*J. Agric. Food. Tech.*, 7(7)1-6, 2017

ISSN 2090 – 424X
**Journal of Agriculture and Food Technology**
*www.textroad.com*



# Effects of Storage Durations on the Biochemical Quality of Apple *(Malus domestica)* Cultivars

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## ABSTRACT

The main objective of the present research was to study the influence of storage duration on the starch, reducing sugar, vitamin C and phenol contents of apple cultivars stored in underground pit using a wooden box as storage material. The study aimed to develop low cost infrastructures for post-harvest storage of the fruit as it needs low investment and easy to operate. Apple cultivars Crispin, Jonagold, Jonagored, Red delicious and BR were harvested at optimum maturity and stored for 0, 30, 60 and 90 days in underground pit with somehow lower temperature created in a storage facility. The experiment was laid out in a Completely Randomized Design (CRD) and each treatment replicated three times. The biochemical changes in fresh fruit samples were analyzed and determined at 30 days intervals during storage. The study revealed that the cultivar Crispin had the highest starch (6.22 mg/100g) and vitamin C (17.30 mg/100g) contents. Red delicious had the highest reducing sugar (13.14mg/g) contents but the lowest in starch (4.5 mg/100g) and phenol (10.3 mg/g) contents. In this study, the highest phenol (13.2mg/g) and the lowest starch (4.5mg/100g) contents were observed in fresh fruit sample of BR cultivar. The cultivar Jonagold had the lowest vitamin C (14mg/100g) contents. Contents of starch, reducing sugar, phenol and vitamin C decreased significantly at the end of 90 day after storage. These results indicate that the apple cultivar Crispin had good quality attributes, whereas the cultivar Jonagold and red delicious were easily rotted in the underground storage facility in the study.

**KEY WORDS:** Apple, bio-chemical changes, storage duration, underground pit, wooden box

## INTRODUCTION

Temperate fruits are widely adapted and produced in Ethiopian highlands of the different regions; even though the country is not in the temperate zone for apples, other temperate fruits are grown at suitable climate by virtue of high altitude. Chencha District (Woreda) in the Gamo Gofa administrative zone of the southern region of Ethiopia. More than 100 apple varieties are found in the study area and the area is conducive to cultivate this varieties and serving as a resource base for the rest of the country. Current apple fruit production in Chencha is about 15 metric tons per year while the overall country production is estimated to be about 50 metric tons. There is therefore an unmet market demand for the Chencha apple [12]. The yearly per head income of some farmers in the Chencha Woreda has risen up to 100,000–300,000 birr from poem sales only [4]. Thus, producing and marketing of quality fruits would increase the income of farmers.

Apple production is impacting the livelihood of Chencha community in a better way, for its higher yield on small plot of land and relatively higher marketing price. Nowadays, it is the major source of household income. Moreover, the high demand for apples has made its production an interesting business for rural dwellers. The type of apple cultivars, stage of maturity at picking, handling before storage, how soon they are cooled down, the temperature and humidity of the storage area are factors which would affects the duration of the fruit in the storage [22]. Vitamins, minerals, electrolytes, antioxidants and fiber are produced from apple fruit and juices and which are extensively used_as health foods [25]. However, lack of storage systems were one of the major constraints in apple production and marketing in Chencha area. Thus, storage is required to catch good market price and ensure its supply during the off-season [7]. Investigating or developing low cost infrastructures for post harvest storage of the fruit is very important in developing countries like Ethiopia, since it needs low investment and easy to operate. This research was also intended towards such effort using underground pit storage facility using the advantage of somehow low temperature created inside it.

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Despite the knowledge gaps and less skillfulness in apple production, there is ample amount of fruit production in the research area without storage facilities to balance the demand and supply. Fruits are sold at farm gate price by producers and through different actors in the market chain reaches consumers at local and distance markets. The complete harvest and sell at a time creates a higher supply and lower demand in the market which results in lower fruit price lower income to producers. This research intends to investigate the storability of healthy fruits from major cultivars grown in the area at somehow lower temperature created in underground storage facility. The more storable fruits with longer duration will meet high demand periods in the market and can yield better income from the fruit sale to the producer. Therefore the research investigated the effect of different storage durations on the bio-chemical quality of major apple cultivars that was stored in underground pit storage using a wooden box as storage material. The changes in starch, reducing sugar, vitamin 'C' and phenol contents in fresh fruit sample were assessed and documented.

