RESPONSE OF APPLE CULTIVARS TO DIFFERENT STORAGE DURATIONS

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ABSTRACT

The experiment was carried out to evaluate the performance of different apple cultivars during storage at Department of Horticulture, Agricultural University, Peshawar, Pakistan during 2007-08. The fruit of apple cultivars: Royal Gala, Mondial Gala, Golden Delicious and Red Delicious were harvested at commercial maturity and stored at 5±1°C with 60-70 % relative humidity. Physico-chemical changes in fruit were determined at 30 days interval during storage. Apple cultivar Red Delicious had the highest TSS/Acid ratio (23.12), fruit firmness (5.98 kg/cm^2) and the least weight loss (2.22 %). Starch score was the maximum (5.22) in cultivar Golden Delicious. The percent weight loss, total soluble solids, pH and TSS/Acid ratio increased with increase in storage duration while starch score and firmness of fruit declined with increase in storage duration.

Key Words: **Apple, firmness, weight loss, pH, storage performance, cultivars.**

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INTRODUCTION

Apple (*Pyrus domestica* L.) is one of the most important tree fruit of the world. Due to its high nutritional value, it ranks third in consumption after citrus and banana (Bokhari, 2002). In Pakistan its cultivation is limited and restricted to the northern hilly tracks of Punjab and Khyber Pakhtunkhwa, and the Quetta region of Balochistan. In Khyber Pakhtunkhwa, the apple plantation is distributed in Swat, Dir, Mansehra, Parachinar, Chitral, Hunza, North and South Waziristan Agencies. District Swat, with an area of approximately 4000 square miles with in the Malakand Division, is the most important of all the apple producing districts of Khyber Pakhtunkhwa followed by the districts of Mansehra, Dir, Abbottabad, Chitral and Hunza (Bokhari, 2002; Ali *et al.,* 2004). The apple gives better yield in relatively long, cool and slow growing season, the type of climate which usually prevails at altitudes of 1700-2500 m. The apple cultivars grown in Pakistan may vary considerably in physico-chemical characteristics such as titratable acidity, soluble solids, firmness, ethylene production and weight loss in cold storage (Golias *et al.,* 2008) which may in turn influence the texture and storage performance of apple cultivars (Perring, 1989; Hoehn *et al.,* 2003). Apple fruit is stored in cold storages due to its high demand throughout the year. It is estimated that about 17% of apples produced in Balochistan are lost during postharvest operations (Shah *et al.,* 2002). In Pakistan, apples kept under the conditions of cold storage for 22 weeks losses were found to be 28 percent (Ilyas *et al.,* 2007). The problem is further 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. Among the external conditions, temperature and relative humidity during postharvest handling operations are the most important factors influencing the storage performance of apple (LeBlanc *et al.,* 1996), which affect the fruit firmness, juice content, weight loss, pH, soluble solids content (SSC), and other quality parameters (Tu *et al.,* 2000). The internal factors may vary due to differences in fruit physiology and anatomy. Saleh *et al.* (2009) reported that fruits of apple cultivars Golden Delicious, Starking Delicious, Star Cremson and Gala stored at 85-90% relative humidity and 0ºC for 0 to 180 days exhibited significant differences in physiological and anatomical parameters. The differences in storage performance may be due to ethylene production, responsible for the changes in texture and firmness and fruit softening (Stow *et al.,* 2000; Johnston *et al.,* 2001; Nilsson and Gustavsson, 2007). Water loss may also vary significantly among apple cultivars resulting in significantly different weight loss even under similar storage conditions (Khan and Ahmad, 2005). The physical properties of apple fruit may also have significant influence on storage performance of apple because it influences water loss, gas exchange and subsequent storage life (Meisami *et al.,* 2009). Fruit density has also been used as maturity index in many fruits and vegetables such as apricots, strawberries, tomato, pea, etc (Wolfe *et al.,* 1974; Zaltzman *et al.,* 1987). According to Zaltzman *et al.* (1987), the fruit density is also related to the content of juice and dry matter (Jordan *et al.,* 2000) and may indicate the maturity as well as quality changes in fruit during storage (Mitropoulos and Lambrinos, 2000). The present experiment was, therefore, conducted to evaluate the performance of different apple cultivars during storage.

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 during 2007-08. The unhealthy, diseased and bruised fruits were discarded while fruits of uniform size were selected through visual observation 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^{o}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 brought to Postharvest Laboratory, Department of Horticulture, Agricultural University, Peshawar, Pakistan for physico-chemical studies. The data were recorded and statistically analysed for the following post harvest quality parameters at 30 days intervals.

