

## INFLUENCE OF STORAGE DURATION ON PHYSICO-CHEMICAL CHANGES IN FRUIT OF APPLE CULTIVARS

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### ABSTRACT

The objective of the present research was to study the influence of storage duration on physico-chemical changes in fruit of apple cultivars. The fruits of apple cultivars: Royal gala, Mondial gala, Golden delicious and Red delicious were harvested at optimum maturity and stored for 0, 30, 60, 90, 120 and 150 days in cold storage. The experiment was laid out in Completely Randomized Design (CRD) with twenty four treatment combinations. Physico-chemical changes in fruit were determined at 30 days interval during storage. Apple cultivar Red delicious had the highest juice content (58.47 %), TSS/Acid ratio (23.12), ascorbic acid (13.12 mg/100g), fruit firmness (5.98 kg/cm<sup>2</sup>), fruit density (0.82 g/cm<sup>3</sup>) as well as the least weight loss (2.22%) but also had the highest bitter pit (11.86%) and soft rot (13.53%) incidence. Titratable acidity was the highest (0.55%) in cultivar Mondial gala and starch score was the maximum (5.22) in cultivar Golden delicious. The percent weight loss, total soluble solids, total sugar, pH, TSS/Acid ratio, bitter pit incidence and soft rot increased with increase in storage duration while juice content, starch score, titratable acidity, ascorbic acid, firmness and density of fruit declined with increase in storage duration. The results indicated that apple cultivar Red delicious has good quality attributes, whereas cultivar Royal gala has the lowest incidence of bitter pit during prolong storage.

**Keywords:** Physico-chemical attributes, apple, firmness, weight loss, bitter pit, storage performance, cultivars.

### INTRODUCTION

Apple (*Pyrus domestica* L) is one of the most important tree fruit of the world. It is a highly nutritive fruit which is a rich source of sugars 11%, fat 0.4%, protein 0.3%, carbohydrates 14.9%, vitamins and minerals. (Hussain, 2001). Due to its high nutritional value, it ranks third in consumption after citrus and banana (Bokhari, 2002). The apple cultivars grown in Pakistan vary considerably in physico-chemical characteristics and weight loss in cold storage (Golias *et al.*, 2008) which may in turn influence the texture and storage performance of apple cultivars (Hoehn *et al.*, 2003). Being in high demand through out the year, the apple is generally stored in warehouses but cold storage is required for long term storage and quality retention (Ilyas *et al.*, 2007). About 17% of apples produced in Balochistan are lost during postharvest operations (Shah *et al.*, 2002) and 28% losses have been reported with cold storage for 22 weeks (Ilyas *et al.*, 2007). Storage problems are complicated by the fact that various cultivars may vary significantly in their storage performance (Golias *et al.*, 2008). The postharvest losses may depend on external and internal conditions, which affect the fruit firmness, juice content, weight loss, pH, soluble solids content (SSC), and other quality parameters (Tu *et al.*, 2000). Saleh *et al.*, (2009) reported that fruits of apple cultivars Golden delicious, Starking delicious, Star cremson and Gala exhibited significant

differences in physiological and anatomical parameters such as ethylene production, responsible for the changes in texture and fruit softening (Nilsson and Gustavsson, 2007) and water loss (Khan and Ahmad, 2005). The present experiment was, therefore, conducted to evaluate the influence of storage duration on physico-chemical changes in fruit of apple cultivars.

### MATERIALS AND METHODS

The apple fruits from cultivars: Royal gala, Mondial gala, Golden delicious and Red delicious were harvested at commercial maturity stage at Matta, Swat. Unhealthy, diseased and bruised fruits were discarded and fruits of uniform size were selected for the study. The fruits of each cultivar were divided into six groups each containing 30 fruits, packed in corrugated boxes and stored in cold storage at 5±1°C with 60-70% relative humidity for 0, 30, 60, 90, 120 and 150 days. At the end of each storage interval the fruits were analysed for physico-chemical quality. The data were recorded and statistically analysed for the following post harvest quality parameters at 30 days intervals.

