International Journal of Advanced Research in Biological Sciences
ISSN: 2348-8069
www.ijarbs.com
DOI: 10.22192/ijarbs Coden: IJARQG(USA) Volume 4, Issue 7 - 2017

Research Article

DOI: http://dx.doi.org/10.22192/ijarbs.2017.04.07.019

Postharvest quality of apple (*Malus domestica Borkh*) as influenced by storage conditions

Babar Khan[1], Syed Zulfiqar Ali[2], Sikander Shahzad[3], Muhammad Basharat[4], Jaffar Ali[5*], Zobia Jabeen[2], Mohammad Waris[2] and Shagufta Fahmid[6]

[1]Department of Food Technology, Balochistan Agriculture College, Quetta, Pakistan
[2]Department of Plant Pathology, Balochistan Agriculture College, Quetta, Pakistan
[3]Department of Computer Science, Balochistan Agriculture College, Quetta, Pakistan
[4]Office of Agriculture Extension (Plant Protection), Jaffarabad, Balochistsn, Pakistan
[5]Office of Agriculture Extension (Plant Protection), Barkhan, Balochistan, Pakistan
[6]Department of Chemistry, Sardar Bahadur Khan Women's University, Quetta, Pakistan
*Corresponding author: *jaffaraj2010@yahoo.com*

Abstract

A laboratory study was carried out during 2016 to assess the effect of storage conditions on the fruit quality of apple. The apples were passed through all the procedures needed for storage and designated as groups A (Refrigeration=7^{o}C), B (Cold storage=16^{o}C) and C (Room temperature=25-28^{0}C). The processed apples were determined for various quality characters at various storage periods which include pH, Total Soluble Solids (TSS), ash, vitamin-C, acidity, moisture, colour, specific gravity etc. The pH of stored apples increased at refrigeration temperatures of 7^{0}C (4.53) and decreased at cold storage temperature of 16^{0}C (4.20). The extending storage periods resulted in increase in pH from 0 to 14 days. The highest mean TTS (16.10%), ash content (0.34%), vitamin C (6.24%) and acidity (0.29%) was observed under the cold storage temperature of 16^{0}C. However, the refrigeration temperature of 7^{0}C and cold storage temperature of 16^{0}C exhibited statistically similar results for moisture content (83.94; 83.33%), colour (8.11; 8.11) and specific gravity (0.62; 0.62). The extending storage periods reduced the mean TTS (15.68 to 13.85%) ash content (0.35 to 0.30%), moisture content (85.03 to 74.00%), specific gravity (0.64 to 0.57) and colour (8.22 to 5.33) from 0 to 14 days. The results indicated that the postharvest storage response of apples in relation to storage temperatures and storage periods varied in different physico-chemical properties of the fruit. However, the cold storage temperature of 16^{o}C was found an appropriate postharvest storage temperature followed by refrigeration temperature of 7^{o}C, because under room temperature, the physico-chemical and apparently microbiological changes started occurring after one week of storage and fruit quality did not remain useable.

Keywords: Apple, postharvest quality, storage temperature, storage duration

Introduction

Apple (*Malus demestica Borkh*) is a member of sub family Pomoideae in Rosaceae family and world's 80% supply comes from Europe (Beers *et al*., 2005). Apple is highly nutritious, aromatic and delicious fruit, rich in Vitamin C, B and A as well as contains about 11% sugar besides appreciable amounts of essential minerals. It has colour appeal, appetite and is the most refreshing. Apples are an alkaline food because they

contain pectin. They are also an eliminative food as Pectin from apples takes in excess water in the intestines, making a soft bulk that creates a mild, non-irritating stimulant (Sabir *et al*., 2004). Balochistan is the key contributor of apple production in Pakistan while Khyber Pakhtunkhwa (KPK) stands on second number contributing 25% to total national apple production. After Balochistan and KPK, Punjab province also contributes to apple production as its upper part (Potohar and Muree) produce apples. Azad Kashmir is also a renowned place of apple growth and Kashmir's apple is used as term because of its taste (Syed, 2013).

The apple varieties have varied nutritional qualities and studies show that Amri contains 12.68% vitamin C, Golden Delicious 9.70%, Mashhadi 9.10% and Kalakulu 8.70% (Crouch, 2003). The acidity of apples varies during storage and varieties of apple vary significantly ($P<0.05$) for this characteristics (Tahir & Ericsson, 2003). Higher levels of vitamin C, total sugars, TSS and acidity in Amri apple and six weeks storage without quality deterioration has been reported by Ali *et al.* (2004). Amri apple suffers higher weight loss (19.2%) and less by Kalakulu (16.3%) at room temperature storage (Khan & Ahmad, 2005). Golab Kohanz & Shafi Abadi apple varieties possesses 86 and 84% moisture, no variation in fruit pH (Chakespari *et al*., 2010). Olufunmilola & Oladapo (2011) reported that moisture content in apple may be 53.5% in peel to 86.3% in pulp; lower titratable acidity (1.2%) and higher sugar (5.4 Brix).