Starch Content

Starch content was calculated at 30 days intervals of 150 days storage with the help of starch-iodine test. Iodine solution was prepared by dissolving 6 g of KI in 400 ml of water, and then added 1 g of I_2. Slices of fruit dipped into iodine solution for 1 minute. Then the slices removed from the solution and let stand for 2 minutes. Each slice washed quickly in water and estimated the percentage of starch. Starch showed up as dark blue area and white areas represented sugar. The starch content was calculated according to Generic chart scores (1-8), where 1 represents the least and 8 the highest starch scores.

Fruit pH

The fruit pH of all treatments in each replication during storage at 30 days interval was determined with the help of electronic pH meter.

Total Soluble Solids (%)

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).

Percent Acidity

Acidity was determined by neutralization reaction (AOAC, 1990).

TSS/Acid Ratio

The total soluble solids and acid ratio was calculated with the help of following formula.

$$\text{TSS/Acid} = \frac{\text{Total soluble solids}}{\text{Titratable acidity}}$$

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:

$$\text{Weight loss (\%)} = \frac{\text{Weight of fresh fruits} - \text{Weight after interval}}{\text{Weight of fresh fruits}} \times 100$$

Fruit Firmness (kg/cm^2)

Data pertaining to fruit firmness was recorded with the help of penetrometer (Effigi, 11mm Prob.) for five fruits per treatment (Pocharski, *et al.*, 2000).

Statistical Analysis

The data was analyzed by using completely randomized design (CRD) with factorial arrangement having twenty (four treatment four cultivars and six intervals) combinations repeated 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

Loss of Starch Content (Score)

The starch content varied significantly among cultivars with the maximum starch content score (5.22) recorded in Golden Delicious, that was statistically at par with Red Delicious and Royal Gala. Mondial Gala, however, had significantly lower starch content score of 4.58. The loss of starch content significantly increased with incremental increase in storage duration. The maximum mean starch score (7.05) recorded in fresh fruit, decreased with increase in storage duration to the minimum score (2.54) at the end of 150 days Table I. The starch content of apple fruit depends mainly on the cultivars which may show significant variation (Ghafir *et al*., 2009). The storage durations significantly affected the starch content of apple. Since starch is the major storage carbohydrates in apple fruit (Beaudry *et al*., 1989), it is converted to sugars at the onset of ripening and during storage to meet the respiratory demand of the fruit (Crouch, 2003).

Table I ***The effect of storage duration on starch (scores), pH, TSS (%), TSS/Acid ratio, weight lost (%) and fruit firmness (kg/cm^2) of apple cultivars***

Cultivar	Starch (Scores)	pH	TSS (%)	Percent Acidity	TSS/Acid ratio	Weight loss (%)	Firmness (kg/cm^2)
Royal Gala	4.86 ab	3.80	11.36	0.54 a	22.18 b	2.43 ab	5.19 b
Mondial Gala	4.58 b	3.75	11.64	0.55 a	22.95 b	2.40 ab	5.15 b
Golden Delicious	5.22 a	3.92	11.68	0.51 a	24.38 ab	2.91a	5.27 b
Red Delicious	4.94 ab	3.79	12.03	0.48 b	26.81 a	2.22 b	5.98 a
LSD at α 0.05	0.51	NS	NS	0.05	2.71	0.43	0.25
Storage Duration (days)							
0	7.05 a	3.52 b	9.93 e	0.67 a	15.00 e	0.00 e	6.59 a
30	6.22 b	3.58 b	10.73 d	0.62 a	17.57 e	1.06 d	6.31 b
60	5.68 c	3.70 b	11.39 cd	0.57 b	20.28 d	2.06 c	5.78 c
90	4.74 d	3.78 b	12.25 bc	0.48 c	25.78 c	3.25 b	5.18 d
120	3.18 e	4.09 a	12.70 ab	0.42 d	30.91 b	4.05 a	4.50 e
150	2.54 f	4.23 a	13.08 a	0.38 e	34.95 a	4.53 a	4.04 f
LSD at α 0.05	0.67	0.34	0.69	0.05	2.68	0.43	0.25
Interactions				**Significance Level**			
C × S	NS	NS	NS	NS	NS	NS	NS

Mean followed by similar letter(s) in column do not differ significantly
NS = Non Significant and * = Significant at 5 % level of probability.
C × S = Interaction of cultivar and storage duration.

Fruit pH

A gradual increase in pH recorded with increase in storage duration. The maximum pH (4.23) observed for fruits stored for 150 days while minimum pH (3.52) recorded for fresh harvested fruits. The effect of storage duration on pH of apple fruits was non significant for fruits stored up to 90 days and was also non significant for fruits stored between 120 and 150 days. The changes in titratable acidity are significantly affected by the rate of metabolism (Clarke *et al*., 2001) especially respiration which consumed organic acid and thus decline acidity (Rivera, 2005; Ghafir *et al*., 2009). While there was a non-significant difference in pH among apple cultivars however, the pH declined gradually with increasing storage durations. The pH of the fruit depends mainly on organic acid in the fruit, which are consumed in respiration, resulting lower acidity and high pH with increasing storage duration (Khalid, 1974; Chang *et al*., 1999; Rivera, 2005; 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 (Weibel *et al*., 2004; Peck *et al*., 2006). 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. 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 (Mahajan, 1994; 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).