**Weight loss (%):** Five fruits in each treatment were separated for weight loss test. The initial weight of each fruit was noted with the help of electronic balance. The average loss of weight in all the treatments was calculated at 30 days intervals. The weight loss (%) was calculated as under:

$$\text{Fruit weight loss (\%)} = \frac{\text{Initial weight} - \text{final weight}}{\text{Initial weight}} \times 100$$

**Total soluble solids (<sup>o</sup>Brix):** Total Soluble Solids of the fruit was determined at 30 days intervals of 150 days storage accordingly. Total soluble solids (TSS) were measured with a hand refractometer (Kernco, Instruments Co. Texas).

**Reducing and non reducing sugars:** Total, reducing and non-reducing sugars were determined by titration method and acidity was determined by neutralization reaction as described in AOAC (1990). Ascorbic acid was determined by the standard method as reported in AOAC (1990).

**Fruit firmness (kg/cm<sup>2</sup>):** Data pertaining to fruit firmness was recorded with the help of penetrometer (Effigi, 11mm Prob.). For this purpose five fruits in each treatment were taken and penetration force was measured by gently inserting the prob into the equatorial region of the fruit. Fruit firmness reading was recorded and averaged for each fruit. The readings for all five fruit were averaged to represent the corresponding treatments (Pocharski *et al.*, 2000).

**Density of fruit (g/cm<sup>3</sup>):** Density of fruit for each treatment in each replication was calculated by water displacement method (Meisami *et al.*, 2009).

$$\text{Density of fruit} = \frac{M}{V}$$

Where, M is the mass of fruit and V is the volume of fruit.

**Bitter pit (%):** Percent bitter pit incidence was observed visually in each treatment by calculating the surface area of each fruit covered with the symptoms of bitter pit at time 0 and 30 days interval of cold storage.

**Soft rot (%):** Percent soft rot in each replication of treatments was examined visually and counted during 150 days storage and their disease percentage of fruits was calculated by formula as under.

$$\text{Percent disease incidence (\%)} = \frac{\text{Number of diseased fruits}}{\text{Total number of fruit}} \times 100$$

**Statistical Analysis:** The data were recorded and analyzed by using completely randomized design (CRD) with factorial arrangement having twenty four treatment combinations replicated three times and means were further assessed for differences through Least Significant Difference (LSD) test. Statistical computer software, MSTATC (Michigan State University, USA), was applied for computing both the ANOVA and LSD (Steel *et al.*, 1997).

## RESULTS AND DISCUSSION

**Weight loss (%):** The weight loss in fruit depends on the structure of the skin and nature of waxes on the surface of the fruit (Veraverbeke *et al.*, 2003). The moisture loss decreases the visual quality and contributes to the loss of turgor pressure and subsequent softening (Chien *et al.*, 2005). The maximum weight loss (2.91%) was recorded in cultivar Golden Delicious, followed by Royal Gala and Mondial Gala with 2.43 and 2.40% respectively, though the difference in these three cultivars was non significant. The minimum weight loss (2.22%) was recorded in Red delicious. The percent weight loss increased significantly with incremental increase in storage duration to 4.05 and 4.53% with 120 and 150 days respectively (Table I). The least weight loss in Red delicious may be due to thicker waxy layer, characteristics of this cultivar (Veraverbeke *et al.*, 2001). The moisture and subsequent weight loss in fruits increased linearly with increase in storage duration due to water loss and respiration (Ghafir *et al.*, 2009).

**Total soluble solids (%):** Total soluble solids of apple and other fruits is a major quality parameter which is correlated with the texture and composition (Kamiloglu, 2011). The total soluble solids of apples fruit increased gradually with increasing the storage durations. The maximum total soluble solids (13.08%) were recorded in fruits stored for 150 days as compared to 9.93% observed in fresh harvested fruits (Table I). Ali *et al.*, (2004) reported significant variations in TSS, acidity and other physico-chemical characteristics of apples harvested from different varieties but the different cultivars under study exhibited non significant variations in total soluble solids. The total soluble solids increased during storage (Rivera, 2005). The increase in TSS could be attributed to the breakdown of starch (Beaudry *et al.*, 1989) into sugars (Crouch, 2003) or the hydrolysis of cell wall polysaccharides (Ben and Gaweda, 1985).