Major apple harvest comes during August/September and in these months entire fruit market reflects apple centred trade. However, apple growers do not fetch proper price during this period of two months due to overabundance of apple in the market (Asif, 2002). For achieving good apple price, its storage conditions to be improved to maintain the edible quality for a longer time, so that the fruit is marketed according to the consumption (Widayat *et al*., 2003). This fruit has great potential to be consumed for a longer duration when kept under proper storage temperatures (Asif, 2002).

The storage conditions are the key factors to influence the postharvest quality of apple. Despite diverse production and marketing related issues, the growers achieve a phenomenal profit that eventually encouraged the growers to increase fruit production (Biolatto *et al*., 2005). The weight of fruit is lost during storage gradually; and with the weight loss, the fruit colour and other nutritional quality traits are simultaneously influenced (Lee & Kader, 2000). Storage temperature is the major factor that influences the weight loss and other quality characteristics of apple. The flesh firmness of storage Golden Delicious apples decreases when stored at 5-10^{o}C or 20^{o}C (Neves, 1984). However, the weight loss is mainly associated with temperature, relative humidity and evaporation (Montgomery, 1997; Molnar, 1995; Scalzo *et al*., 2003; Dixon *et al*., 2004 and Luning & Marcelis, 2006). The studies carried out in the past (Marcilla *et al*., 2006; Wandel & Bugget, 1997; Vashishtha, 1998) have reported that temperature and storage duration affect the vitamin C content of fruit considerably (Kadzere *et al*., 2006). The storage temperature and duration have linear association in relation to changes quality and shelf life of fruits (Lee & Kader, 2000). Under low storage temperature chilling injury could be a risk and fruit storage life may be reduced (Tembo *et al*., 2008).

Materials and Methods

The apple samples (Golden Delicious variety) were collected from local market of Hyderabad and brought to the laboratory of Institute of Food Sciences and Technology, Faculty of Crop Production, Sindh Agriculture University (SAU), Tandojam, Pakistan. The proper arrangements were made for storage of fruits. The fruits were initially washed with fresh water and left in the laboratory to evaporate the external surface moisture on the sample fruits. After the fruits were ready for further process, these were packed in small paper boxes (cartons). Each carton packing contains 10 apples with labels of different treatments consisted of different storage conditions (temperature) and storage durations. The following methods/procedures were employed for determination of apples:

Colour

The fruit samples in different treatments were evaluated organoleptically for color by three semi-trained judges using Hedonick scale as described by Land & Shapherd (1988).

Vitamin-C

Vitamin-C was determined using phenol indophenol dye method (AOAC, 2000). 10g fresh samples were blended with metaphosphoric acetic acid extracting solution to homogenous slurry. 5ml of the filtrate extract were then titrated with standard indophenol to pink end point.

Specific gravity

Specific gravity was determined by water displaced method as described by Mazumdar & Majumder (2003). Apple fruit were washed with distilled water, dried and weighed one by one. Measuring cylinder with a capacity of 1000ml was taken and filled with 500ml of distilled water. Apple fruits were dipped in measuring cylinder. The volume of water displaced was noted. The specific gravity was determined by the following formula:

$$\text{Specific gravity} = \frac{\text{Weight of apple fruit}}{\text{Volume of water displaced}}$$

Moisture (%)

The moisture content of apple fruit was determined according to the method of AOAC (2000). An empty flat-bottomed aluminium dish was sterilized and weighed. The sample (5g) was placed in the pre-weighed dish and placed in an oven at 70°C. The dish was removed after 3 hours and cooled in desiccator for 1 hour and weighed. The moisture content was calculated by using the following formula:

$$\text{Moisture (\%)} = \frac{\text{Wt of fresh sample - Wt of dried sample}}{\text{Wt of fresh sample taken}} \times 100$$

pH

pH of the apples was determined by using pH meter (Hana Instrument, HI8417, Italy).

Total Soluble Solids (%)

TSS were determined using Atago RX 1000 digital refractometer. A drop of juice was extracted and placed on clean prism of Refractometer and the lid was closed. Reading was taken directly from the scale at room temperature.

Ash (%)

Ash percentage was determined by gravimetric method as described by AOAC (2000) using muffle furnace.

