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Effects of Storage Durations on the Biochemical Quality of Potato (*Solanum tuberosum* L.) Varieties Cultivated at Chenchaworeda, Gircha Highland Fruits and Vegetables Research Center, SNNPR, Ethiopia

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Abstract

Potato (*Solanum Tuberosum* L.) is considered to be one of the strategic crops for ensuring food security in Ethiopia. Unavailability of improved storage facilities in Ethiopia is one of among major limiting factors to potato productivity. Therefore, the main objective of this research were to study the effect of storage duration on the biochemical properties of major potato varieties cultivated in the study area stored under modified dark room storage for 0, 30, 60 and 90 days. The biochemical characteristics were assessed at each 30 days end of storage. The study revealed that starch highest and least starch content was obtained for Jalegne (46.43%) and Degemign (44.95%) varieties respectively followed by Belete, the local “Sussallho”, and Gudagne. The highest (47.68%) and the least (33.96%) amount of starch were recorded at 0 and 90 days of storage periods. The study revealed that starch content was decreased significantly with increasing storage period. The highest and the least vitamin C was obtained for Degemign (45.32 mg/100gm) and Gudagne (35.06 mg/100gm) varieties respectively. The highest (1.26 Mg/gm) the least (0.90 Mg/gm) amount of reducing sugar content was measured prior to storage and at 90 days of storage periods respectively. In this study Jalegne (3.04%) and Gudagne (0.69%) had the highest and least amount crude protein content whereas total carbohydrate content was highest (86.44%) and least (62.04%) prior to storage and at 90 days of storage periods respectively. Therefore, the study showed that farmers can store their tubers in same way as possible in the warehouse used in this study. Further research should focus on improving the potato warehouse ventilation, airtightness, light interference as well as temperature and relative humidity control mechanism.

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Keywords

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Introduction

Potato is considered to be one of the strategic crops for ensuring food security in Ethiopia (Mulatu *et al.*, 2005). In Ethiopia, potato has increasingly become a source of cash income for farmers, and retains its importance for household consumption and the government well on the way to support and facilitate the emerging private sector

in this key issue of profitable agriculture (Mulatu *et al.*, 2005; Haar, 2012). As in all horticultural produce, the quality of potato tubers is closely linked to the tuber specific gravity, dry matter, starch to reducing sugar ratio, amylose%, minerals and vitamin C and varies widely in relation to different factors such as climate, growing conditions, variety, maturity at harvest and harvesting methods (Bentini *et al.*, 2006). Dry matter is

an important aspect of tuber quality and is affected by a wide range of factors, including most importantly, environmental factors during growth of the crop and development of the tuber, variety and storage conditions (Chemada *et al.*, 2014). Technological factors such as ripeness and storage conditions (temperatures, relative humidity, and air circulation) during the time of elapsing between harvesting and processing all contribute to the final potato product quality (Singh and Kaur, 2009).

As a general rule, any environmental or management factor that increases specific gravity also decreases sugars, and vice versa. Additional factors including maturity, temperature, variety, storage stress, and handling that influence tuber sugars in a unique fashion. According, Karenlampi and White (2009) preharvest (fertilizer applied, growing environment, tuber maturity at harvest and harvesting methods), postharvest operation (curing, storage conditions like temperature, relative humidity, light and processing methods) factors and variety are the main factors that would influence potato tuber quality. Quality of the potato tuber has been found to vary between and within varieties when grown under different cultural and environmental conditions. Sanitation consists of cleaning and disinfecting all equipment, storage, tools and pallet boxes that contact the seed potatoes. Tuber size, shape, appearance, absence of diseases or defects, flavor, and cooked texture all contribute to potato quality. Good storage should prevent excessive loss of moisture, development of rots, and excessive sprout growth.