**Total sugar (%):** A significant increase in total sugar was recorded with increasing the storage duration so that it increased from 9.58% in fresh fruits to 12.33% in fruit juice stored for 150 days. The differences in total sugar observed between fruit stored for 30 and 60 days as well as fruit stored for 90 and 120 days were non significant (Table I). 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). The increase in sugars during storage is therefore in line with the observation on loss of starch during the storage period.

**Titrateable acidity (%):** The titrateable acidity was the highest (0.55%) in cultivar Mondial gala, followed by Royal gala and Golden delicious with 0.54 and 0.51%.

The titratable acidity of apple juice decreased significantly with increasing storage duration so that it was the highest (0.67%) in fresh harvested fruits while the least (0.38%) in fruits stored for 150 days (Table I). Different cultivars of apple varied significantly in percent acidity with the maximum titratable acidity in cultivar Mondial gala followed by Royal gala and Golden delicious while the lowest titratable acidity was in Red delicious and it declined with the increase in storage duration in all the cultivars under study. The changes in titratable acidity are significantly affected by the rate of metabolism (Clarke *et al.*, 2003) especially respiration, which consumed organic acid and thus decline acidity during storage (Ghafir *et al.*, 2009).

**Ascorbic acid (mg/100g):** Ascorbic acid is usually considered as an index of nutrient quality in apple fruit. Ascorbic acid is a bioactive compound having antioxidant properties (Lata, 2007). The ascorbic acid of different apple cultivars varied significantly with the highest (13.12 mg/100g) in cultivar Red delicious, while it was the minimum (9.82 mg/100g) in cultivar Golden Delicious (Table II). The interaction effect of cultivars and storage duration was also significant. The maximum ascorbic acid (15.60 mg/100g) with 0 days storage in cultivar Red delicious declined while the minimum 7.22 mg/100g was observed with 150 days storage in cultivars Golden delicious. The percent decline in ascorbic acid different cultivars over 150 days was the highest 42.95% in cultivars Royal gala followed by Mondial gala and Golden delicious with 41.26 and 38.13% respectively (Figure I). While, cultivar Red delicious not only had the maximum ascorbic acid at 0 day storage, it was also characterized by relatively slow decline during storage (27.12%). The apple cultivars differ significantly in their ascorbic acid content (Nour *et al.*, 2010). Cultivar Red delicious had the highest Ascorbic acid followed by Royal gala and Mondial gala while it was the lowest in Golden delicious. The ascorbic acid decreased significantly with incremental increase in storage duration (Hayat *et al.*, 2003). The ascorbic acid in fruits is sensitive to storage temperature or duration and its degradation is enhanced by adverse handling and storage conditions such as higher temperatures, low relative humidity, physical damage, and chilling injury (Adisa, 1986). Beside abiotic factors, the ascorbic acid can be irreversibly oxidized (Pardio-Sedas *et al.*, 1994), which decreases the edible quality and increases susceptibility to different physiological disorders during storage (Jung and Watkins, 2008). Our findings that apple cultivars may vary not only in their initial ascorbic acid content but also the rate of decline during storage (Nour *et al.*, 2010).

**Firmness (kg/cm<sup>2</sup>):** Fruit firmness is an important criterion for edible quality and market value of apples (De-Ell *et al.*, 2001) and loss of fruit firmness is a serious problems resulting in quality losses (Kov *et al.*, 2005).

The fruit firmness was the highest (5.98 kg/cm<sup>2</sup>) in Red delicious while the least (5.15 kg/cm<sup>2</sup>) in Mondial gala followed by Royal gala and Golden delicious with 5.19 and 5.27 kg/cm<sup>2</sup> respectively. The fruit firmness significantly decreased with increase in storage duration. It decreased from the maximum of 6.59 kg/cm<sup>2</sup> for fresh fruits to the minimum of 4.04 kg/cm<sup>2</sup> for fruits stored for 150 days (Table II). The apple cultivars varied significantly in firmness with Red delicious having the maximum while Mondial gala had the minimum firmness. The firmness of the fruit depends on rate of evapo-transpiration, respiration rates, resulting in loss of solutes and water (Ghafir *et al.*, 2009). The optimum firmness and texture of apple fruit, is a major quality parameter (Peck *et al.*, 2006). The difference in firmness of different apple cultivars is due their pectin composition (Billy *et al.*, 2008) and significantly decreased with increasing storage duration (Table II) due to disassembly of primary cell wall and middle lamella structures (Cosgrove *et al.*, 1997) resulting in soft and mealy fruit (Gomez *et al.*, 1998).