Acidity (%)

Acidity (malic acid mg/5g fr.wt) was determined according to the method of Association of official Analytical chemists (AOAC, 2000) with slight modification. Apple juice diluted with distilled water (25ml) and titrated with 0.1 N NaOH solution using titration kit, where phenolphthalein (3-5 drops) was used an indicator. The volume of alkali used was noted, and calculation was made using following formula:

$$\text{Titratable acidity (malic acid mg/5g fr.wt)} = \frac{d \times 0.006 \text{ (If NaoH solution is 0.1N)}}{a \times b \times c}$$

Where

a= Weight of sample, b= volume of aliquot taken for examination, c= Volume made with distilled water, d= Average burette reading for sample.

The collected data were statistically analysed. The analysis of variance was worked out to ascertain the significance level of the differences, while Duncan's Multiple Range Test (DMRT) was employed to compare the treatment groups as per the methods suggested by Gomez and Gomez (1984).

Results

Colour

The colour of the apples stored at different temperatures assessed by a panel of judges using 10 points hedonic scale varied significantly ($P<0.05$) for storage temperatures as well as by storage duration. The colour of apples kept under refrigeration temperature (7°C) and cold storage temperature (16°C) was rated at equally 8.11 score out of 10, while the colour rating for apples kept under room temperature (control) came to zero after 14 days of storage and average score was 4.55 marks out of a total 10. The results further indicated that storage of apples under room temperature (control) resulted in spoiling of the fruits and hence the judges disliked the appearance of the fruits when determined after 14 days of storage and the colour rating for apples stored under refrigeration temperature (7°C) and cold storage temperature (16°C) were non-significant However, extending storage of apples resulted in a lower ranking of these fruits for colour; ($P>0.05$) and was in the range of 8 to 8.66 out of 10, indicating that the quality of fruits remained good under cold storage and refrigeration temperatures (**Table 1**). The coefficient of variation (11.24%) indicates some heterogeneity in the sample fruits for this character.

Table 1: Colour of apple as affected by different postharvest storage temperatures

Storage Temperatures	Storage period			Mean	Statistical analysis			
	0 days	7 days	14 days		Factor	T	P	T×P
T1= Refrigeration Temp (7°C)	8.00 a	8.33 a	8.00 a	8.11 a	S.E.	0.2596	0.2596	0.4496
T2=Cold storage Temp (16°C)	8.00 a	8.33 a	8.00 a	8.11 a	LSD 0.05	1.355	1.438	1.304
T3=Room Temp (25-28°C)	8.66 a	5.00 b	0.00 c	4.55 b	LSD 0.01	1.873	2.066	1.761
Mean	8.22 a	7.22 a	5.33 b		CV%	11.24		

T=Storage Temperature, P=Storage Period

Vitamin-C (%)

The vitamin-C in apple fruits stored apples differed significantly (P<0.05) due to storage temperatures and storage duration (**Table 2**). The vitamin-C in apples kept under cold storage temperature (16°C) was markedly higher (6.24%) as compared to 4.68 and 4.27% obtained under refrigeration temperature (7°C) and room temperature (control), respectively. It is further evident from the data that vit-C content of the stored apples was relatively higher (5.41%) when analysed after 7 days of storage and it was significantly (P>0.05) decreased to 5.10 and 4.68% before storage and after 14 days of storage, respectively. The results showed that storage of apples under room temperature (control) and refrigeration temperature (7°C) resulted in decreased vitamin-C content, while storing apples at cold storage temperature (16°C) maintained the vitamin-C level positively. Similarly, the prolonged storage resulted in decreased vitamin-C in stored apples. The LSD test suggested that differences in vitamin-C of apples stored under refrigeration temperature (7°C) and room temperature (control) were non-significant (P>0.05), while significant when these treatments were compared with apples kept under cold storage temperature (16°C). The coefficient of variation (5.29%) indicates that the apple samples used for determination for vitamin-C were homogenous.

Table 2: Vitamin-C (%) of apple as affected by different postharvest storage temperatures

Storage Temperatures	Storage period			Mean	Statistical analysis			
	0 days	7 days	14 days		Factor	T	P	T×P
T1= Refrigeration Temp (7°C)	4.06 d	5.66 b	4.32 d	4.68 b	S.E.	0.0893	0.0893	0.1547
T2=Cold storage Temp (16°C)	6.36 a	6.42 a	5.94 b	6.24 a	LSD 0.05	0.4670	0.495	0.4495
T3=Room Temp (25-28°C)	4.89 c	4.17 d	3.77 e	4.27 b	LSD 0.01	0.6456	0.712	0.6070
Mean	5.10 a	5.41 a	4.68 b		CV%	5.29		