## MATERIALS AND METHODS

### Description of the Study Area

The research was conducted at Gamo Highlands, Southern Ethiopia in Chencha Woreda at Girecha kebele 7Km far from the Woreda. Apple has become a very valuable crop of the area and is highly cultivated over large hectares. Chencha Woreda is located in the Gamo Gofa administrative zone of the SNNPR of Ethiopia with an altitude ranging between 1600-3200MASL. It has two agro-ecological zones: 'dega' (2300-3200MASL, 82%) and 'woinadega' (1500-2300MASL, 18%); with total area of 37,650ha.The mean annual temperature and rainfall of the study areas are 22.5ºC and 810-1600mm/annum respectively. More than 100 apple varieties are found in the study area [12], but the major apple variety under cultivation were used for the study grown in the Woreda.

### Sampling Size and Treatments

Apple cultivars Crispin, BR, Red Delicious, Jonagored and Jonagold under cultivation in farmers' field were used for the study. The fruit was harvested from six representative kebeles of the Woreda from 10 apple producing farmers. Thirty kg of fruit from each cultivar were collected and replicated three times (10Kg/box) and stored in the prepared underground cold room using a wooden storage box (Figure 1). Three fruit samples from each replication were drawn at each end of 0, 30, 60, and 90 days of storage period for the measurement of physicochemical properties of the fruit and its correlation with different fruit quality parameters. Freshly harvested mature fruits not infected and/or mechanically damaged apple, from each variety were collected from selected farmers' farm and sorted at the same maturity level. Healthy and sound fruits were stored in underground storage using a wooden box as storage material in the study area by measuring the temperature difference inside at 0, 30, 60 and 90 end of storage period. The underground cold storage was prepared at Girecha kebele 7Km far from Chencha Woreda. Three samples in each treatment replication were separated for the bio-chemical test.

### The Underground pit

The underground was prepared by dug soil from the ground with 4mx4m width and height respectively. House was constructed above the underground with length, width and height of 6mx4.5mx6m respectively. The house in all sides above the underground was constructed from bamboo wood and air allowed circulating inside underground pit through bamboo wall of the house. Inside the underground all sides were tightly covered by wood. The above part of the underground pit was covered tightly from wood and then sealed by grass and soil. The above ground made leveled. The temperature inside in underground storage was measured with help of hygrometer and the reading was taken from the sheet once per week and the average computed for each storage period (0, 30, 60 and 90). The hygrometer was first calibrated for the reading of temperature inside in prepared underground storage.

**Figure 1:** The house constructed above underground pit and wooden box used inside the storage to hold fruits

**Determination of the bio-chemical characteristics of the fruit**

The fruit bio-chemical analysis was carried out at Arbaminch University Organic Chemistry Laboratory. Preparation of samples and crude extract were carried out followed the method Awolu et al (2013) [1].

Determination reducing sugar and starch content: Reducing sugar content of the apple was determined by dinitrosalicylic acid (DNS) method (Miller, 1959) cited in Masud et al (2014) [20]. The starch content of the apple flesh was determined by the anthrone method as followed Jayaraman (1981) cited in Masud et al (2014) [20].

Determination phenolic and Vitamin 'C' content: The vitamin 'C' content was determined by iodine titration [14]. The total phenol content was determined followed the methods of Ferreira et al (2007) [10]

Data analysis: The data were analyzed by using SAS (version 9.2) statistical package for factorial completely randomized design (CRD) ANOVA and each treatment replicated three times. Significantly different means were separated through Least Significant Difference (LSD) test at 5%.