**Density of Fruit (g/cm<sup>3</sup>):** The density of the fruit is a physical characteristic related to the dry matter (Jordan *et al.*, 2000), total sugars (Robert *et al.*, 2000), starch content and juice content (Zaltzman *et al.*, 1987). The maximum density of fruit (0.82 g/cm<sup>3</sup>) was recorded in Red delicious, followed by Golden delicious and Mondial gala with density of 0.80 and 0.78 g/cm<sup>3</sup> respectively, however, the interaction was non significant among these three cultivars. The minimum density of fruit (0.77 g/cm<sup>3</sup>) was recorded in Royal gala. A significant decrease in density of fruit was recorded with increase in storage duration. The density of fruit was decreased from a maximum of 0.82 g/cm<sup>3</sup> recorded in fresh harvested fruit to a minimum of 0.77 g/cm<sup>3</sup> observed after 150 days storage. Whereas, the effect of storage duration was non significant on density of fruits stored up to 120 days (Table II). The density of apple fruit is a function of air spaces and solutes dissolved in the cell sap (Bayindirli, 1993). The apple cultivars varied significantly in fruit density (Vincent, 1989) which could be due to differences in biochemical composition (Ghafir *et al.*, 2009) and moisture loss during storage (Rivera, 2005). Since the apple fruit lose considerable moisture during storage, its density tends to decrease during storage. Therefore, the density is high in fresh fruits and decline during storage (Sakiyama and Nakamura, 1976) due to collapse of intercellular spaces and loss of moisture (Mitropoulos and Lambrinos, 2000).

**Bitter pit (%):** Bitter pit is a physiological disorder, located mainly on the calyx end (Ferguson and Watkins, 1989). The apple cultivars varied significantly in bitter pit incidence. The maximum bitter pit incidence (11.86%) was recorded in Red delicious, followed by Golden delicious with 9.33% bitter pit incidence (Table II). The

bitter pit incidence increased significantly with increasing storage duration in all the cultivars under study. After 150 days storage, the bitter pit incidence was significantly lower in Royal Gala and Mondial gala with 10.51 and 11.57% respectively with the difference being non significant. The maximum bitter pit incidence of 29.63% was recorded in cultivar Red delicious (Figure II). The incidence of bitter pit depends on genetic factors (Crouch, 2003) as well as growth conditions and maturity at harvest (Crouch, 2003) or Ca concentration of the fruit (Pesis *et al.*, 2009) and other nutrition (Fallahi *et al.*, 1997). The incidence of bitter pit increases with increasing storage duration (Pesis *et al.*, 2009). While the symptoms of bitter pit were not visible immediately after harvest but 18.85% of the fruit showed its symptoms after 150 days storage. The lower bitter pit incidence in Royal gala and Mondial gala indicates the resistance of these cultivars to bitter pit incidence (Spotts *et al.*, 1999). However, the high Bitter pit incidence in Red delicious, despite high ascorbic acid, suggests that its incidence may not be related to ascorbic acid content of the fruit as suggested by Mattheis and Rudell, (2008).