T=Storage Temperature, P=Storage Period

Specific gravity

The specific gravity of stored apple fruits (**Table 3**) varied significantly (P<0.05) due to storage temperatures as well as by storage periods. The specific gravity in apples kept under refrigeration temperature (7°C) and cold storage temperature (16°C) was higher i.e. 0.62 and 0.62, respectively as compared to 0.58 in apples kept under room managed to keep specific gravity within normal values. Similarly, the extending storage resulted in a temperature (control). The specific gravity of stored apples was markedly higher (0.64) when determined before storage, while the specific gravity relatively decreased to 0.61 and 0.57 when determined after 7 and 14 days of storage, respectively. The results further showed that storage of apples under room temperature (control) resulted in decreased specific gravity, while storing apples at cold storage temperature (16°C) and refrigeration temperature (7°C) decrease in the specific gravity after 7 days and 14 days of storage. The LSD test suggested that

differences in specific gravity of apples stored under refrigeration temperature (7°C) and cold storage temperature (16°C) were non-significant (P>0.05), while significant when these treatments were compared with apples kept under room temperature (control). The coefficient of variation (3.63%) indicates that the fruits used as samples in the study were homogenous for this parameter.

Table 3: Specific gravity of apple as affected by different postharvest storage temperatures

Storage Temperatures	Storage period			Mean	Statistical analysis			
	0 days	7 days	14 days		Factor	T	P	T×P
T1= Refrigeration Temp (7°C)	0.64 a	0.62 b	0.61 b	0.62 a	S.E.	0.0074	0.0074	0.0128
T2=Cold storage Temp (16°C)	0.64 a	0.62 b	0.59 c	0.62 a	LSD 0.05	0.0174	0.0184	0.0167
T3=Room Temp (25-28°C)	0.64 a	0.58 c	0.51 d	0.58 b	LSD 0.01	0.0240	0.0265	0.0226
Mean	0.64 a	0.61 b	0.57 c		CV%	3.63		

T=Storage Temperature, P=Storage Period

Moisture (%)

The stored apples subjected to moisture determination indicated significant variation (P<0.05) due to different storage temperatures and storage duration. The highest moisture (**Table 4**) was observed in apples kept under refrigeration temperature of 7°C (83.94) followed by cold storage temperature of 16°C (83.33). These results are statistically similar with each other. However, the lowest moisture percent was observed in apples stored under room temperature (73.27). The moisture content of stored apples was markedly higher (85.03%) when determined before storage, while it reduced to 81.51 and 74.00% when analysed after 7 and 14 days of storage, respectively. The storage of apples under room temperature (control) resulted in decreased moisture content, while storing apples at cold storage temperature (16°C) and refrigeration temperature (7°C) maintained the normal moisture content. Similarly, the extending storage resulted in a decrease in the moisture after 7 days and 14 days of storage. The LSD test suggested that differences in moisture of apples stored under refrigeration temperature (7°C) and cold storage temperature (16°C) were non-significant (P>0.05), while significant when these treatments were compared with apples kept under room temperature (control). The coefficient of variation (1.79%) suggesting that the fruits used as samples in the study were homogenous for this character.

Table 4: Moisture (%) of apple as affected by different postharvest storage temperatures

Storage Temperatures	Storage period			Mean	Statistical analysis			
	0 days	7 days	14 days		Factor	T	P	T×P
T1= Refrigeration Temp (7°C)	86.04 a	85.22 a	80.56 b	83.94 a	S.E.	0.478	0.478	0.8279
T2=Cold storage Temp (16°C)	85.06 a	82.51 b	82.42 b	83.33 a	LSD 0.05	2.495	2.648	2.402
T3=Room Temp (25-28°C)	83.99 a	76.80 c	59.02 d	73.27 b	LSD 0.01	3.450	3.805	3.244
Mean	85.03 a	81.51 b	74.00 c		CV%	1.79		

T=Storage Temperature, P=Storage Period

pH

The pH of apples stored at different temperatures differed significantly (P<0.05) due to temperatures and storage periods (**Table 5**). The pH of apples stored under refrigeration temperature (7°C) and Room temperature (25-28°C) was higher i.e. 4.53 and 4.42, respectively; while the lowest pH of 4.20 was

observed under cold storage temperature of 16^{0}C. The effect of storage period indicated that the pH was relatively higher 4.48 and 4.47 when stored apples were determined after 7 and 14 days of storage, while the lowest fruit pH of 4.21 observed before storage. It was observed that fruit pH increased with the prolonged storage period of apples, while reduced temperature (refrigeration 7^{o}C) caused increase in pH, and cold storage temperature (16^{o}C) resulted in decreased fruit pH. This indicates that stored apples under cold storage conditions (16^{o}C) is better to maintain fruit pH. The differences in fruit pH kept under refrigeration temperature (7^{o}C) and Room temperature (control) were non-significant (P>0.05); and similarly after 7 and 14 days of storage, the fruit pH was almost similar.

