	10.52	10.72	10.92	**10.39**
	T_3	9.82	10.52	11.32	12.22	12.82	13.42	**11.69**	9.82	9.92	10.32	10.52	10.62	10.72	**10.32**
	T_4	9.82	10.42	11.22	12.12	12.82	13.32	**11.62**	9.82	10.02	10.22	10.42	10.62	10.82	**10.32**
	T_5	9.82	10.02	10.72	11.52	12.12	12.82	**11.17**	9.82	9.82	9.92	10.02	10.12	10.22	**9.99**
	Sub Mean	**9.82**	**10.58**	**11.56**	**12.42**	**13.08**	**13.66**	**11.85**	**9.82**	**9.96**	**10.24**	**10.48**	**10.66**	**10.84**	**10.33**
H_3	T_1	10.26	11.56	12.96	14.06	14.46	14.86	**13.03**	10.26	10.56	10.96	11.16	11.46	11.76	**11.03**
	T_2	10.26	11.26	12.36	13.06	13.96	14.66	**12.59**	10.26	10.36	10.56	10.76	10.96	11.16	**10.68**
	T_3	10.26	10.76	12.06	12.66	13.46	14.16	**12.23**	10.26	10.36	10.46	10.56	10.66	10.86	**10.53**
	T_4	10.26	10.86	12.16	13.06	13.86	14.36	**12.43**	10.26	10.26	10.46	10.66	10.76	10.86	**10.54**
	T_5	10.26	10.26	11.06	11.96	12.86	13.76	**11.69**	10.26	10.26	10.36	10.36	10.46	10.56	**10.38**
	Sub Mean	**10.26**	**10.94**	**12.12**	**12.96**	**13.72**	**14.36**	**12.39**	**10.26**	**10.36**	**10.56**	**10.70**	**10.86**	**11.04**	**10.63**
	Grand Mean	**9.83**	**10.53**	**11.55**	**12.37**	**13.13**	**13.75**	**11.86**	**9.83**	**9.98**	**10.21**	**10.41**	**10.61**	**10.79**	**10.30**

CD ($p \leq 0.05$) – Ambient			CD ($p \leq 0.05$) – Refrigerated		
Harvest (H)	=	0.213	Harvest (H)	=	0.209
Treatment (T)	=	0.207	Treatment (T)	=	0.205
H x T	=	0.114	H x T	=	0.125
Storage (S)	=	0.316	Storage (S)	=	0.319
H x S	=	0.322	H x S	=	0.324
H x S x T	=	0.221	H x S x T	=	0.219

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

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