**Soft rot (%):** Significant differences among apple cultivars have been observed for percent soft rot during storage. The minimum percent soft rot incidence (8.82%) observed in Mondial gala, followed by Royal gala and Golden delicious with 8.93 and 10.56% respectively. The soft rot of apple fruit increased with incremental increase in storage durations to the maximum of 24.98% after 150 days storage (Table II). The interaction of cultivars and storage duration showed significantly high soft rot incidence with increasing storage duration after 150 days

storage (30.50%) in cultivars Red delicious. The lowest soft rot incidence of 21.30% was observed in cultivar Royal gala with the same storage duration (Figure III). It is found that some cultivars are more susceptible to decay than the others. (Spotts *et al.*, 1999). While there was no soft rot incidence after harvest, significant differences among apple cultivars were observed after storage for 150 days with the highest soft rot in Red delicious (Table II). The increase in soft rot incidence with increasing storage duration varied significantly with cultivars. While cultivars Royal gala had the least soft rot incidence, cultivars Red delicious had the 30.16% higher soft rot incidence than Royal gala (Figure III). Since Royal Gala' is extremely resistant to wound pathogens (Spotts *et al.*, 1999), thus may have low soft rot incidence. Attempts have been made to correlate the loss of ascorbic acid with increased susceptibility to physiological disorders and pathogens in apple fruit during storage (Watkins *et al.*, 2003). It has been suggested that the development of physiological disorders in apple fruit during extended storage may be due to decreased antioxidant activities of different antioxidant compounds including ascorbic acid (Watkins *et al.*, 2003), yet no correlation is observed between ascorbic acid and the incidence of soft rot or bitter pit (Mattheis and Rudell, 2008). By contrast, Red delicious, having higher ascorbic acid at any storage interval (Figure 3) also high soft rot incidence. It suggests that soft rot incidence may not be correlated with ascorbic acid (Mattheis and Rudell, 2008) but rather the general senescence and subsequent susceptibility of the fruit to decay.

**Table I: The effect of storage duration on weight lost (%), percent juice (%), starch, TSS (<sup>0</sup>Brix), total sugar (%), titratable acidity (%) and pH of apple cultivars**

Cultivar	Weight loss (%)	TSS ( <sup>0</sup> Brix)	Total sugar (%)	Titratable acidity (%)
Royal Gala	2.43 ab	11.36	10.81	0.54 a
Mondial Gala	2.40 ab	11.64	10.93	0.55 a
Golden Delicious	2.91a	11.68	10.79	0.51 a
Red Delicious	2.22 b	12.03	10.98	0.48 b
LSD at $\alpha$ 0.05	0.43	NS	NS	0.05
<b>Storage Duration (days)</b>				
0	0.00 e	9.93 e	9.58 d	0.67 a
30	1.06 d	10.73 d	10.05 c	0.62 a
60	2.06 c	11.39 cd	10.75 c	0.57 b
90	3.25 b	12.25 bc	10.98 b	0.48 c
120	4.05 a	12.70 ab	11.60 b	0.42 d
150	4.53 a	13.08 a	12.33 a	0.38 e
LSD at $\alpha$ 0.05	0.43	0.69	0.60	0.05
<b>Interactions</b>				
C $\times$ S	NS	NS	NS	NS

Mean followed by similar letter(s) in column do not differ significantly from one another,

NS = Non Significant and \* = Significant at 5 % level of probability.

C  $\times$  S = Interaction of cultivar and storage duration

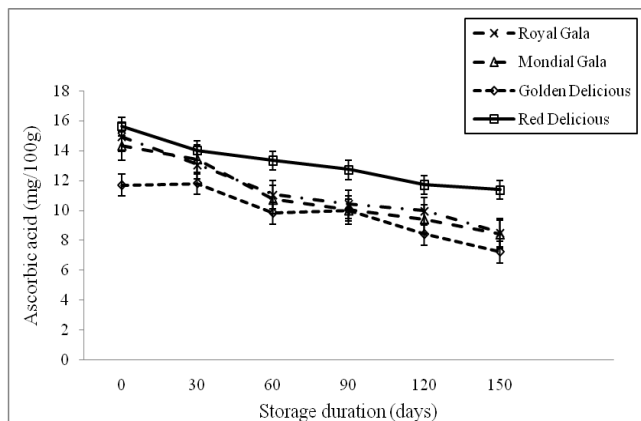
**Table II: The effect of storage duration on ascorbic acid (mg/100g), firmness (kg/cm<sup>2</sup>), density of fruit (g/cm<sup>3</sup>), soft rot (%) and bitter pit (%) of apple cultivars**