Table 5: pH of apple as affected by different postharvest storage temperatures

Storage Temperatures	Storage period			Mean	Statistical analysis			
	0 days	7 days	14 days		Factor	T	P	T×P
T1= Refrigeration Temp (7^{o}C)	4.17 c	4.78 a	4.65 b	4.53 a	S.E.	0.0236	0.0236	0.0409
T2=Cold storage Temp (16^{o}C)	4.27 c	4.14 c	4.20 c	4.20 b	LSD 0.05	0.1231	0.1306	0.1185
T3=Room Temp (25-28^{o}C)	4.19 c	4.52 b	4.55 b	4.42 a	LSD 0.01	0.1701	0.1876	0.1600
Mean	4.21 b	4.48 a	4.47 a	-	CV%	1.61		

T=Storage Temperature, P=Storage Period

Total soluble solids (%)

The TSS of storage apples varied significantly (P<0.05) due to temperatures and storage duration (**Table 6**). Total soluble solids of apples stored under cold storage temperature of 16^{o}C were higher (16.10%) as compared to 14.21 and 14.09% obtained under room temperature (control) and refrigeration temperature (7^{o}C), respectively. The TSS were markedly higher (15.68%) when apples were analysed before storage, while the TSS content in stored apples was significantly (P>0.05) reduced to 14.87 and 13.85 when observed after 7 and 14 days of storage, respectively. The results suggested that storage of apples under room temperature (control) or refrigeration temperature (7^{o}C) resulted in decreased TSS content, while storing apples at cold storage temperature (16^{o}C) affected the TSS content positively. Similarly, storage period showed negative effect on TSS content and prolonging storage period resulted in a considerable decrease in TSS content. The LSD test showed that differences in TSS of apples stored under room temperature (control) and refrigeration temperature (7^{o}C) were non-significant (P>0.05), while significant when these treatments were compared with cold storage of apples.

Table 6: Total soluble solids (%) of apple as affected by different postharvest storage temperatures

Storage Temperatures	Storage period			Mean	Statistical analysis			
	0 days	7 days	14 days		Factor	T	P	T×P
T1= Refrigeration Temp (7^{o}C)	14.85 d	13.42 f	14.00 e	14.09 b	S.E.	0.0821	0.0821	0.1422
T2=Cold storage Temp (16^{o}C)	16.32 a	16.43 a	15.54 c	16.10 a	LSD 0.05	0.4298	0.4562	0.4138
T3=Room Temp (25-28^{o}C)	15.88 b	14.74 d	12.01 g	14.21 b	LSD 0.01	0.5942	0.6554	0.5587
Mean	15.68 a	14.87 b	13.85 c		CV%	1.66		

T=Storage Temperature, P=Storage Period

Ash content (%)

The ash content in storage apples differed significantly (P<0.05) due to temperatures and storage periods (**Table 7**). The ash content of apples kept under cold storage temperature (16^{o}C) were higher (0.34%) and statistically similar with the results obtained under refrigeration temperature of 7^{0}C (0.33%). However these results are non-significant with the results obtained under room temperature (control). The ash content in stored apples was relatively higher (0.35%) when determined before storage, while the ash content in apples was significantly (P>0.05) decreased to 0.32 and 0.30 percent when determined after 7 and 14 days

of storage, respectively. The storage of apples under room temperature (control) resulted in decreased ash content, while storing apples at cold storage temperature (16°C) or refrigeration temperature (7°C) maintained the ash content level positively. Similarly, the prolonged storage resulted in decreased ash content in stored apples. The LSD test showed that differences in ash content of apples stored under refrigeration temperature (7°C) and cold storage temperature (16°C) were non-significant (P>0.05), while significant when these treatments were compared with apples kept under room temperature (control). The coefficient of variation (6.23%) suggested that the sample apples examined for ash content were homogenous.

Table 7: Ash content (%) of apple as affected by different postharvest storage temperatures

Storage Temperatures	Storage period			Mean	Statistical analysis			
	0 days	7 days	14 days		Factor	T	P	T×P
T1= Refrigeration Temp (7°C)	0.33 b	0.34 b	0.32 c	0.33 a	S.E.	0.0068	0.0068	0.0117
T2=Cold storage Temp (16°C)	0.37 a	0.34 b	0.30 d	0.34 a	LSD 0.05	0.0174	0.0184	0.0167
T3=Room Temp (25-28°C)	0.33 b	0.28 e	0.28 e	0.30 b	LSD 0.01	0.0240	0.0265	0.0226
Mean	0.35 a	0.32 b	0.30 c		CV%	6.23		

T=Storage Temperature, P=Storage Period

Acidity (%)