## RESULTS AND DISCUSSIONS

**Starch Content**

Significant variations were observed in starch content in apple fresh fruit sample for storage durations, cultivars and storage durations cultivar interaction in the study. The highest (6.22 mg/100g) starch was measured for the cultivar Crispin but least (4.5 mg/100g) in BR. The study revealed that the starch content was highest (6.25 mg/100g) and least (4.63 mg/100g) at 60 and 90 days of storage durations respectively. During the present study the starch content in fresh fruit sample was decreased insignificantly from 0 to 30 and significantly from 60 to 90 days of storage duration respectively (Table 1). The starch content of apple fruit depends mainly on the cultivars which may show significant variation [11]. The insignificant decrease from 0 - 30 and significant decrease from 60 - 90 days of storage durations respectively was evident that starch is the major storage carbohydrates in apple fruit [2], it is converted to sugars at the onset of ripening and during storage to meet the respiratory demand of the fruit [6]. Similarly, [17] reported the loss of starch content significantly increased with incremental increase in storage duration. The apple fruit accumulate starch at the early stages of maturation that is later on hydrolyzed to sugars at edible maturity [19]. On the contrary, the significant increase in starch content with the increased in storage duration from 30 to 60 days probably related with the variation in temperature and relative humidity made in the underground pit storage facility and genetic factors.

**Reducing Sugar**

The storage durations significantly affected the reducing sugar content of the fruit sample. The reducing sugar content the apple fruit not depends on cultivars and didn't show significant variation. It was highest (13.8mg/g) and least (11.31mg/g) at 60 and 90 days of storage durations respectively (Table 1). Significant variation was observed in reducing sugar contents in cultivars storage durations interaction. The cultivar Red delicious (13.14mg/g) had the highest reducing sugar content followed by BR, Crispin, Jonagold and Jonagored respectively (Table 1). In the study highest (14.23mg/g) and the least (10.34mg/g) amount of reducing sugar per fresh fruit sample were recorded at 60 and 90 days of storage durations for the cultivar Crispin and BR respectively (Table 1). The increased reducing sugar contents from 30 to 60 days of storage is likely due to the conversion of starch to sugars during storage resulting increase in reducing sugars with storage duration. Since the starch content decline during storage (Table 1), it is likely to observe increased TSS, predominantly sugars [6]. This finding reported that the storage

duration at 60 days was optimum for the accumulation of reducing sugar of the fruit and extended duration of storage would resulted decrease in the amount of reducing sugar of the fruit under the storage durations. The increased reducing sugar at 60 days of storage duration may in part be due to the loss of moisture during storage since the variation in temperature in the underground storage resulting in higher concentration of sugars per unit volume of water [26]. In line with this findings [7] reported that the conversion of starch to sugars continued during storage and hence the total and reducing sugars content were increased with storage duration.

**Phenolic Content**

Apples have been identified as one of the main dietary sources of antioxidants, mainly phenolic compounds [3]. In this study no significant variations were observed in phenol content for cultivars, storage durations and for storage duration cultivar interaction. The phenol content was highest (13.24mg/g) and least (9.56mg/g) at 60 and 90 days of storage durations respectively (Table 1). The study revealed that the phenol content was insignificant at 0 to 30 days of storage durations and significantly increased at 60 days of storage durations. It was decreased significantly at 90 days of storage durations. The study showed cultivar BR and Red delicious had the highest (13.2 mg/g) and the least (10.3 mg/g) amount phenol in apple fresh fruit sample respectively (Table 1). The significant variation made in phenol content in the study was probably in line with [13] who have reported the phenolic content vary among different apple cultivars, within different tissues of the fruit, growing conditions, cultural practices, ripeness during harvest, post-harvest storage conditions, and processing [15]. The insignificant variation in phenol content at 0 and 30 days of storage in the study probably in agreement with [3] who reported storage has little to no effect on apple phytochemicals. In line with [24] reported during storage the concentration of phenol was kept almost constant and the amount of phenolic compounds in fresh apples may be affected by variety, crop type and environmental conditions. There are also small changes in phytochemicals during the maturation and ripening of the fruit. This investigation also reported that the temperature variation made inside the underground pit storage would be also account for the increased or decreased in phenol amount.