Cultivar	Ascorbic acid (mg/100g)	Firmness (kg/cm <sup>2</sup> )	Fruit Density (g/cm <sup>3</sup> )	Bitter Pit (%)	Soft Rot (%)
Royal Gala	11.30 b	5.19 b	0.77 b	5.02 c	8.93 bc
Mondial Gala	11.03 b	5.15 b	0.78 ab	5.90 c	8.82 c
Golden Delicious	9.82 c	5.27 b	0.80 ab	9.33 b	10.56 b
Red Delicious	13.12 a	5.98 a	0.82 a	11.86 a	13.53 a
LSD at $\alpha$ 0.05	0.70	0.25	0.05	1.01	1.17
Storage Duration (days)					
0	14.12 a	6.59 a	0.82 a	0.00 f	0.00 f
30	13.06 b	6.31 b	0.81ab	2.06 e	3.20 e
60	11.06 c	5.78 c	0.80 ab	5.45 d	6.45 d
90	10.53 cd	5.18 d	0.78 ab	8.23 c	11.63 c
120	10.27 d	4.50 e	0.78 ab	13.58 b	16.50 b
150	8.87 e	4.04 f	0.77 b	18.85 a	24.98 a
LSD at $\alpha$ 0.05	0.67	0.25	0.05	1.00	1.68
Interactions					
C $\times$ S	*Fig. 1	NS	NS	* Fig. 2	* Fig. 3

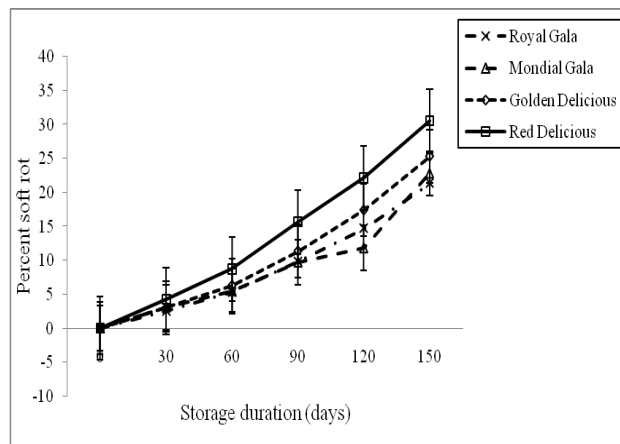
Mean followed by similar letter(s) in column do not differ significantly from one another,

NS = Non Significant and \* = Significant at 5 % level of probability.

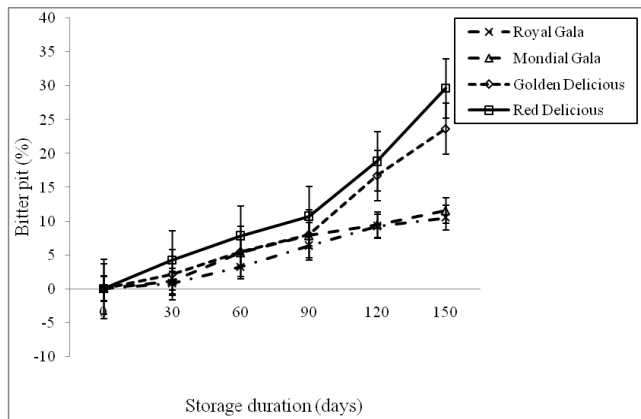
C  $\times$  S = Interaction of cultivar and storage duration.



**Fig. I. Effect of storage duration on ascorbic acid (mg/100g) of apple cultivars**



**Fig. III. Effect of storage duration on soft rot incidence (%) of apple cultivars**



**Fig. II. The influence of storage duration on bitter pit incidence (%) of apple cultivars**

**Conclusions:** Apple cultivar Red delicious due to its high juice content, TSS/Acid ratio, ascorbic acid, fruit firmness and density and the least weight loss during storage can be recommended for refrigerated storage for 150 days with out serious losses of physico-chemical quality attributes. Cultivar Mondial with the least soft rot incidence and cultivar Royal gala with the lowest incidence of bitter are recommended for long term storage despite relatively low quality attributes.

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