The acidity of apples stored at different temperatures varied significantly (P<0.05) due to storage temperatures and storage duration (**Table 8**). The highest acidity (0.29%) was recorded under the cold storage temperature of 16°C followed by refrigeration temperature of 7°C (0.26%) and room temperature (0.24%). However there was no effect of storage period on the acidity of the apples when kept under cold storage temperature of 16°C. The highest acidity (0.29%) of apples was recorded after 7 days of storage, while the lowest and similar results obtained before storage (0.25%) and after 14 days of storage (0.25%) of the apples. The apples kept under room temperature (control) resulted in decreased acidity level, while storing apples at cold storage temperature (16°C) increased the acidity content of the apples. Similarly, the extending storage resulted in a slight increase in acidity after 7 days of storage, but reduced after 14 days of storage. The LSD test suggested that differences in acidity of apples stored under refrigeration temperature (7°C) and cold storage temperature (16°C) were non-significant (P>0.05).

Table 8: Acidity (%) of apple as affected by different storage temperatures

Storage Temperatures	Storage period			Mean	Statistical analysis			
	0 days	7 days	14 days		Factor	T	P	T×P
T1= Refrigeration Temp (7°C)	0.24 b	0.28 a	0.25 b	0.26 a	S.E.	0.0092	0.0092	0.0159
T2=Cold storage Temp (16°C)	0.28 a	0.30 a	0.28 a	0.29 a	LSD 0.05	0.0550	0.0401	0.0529
T3=Room Temp (25-28°C)	0.23 b	0.27 a	0.22 b	0.24 b	LSD 0.01	0.0760	0.0639	0.0715
Mean	0.25 b	0.29 a	0.25 b		CV%	10.36		

T=Storage Temperature, P=Storage Period

Discussion

Pakistan is rich in resources related to agricultural production and demand of fruits and vegetables produced in Pakistan has increased which has developed a better chance to export the surplus produces and earn precious foreign exchange for the nation. Postharvest quality of apple is mainly associated with the storage conditions. According to Biolatto *et al*. (2005) despite multifarious problems, the apple growers obtain a phenomenal profit which leads to ultimate efforts for increasing the fruit production. There is a gradual weight loss in different varieties of apple during storage. Fruit colour changes appreciably without refrigeration and when regular determination is made for the weight, dry matter, sugar, soluble acid and ascorbic acid contents, flavour and aroma of apple, weight loss during storage

condition were highest in Golden Delicious and lowest in Red Delicious (Lee & Kader, 2000). Vitamin C decreased during storage, maximum decrease in acidity lead us to the conclusion that it can be stored up to six weeks after maturity to fetch good market price and may be stored up to six weeks without deteriorating its internal fruit quality. According to Neves, (1984), decrease in flesh firmness during storage of delicious apples at 5-10^{o}C or 20^{o}C has also been reported; while Scalzo *et al*. (2003) reported that weight loss in different varieties of apple depends upon post harvest temperature. The present study was carried out to examine the effect of postharvest storage temperatures on the physico-chemical properties and shelf life of apple.

The fruit pH was increased with the prolonged storage period of apples, while reduced temperature caused increase in pH, and cold storage temperature decreased fruit pH. This indicates that apple storage under cold storage temperature 16^{o}C is better to maintain the fruit pH. Johnston *et al*. (2005) suggested blow 20°C storage temperature for maintaining the postharvest quality of apples. The storage of apples under room temperature or refrigeration temperature decreased total soluble solids, while storing apples at cold storage temperature total soluble solids improved. These results are in line with those of Banks *et al*. (1997) examined the effect of storage temperatures on apple and stored at 5^{o}C or 10^{o}C. Clarke *et al*. (2001) who found that total soluble solids of apples did not differ significantly when stored under temperature range of 4 or -18^{o}C. The storage of apples under room temperature resulted in decreased ash content, while at cold storage temperature or refrigeration temperature maintained the ash content level positively. Storage of apple under room temperature decreased Vitamin-C content and apples kept at cold storage temperature maintained the Vitamin-C level positively. Crouch (2003) reported that highest amount of vitamin C contents were found under cold storage temperature. Similarly, Ali *et al*. (2004) evaluated the effect of storage at room temperature (25^{o}C) on apple and found non-significant decrease in acidity and significant increase in vitamin-C and total soluble solids during storage. The acidity under room temperature decreased while storing apples at cold storage temperature increased the acidity level slightly. Tahir and Ericsson (2003) reported marked difference in acidity of apples after storage. The moisture content under room temperature decreased, while apples stored at cold storage and refrigeration temperatures maintained the normal moisture content. The fruit weight under room temperature affected adversely, while storing apples at cold storage and refrigeration temperatures maintained the normal weight of single fruit. The dry matter content of apples under room temperature decreased, and storing apples at cold storage and refrigeration temperatures maintained the normal dry matter contents. The specific gravity of stored apples decreased under room temperature but at cold storage and refrigeration temperatures specific gravity within normal values.