Titratable Acidity (%)

The titratable acidity was the highest (0.55 %) in cultivar Mondial Gala, followed by Royal Gala and Golden Delicious with 0.54 and 0.51 %. The difference in titratable acidity in these three cultivars was, however, non significant but Red Delicious had the least titratable acidity (0.48 %). 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*., 2001) especially respiration, which consumed organic acid and thus decline acidity (Rivera, 2005; Ghafir *et al*., 2009).

TSS/Acid Ratio

Total soluble solids of apple and other fruits is a major quality parameter (Weibel *et al*., 2004; Peck *et al*., 2006). The maximum TSS/Acid ratio (26.81) recorded in Red Delicious followed by Golden Delicious with 24.38. The minimum TSS/Acid ratio (22.18) recorded in Royal Gala, followed by Mondial Gala with 22.95, however these two cultivars at par with each other. Storage duration had a significant effect on TSS/Acid ratio of apple juice. The TSS/Acid ratio gradually increased with the increase in storage duration. The TSS/Acid ratio increased from 15.00 in freshly harvested fruit to 34.95 in apple fruit stored for 150 days. Apple cultivars have been shown to have significant differences in TSS and acidity (Ali *et al*., 2004). The TSS/Acid ratio was significantly different among apple cultivars. Cultivar Red Delicious had the highest TSS/Acid ratio followed by Golden Delicious and Royal Gala while Mondial Gala had the lowest TSS/Acid ratio. The TSS/Acid ratio in all cultivars increased with increasing storage duration. The increase in TSS/Acid ratio can be attributed to starch breakdown resulting in free sugars (Beaudry *et al*., 1989) and decline in organic acids due to its consumption in respiration (Mahajan, 1994; Rivera, 2005; Ghafir *et al*., 2009).

Weight Loss (%)

The weight loss in fruit depends on the structure of the skin and nature of waxes on the surface of the fruit (Babos *et al*., 1984; Veravrbeke *et al*., 2003). The moisture loss decreases the visual quality and contributes to the loss of turgor pressure and subsequent softening (Vander-Beng, 1981). 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 so that it increased to 4.05 and 4.53 % with 120 and 150 days respectively. 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 (Erturk, 2003; Gavlheiro *et al*., 2003; Ghafir *et al*., 2009).

Firmness (kg/cm^2)

Fruit firmness is an important criteria for edible quality and market value of apples (Stow *et al*., 2000; 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^2) in Red Delicious while the least (5.15 kg/cm^2) in Mondial Gala followed by Royal Gala and Golden Delicious with 5.19 and 5.27 kg/cm^2 respectively. The fruit firmness significantly decreased with increase in storage duration It decreased from the maximum of 6.59 kg/cm^2 for fresh fruits to the minimum of 4.04 kg/cm^2 for fruits stored for 150 days Table 1. 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 (Gavlheiro *et al*., 2003; Erturk, 2003; Ghafir *et al*., 2009). The optimum firmness and texture of apple fruit, is a major quality parameter (Weibel *et al*., 2004; Peck *et al*., 2006). The difference in firmness of different apple cultivars may be their pectin composition (Billy *et al*., 2008), who reported that Golden Delicious softened easily during storage as compared to 'Fuji' apples. We observed cultivar Golden Delicious had more firmness as compared to Royal Gala, Mondial Gala but was inferior than Red Delicious. The firmness of the apple fruit significantly decreased with increasing storage duration Table I. The firmness of the apple fruit is due to texture of the flesh and textural changes of fruits during ripening due to disassembly of primary cell wall and middle lamella structures (Jackman and Stanley, 1995; Cosgrove *et al*., 1997) and results in soft and mealy fruit that is less desired by consumers (Gomez, *et al*., 1998). The post harvest softening of apple fruit is believed to be related to cell wall breakdown (Fuller, 2008)

due to enzymatic activities (Yamaki and Matsuda, 1977) and pectin solubalization (Bartley *et al*., 1982; Jackman and Stanley, 1995; Chang-Hai *et al*., 2006), reducing the mechanical strength of cell walls which decrease the firmness in apple fruits (Kov and Felf, 2003; Kov *et al*., 2005).

CONCLUSION AND RECOMMENDATIONS

Apple cultivar Red Delicious due to its high TSS/Acid ratio, fruit firmness 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.

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