Abamecha *et al.*, (2025) revealed storage challenges associated with roots and tubers continue to pose difficulties for both producers and consumers, impacting the market for these products. The quality and longevity of roots and tubers are directly affected by storage practices, underscoring the importance of addressing the challenges, perspectives of producers, and opportunities related to storage. Medhin *et al.*, (2001) described storage methods most commonly used are on the floor (*wolel*) up to three months with minimal losses in that time in highlands areas, Bed (*kot/alga*), wooden beds used to keep potatoes for seed, sometimes covered with straw to promote sprouting, granary (*gotta/kefo*) rarely practiced, usually small structures of mud walls covered in straw. Borgel *et al.*, (1980) reported that storage of both seed and ware potatoes is problematic for most farmers, as storage losses can reach fifty percent, sometimes higher. The storage methods typically used by Ethiopian farmers apparently have not changed significantly since that time. Diffused Light Stores

(DLS) developed by CIP, have proven a capacity to maintain the quality of seed tubers, especially in the Central Highlands region (Medhin *et al.*, 2001), however no storage technique or facility for ware potato have been developed and used in the study area. Moreover, most of them have a low financial and technical capacity to construct improved storage to store and sell their produce when prices improve.

Ethiopia lacks proper storage facilities, and farmers are forced to sell their potato harvest at low prices during harvesting and buy seed tubers at high prices during planting. The most common traditional method for roots and tubers in the tropics after they are harvested are pit storage, storing in houses, storing on platforms in the open, leaving the crop underground until needed, clamp storage and barns for yams particularly (Ihekoronye and Ngoddy, 1985). Studies showed that unavailability of improved storage facilities in Ethiopia is one of among major limiting factors to potato productivity (Helen, 2016; Lemma *et al.*, 2020; Abebe, 2019). Potato tuber loss due to decay, excessive sprout, development of rots and disease infestation were the major problems that have been occurred in Chenchaworeda. In addition, information regarding on tuber quality and storage period attributes of both for local and improved potato varieties is still limited. Therefore, the main objective of this research were to study the physicochemical characteristics and storage duration of the major potato varieties cultivated in the study area stored under modified dark room storage for 0, 30, 60 and 90 days. The physicochemical characteristics were assessed at each 30 days end of storage.

Abamecha *et al.*, 2025 in studies reported farmers have historically kept potatoes in a variety of ways, including the floor of their homes, the local granary *Gotera*, and bed-like structures. Potatoes can also be stored locally by just leaving them in the ground unharvested. This permits straightforward storage by postponing harvesting until the potatoes are required for eating and instant selling when prices rise.

Materials and Methods

Description of the Study Area

The research was conducted in Arbaminch University, Gircha High Land Fruits and Vegetables Research Center, in Gamo high lands of Chenchaworeda district with the altitude of 3007masl, in Southern Nations, Nationalities and Peoples Region (SNNPR). Chenchaworeda district is

located in the Gamo administrative zone of the SNNPR of Ethiopia with an altitude range between 1600-3200masl. The topography of the Chencha area is hilly, with slope ranging from 5-60% (GGZAO, 1990). It has two agro-ecological zones: 'dega' (2300-3200masl, 82%) and 'woina dega' (1500-2300masl, 18%); with total area of 37,650ha. The mean annual temperature and rainfall of the study areas are 22.5°C and 810-1600mm/annum respectively. The altitude of Gircha research center is suited to store the potato tubers for extended storage period.

Description of the experimental materials

The most commonly cultivated potato varieties Belete, Jalegne, Gudagne, Degemign and local cultivar known as "Sussallho" were used for the study. Except the local known as Sussallho, all are released from research center as described in Table 1.

Treatments and Experimental Design

The experiment was conducted in modified storage potato ware house constructed at Gircha High Land Fruits and Vegetables Research Center, in Gamo high lands of Chencha district by using completely randomized design (CRD) with five treatments and each treatment replicated three times. Same tray/shelf was used for all treatments in the warehouse which was prepared 100cm above the ground. The potato tubers were stored at 0, 30, 60 and 90 days of storage durations and the physicochemical characteristics were studied and recorded at each 30 days end of storage durations.

Experimental Procedures of the Study

Preparation of Potato Tuber for warehouse storage

The warehouse was constructed in Arbaminch University, Gircha research center with 7m and 4m×4m total height and sizes respectively. Windows and doors had 0.5m×1m and 0.5m×2m sizes respectively. There were also small opened structure aligned above each and every window with 30cm×100cm size covered with mesh wire. These structure allows the entry of small air and to dissipation of heat and carbon dioxide produce by the tubers due to respiration. Windows and doors were opened days once per 30 days gap for the aforementioned purpose and otherwise kept closed to prevent entrance of light and to create darkness. Wooden shelves of different bed structures were installed to hold tubers of the different potato varieties separately. Each

shelf was arranged 50cm height apart and from above the ground. The average temperature and relative humidity of the surrounding environment of the center was collected from meteorology station installed in the center. The outside and inside of the warehouse walls were made up of mud with about 20cm thickness. In addition to the mud, all sides of the walls and roofs inside the warehouse were covered with 50cm thickness grain husk to maintain uniform temperature and relative humidity inside the storage.