The storage of apples under room temperature spoiled the fruits and could not get any ranking; this all happened because of apples under room temperature, and the colour rating for apples stored under refrigeration and cold storage temperatures were in the range of 8 to 8.66 out of 10, indicating that the quality of fruits remained good under cold storage and refrigeration temperatures. These results are further confirmed by numerous past workers and many studies on the effect of storage temperature on quality and storage life of fruits have been done which shows temperature plays an important role on quality of fruits after harvest (Tembo *et al*., 2008). Temperature management is one of the most important tools for extending the shelf life of fruits (Lee & Kader, 2000), because it regulates the rate of all associated physiological and biochemical process.

Lower temperatures may cause chilling injury and higher ones can reduce the storage life of the product. Sabir *et al.* (2004) found color of apple fruit, weight loss percentage, TTS, pH, acidity, total sugar, reducing sugar and Vitamin-C after 15, 30, 45 and 60 days of storage and reported significant changes in these properties during storage periods. Tembo *et al*. (2008) reported 10 days shelf life when stored under 20°C±1 and at 55-60% relative humidity. Aiken & White (2007) reported that the coated apples during cold storage at 0°C, 90-95% RH showed a significant delay in the change of weight loss, firmness, titratable acidity, total soluble solids, decay and color compared to uncoated ones. Khorshidi *et al.* (2010) stored apples under 0, 5 and 12°C and found that storage with 0°C fruit length, diameter, weight, volume, firmness, total titrable acids, total soluble solids, elements of sodium and potassium, marketable quality and color surface could maintain better product quality.

Conclusion

In-depth study showed that postharvest storage response of apple in relation to storage temperature and storage period varied in different physic-chemical properties of the fruit. However, the cold storage

temperature (16°C) was found to be most appropriate post harvest storage condition for apple, followed by refrigeration temperature of 7°C, because under room temperature, the physico-chemical and apparently microbiological changes started occurring after one week of storage and fruit quality did not remain useable.

Suggestions

It is suggested that the appsle after harvest may be storage under the cold storage temperature of 16°C to maintain fruit physico-chemical properties and can be used for a longer time.

References

Aiken, E. A. and L. White. 2007. Changes in chemical wax composition of three different apple (Malus domestica Borkh.) cultivars during storage. Postharvest Biol. & Technol. 23: 197-208.

Ali, M. A., H. Raza, M. A. Khan and M. Hussain. 2004. Effect of Different Periods of Ambient Storage on Chemical Composition of Apple Fruit. International Journal of Agriculture & Biology, 6(3): 568-571.

Asif, A., 2002. Apple the sweet gold of Pakistan. Export Promotion Bureau of Pakistan.

Association of Official Analytical Chemists (AOAC), 2000. Official Methods of Analysis, 17th ed. AOAC International, Gaithersburg, MD.

Banks, N. H., J. G. M. Cutting and S. E. Nicholson. 1997. Approaches to optimising surface coatings for fruits. New Zealand journal of crop and horticultural science 25: 261-272.

Beers, E. H., P. D. Himmel, and R. Talley. 2005. Woolly apple aphid control, 2005. Arthropod Manag. Tests 27: Report A5.

Biolatto A., D. E. Vazquez, A. M. Sancho, F. J. Carduza and N. A. Pensel. 2005. Effect of commercial conditioning and cold quarantine storage treatments on fruit of 'Rouge La Toma' grapefruit (*Citrus paradise* Macf.). Postharvest Biol Technol. 35: 167-176.

Lee S. K. and A. A. Kader. 2000. Preharvest and postharvest factors influencing Vitamin C content of horticultural crops. Postharvest Biol. Technol., 20: 207-220.

Luning, P. A., and W. J. Marcelis. 2006. A techno-managerial approach in food quality management research. Trends in Food Science and Technology, 7: 378-385.

Marcilla A., M. Zarzo and M. A. Delrio. 2006. Effect of storage temperature on the flavour of citrus fruit.

Chakespari, A. G., A. Rajabipour and H. Mobli. 2010. Post Harvest Physical and Nutritional Properties of Two Apple Varieties. Journal of Agricultural Science 2(3): 61-68.

Clarke, C. J., V. A. McGlone and R. B. Jordan. 2003. Detection of brownheart in 'Braeburn' apple by transmission NIR spectroscopy. Postharvest Biol. Technol., 28: 87-96.

Crouch, I. 2003. Methylcyclopropene (Smart fresh TM) as an alternative to modified atmosphere and controlled atmosphere storage of apples and pears. Acta Hort. 600: 433-436.

Dixon J., D. B. Smith and T. A. Elmsly. 2004. Fruit age, storage temperature and maturity effects on Hass Avocado fruit quality and ripening. New Zealand Avocado Growers Association Annual Research Report. 4: 47-53.