**Table 1:** The effect of storage durations on starch, reducing sugar, vitamin 'C' and phenol contents of apple cultivars.

| Cultivars | Starch (mg/100g) | Reducing Sugar (mg/g) | Vitamin C (mg/100mL) | Phenol (mg/g) |
|---|---|---|---|---|
| Jonagold | 5.3c | 12.92a | 14a | 11.4b |
| Jonagored | 5.6b | 12.9a | 17.4a | 11.5b |
| Crispin | 6.22a | 13a | 17.3a | 10.9b |
| Red delicious | 5.4bc | 13.14a | 16a | 10.3b |
| BR | 4.5d | 13.05a | 15a | 13.2a |
| **LSD at α 0.05** | * | NS | NS | NS |
| **Storage Duration** | | | | |
| 0 | 5.38b | 13.6ab | 15a | 11.6b |
| 30 | 5.28b | 13.3b | 16a | 11.5b |
| 60 | 6.25a | 13.8a | 18a | 13.24a |
| 90 | 4.63c | 11.3c | 14a | 9.56c |
| **LSD at α 0.05** | * | * | NS | NS |
| **R-square** | 0.96 | 0.94 | 0.30 | 0.88 |
| **Interaction** | | **Significance Level** | | |
| **V×SD** | * | * | NS | NS |

Mean followed by similar letter(s) in column do not differ significantly from one another,
Significant at 5 % level of probability
*=Significant at 5 % level of probability
NS=Not significant
$R^2$=Coefficient of determination
V×SD=interaction of variety and storage duration

**Vitamin 'C' Content**

Ascorbic acid is a bioactive compound usually considered as an index of nutrient quality in apple fruit [16]. The study revealed that no significant variations were observed for the storage durations, cultivar and storage duration cultivar interaction in vitamin 'C' content. The highest (18 mg/100ml) and the least (14 mg/100ml) vitamin 'C' content was observed at 60 and 90 days of storage durations respectively and it was increased insignificantly with increased in storage durations from 0 up to 60 days of storage period (Table 1). The cultivar Jonagored had the highest (17.36mg/100gm) vitamin 'C' content with minimum difference with Crispin (17.30mg/100gm) followed by Red delicious (15.72mg/100gm), BR (14.8mg/100gm) and least (14.4mg/100g) amount was observed in Jonagold (Table 1). On the contrary to this finding [16] reported interaction effect of variety and storage duration was significant on ascorbic acid content. The lowest vitamin 'C' content measured at 90 days of storage period probably in line with [9] who reported the decrease in vitamin C content of as the ripening days progressed. [23] revealed that apple cultivars differ significantly in their ascorbic acid content. In the previous findings [8] reported Ascorbic acid content gradually declined over six months in cold storage for 'Golden Delicious', 'Delicious', and 'Fuji' apples. [17] reported harvesting stages also significantly affected the ascorbic acid content of apple fruit. Ascorbic acid was the lowest in fruits harvested at early maturity stage. The variations in vitamin 'C' content that we have observed in the study probably due to as reported by [5] most apples are consumed after several months in cold storage, the postharvest metabolism of ascorbate is at least as important as its values at harvest, environmental, cultural, and genetic factors all affect the total concentration of Vitamin 'C' in an apple.

## CONCLUSION AND RECOMMENDATION

The storage system developed in the study influences the bio-chemical characteristics of apple cultivars. Farmers could store their fruits up to 3 - 4 months under similar conditions not to sell their fruits at throw away prices during peak harvest seasons. Underground pit storage of the fruit could be a promising strategy in the study area with minimum installation cost. However, the presence of high ground water at depth beyond 4m in the study area was a bottleneck therefore the depth of underground storage should be between 3m - 3.5m. Further research should focus on improving the storage conditions like applying a good ventilation system and cementing of the underground storage in all sides to promote the storage of the fruit via cooling the storage area. Applying waxing and additional treatments is also recommended to evaluate for better storage durations and maintenance of fruit quality attributes. Fruit rot/decay, increased temperature and high underground water were some of the observed factors that hinder the storage duration of the fruit in the underground pit storage. Thus, the causes for fruit rot/decay in the underground storage should be studied and screened.

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