Gomez, Z. K. and A. A Gomez. 1984. Statistical procedures for Agricultural Research, 2nd edn. (John Wiley and sons, New York..

Johnston, J. W., K. Gunaseelan, P. Pikakala, M. Wang and R. J. Schaffer. 2005. Coordination of early and late ripening events in apples is regulated through differential sensitivities to ethylene. J. Exp. Bot., 60: 2689-2699.

Kadzere, I., C. B. Watkins, I. A. Merwin, F. K. Akinnifesi, J. D. K. Saka and J. Mhango. 2006. Fruit Variability and Relationship between Color at Harvest and Subsequent Soluble Solids Concentrations and Color Development during Storage of Uapaca kirkiana from Natural Woodlands. Hort. Science, 41(2): 352-356.

Khan, M. A. and I. Ahmad. 2005. Morphological studies on physical changes in apple fruit after storage at room temperature. J. Agri. and Social Sciences. 1(2): 102-104.

Khorshidi, G. M., P. K. Andrews, J. P. Reganold and J. K. Fellman. 2010. Apple orchard productivity and fruit quality under organic, conventional and integrated management. Hort. Sci., 41: 99-107.

Land, D. G. and R. Shepherd. 1988. Scaling and Ranking Methods. In: Pigott J. R. (ed.), 1988. Sensory Analysis of Foods. Elsevier Applied Science, London and New York, pp. 169-171.

Spanish Journal of Agricultural Research. 4(4): 336-344.

Mazumdar, B. C. and K. Majumder. 2003. Methods on physico-chemical analysis of fruits. Delhi: Daya Publishing House.

Molnar, P. J. 1995. A Model for overall Description of Food Quality. Food Quality and Preference. 6, 185-190.

Montgomery, D. G. 1997. Introduction to Statistical Quality Control, 3rd edition, Wiley, New York 1997.

Neves, F. L., 1984. Reduction of loss in weight during the cold storage of apples. *Hort. Absts*., 55: 6643.

Olufunmilola, A. A. and A. S. Oladapo. 2011. "Physico-chemical properties of African star apple (*Chrysophylum albidum*) components", Nutrition and Food Science, 41(1): 8-11.

Sabir, S. M., S. Z. A. Shah and A. Afzal. 2004. Effect of Chemical Treatment, Wax Coating, Oil Dipping and Different Wrapping Materials on Physio-chemical Characteristics and Storage Behavior of Apple (*Malus domestica* Borkh). Pakistan Journal of Nutrition 3(2): 122-127.

Scalzo, R. L., D. Lupi, G, Giudetti and A. Testoni. 2003. Evolution of volatile composition of whole apple fruit cv. 'Gala' after storage. *Acta Hort. (ISHS*) 600: 555-62.

Syed,, M. A. 2013. Morphological Studies on Physical Changes in Apple Fruit after Storage at Room Temperature. Journal of Agriculture and Social Sciences, 1(2): 102-104.

Tahir, I. I. and N. A. Ericsson, 2003. Effect of postharvest heating and ca–storage on storability and quality of apple cv. 'Aroma'. Acta Hort., 600: 410–5.

Tembo L., Z. A. Chiteka, I. Kadzere, F. Akinnifesi and F. Tagwira. 2008. Storage temperature affects fruit quality attributes of Ber (*Ziziphus mauritiana* Lamk.) in Zimbabwe. African Journal of Biotechnology, 7(8): 3092-3099.

Vashishtha, B. B. 1998. Jujube or Ber. cultivation in Africa. Paper presented at an international workshop on Ziziphus Mauritania, Harare, Zimbabwe. 13-16, July.

Wandel, M. and A. Bugget. 1997. Environmental concern in consumer evaluation of food quality. Food Quality and Preference, 8(1): 19-26.

Widayat, H. P., M. Schreiner, S. Huyskens and P. Ludders. 2003. Effect of ripening stage and storage temperature on postharvest quality of pepino (*Solanum muricatum* Ait.). Food, Agriculture & Environment, 1(1): 35-41.

Access this Article in Online	
	Website: www.ijarbs.com
Quick Response Code	Subject: Agricultural Sciences
DOI:10.22192/ijarbs.2017.04.07.019	

How to cite this article:
Babar Khan, Syed Zulfiqar Ali, Sikander Shahzad, Muhammad Basharat, Jaffar Ali, Zobia Jabeen, Mohammad Waris and Shagufta Fahmid. (2017). Postharvest quality of apple (*Malus domestica Borkh*) as influenced by storage conditions. Int. J. Adv. Res. Biol. Sci. 4(7): 154-163.
DOI: http://dx.doi.org/10.22192/ijarbs.2017.04.07.019