Sample collection, preparation and storage

Potato tubers from each variety were harvested and collected separately from purposely pre-selected and tagged farmers' farm using nylon sacks. The ware potato tubers free from decay, not infected, physiologically young (produced without major stresses), relatively uniform in size were selected. Potato tubers showing greening, symptoms of diseases any decay or damage were discarded and the remaining sound potato tubers were stored in the warehouse on the partitioned beds (Chemeda *et al.*, 2014). The potato tubers harvested were cured before storage experiment trial under a shade for half days at temperature of 20°C and 75% relative humidity by spreading on the ground covered with a thin straws/husk. Each sample were replicated three times and coded while storage in the warehouse. For the purpose of storage and measurement of physicochemical properties of the tuber 75kg of potato tuber from each treatment was collected and each treatment was replicated three times with 25kg of potato sample from each in the storage. Each treatment and replication was coded in the warehouse. The potato tubers were stored for 30, 60 and 90 days of periods and the first samples were studied at the zero period of storage and the other samples phsico-chemical properties were studied by randomly drawn tubers from each treatment at 30 days of storage period gap.

Starch Content

The study showed that the main effects of variety and storage durations as well as the interaction effects variety and storage durations were significantly ($p < .0001$) influenced the starch content of potato tubers. The highest and the least starch content were obtained for Jalegne (46.43%) and Degemign (44.95%) varieties respectively followed by Belete, the local "Sussallho", and Gudagne. The highest (47.68%) and the least (33.96%) amount of starch was recorded at 0 and 90 days of storage periods. The study revealed that starch content

was decreased significantly with increasing storage period. In agreement with this study the report cited in Wassu Mohammed (2016) revealed that potato cultivars are significantly different in tuber starch content (Hassanpanah *et al.*, 2011; Kaur and Aggarwal, 2014; Ismail *et al.*, 2015). The difference in tuber starch content is probably as Ján Mareček *et al.*, (2013) reported due to the difference in varieties, climatic conditions and fertilization. The temperature difference inside the ware house with the increment of storage duration is paramount importance for the difference in starch content potato varieties. The highest starch content was measured at 0 and 30 days of storage period probably due to the lowest temperature measured at 0 and 30 days of storage period respectively in the ware house. Similarly Olsen *et al.*, (2003) reported that tubers stored at low temperatures contained significantly lower concentrations of starch than tubers stored at higher temperatures. The starch concentration decreased over the whole storage period and during storage, starch content decreases due to respiration while dry matter changes depend on both respiration and evaporation (Zoratan *et al.*, 2016).

Vitamin C

The study showed that the main effects of variety and storage durations as well as the interaction effects of variety and storage durations were significantly ($p < .0001$) influenced the vitamin C content of potato tubers. In this study the Vitamin C content was decreased significantly from 0 to 90 days of storage periods. The highest and the least vitamin C was obtained for Degemign (45.32 mg/100gm) and Gudagne (35.06 mg/100gm) varieties respectively followed Jalegne, the local “Sussallho”, and Belete. The highest (44.77 mg/100gm) and the least (35.19 mg/g,) amount of starch was measured at 0 and 90 days of storage periods respectively. Similarly Bandana *et al.*, (2015) reported that ascorbic acid content declined gradually in potato varieties with the increase in storage duration. The difference in ascorbic acid content in all the varieties probably as reported in Chemedda *et al.*, (2014) due to variety, temperature, soil composition, nitrogen fertilizer application, handling of the tubers, storage temperature, and storage duration. In addition, Luis Valencia-Flórez *et al.*, (2019) cited in described that the initial Vitamin C or ascorbic acid content along with the maturity and variety of the crop determine losses during storage (Pinhero *et al.*, 2009). Potato tubers have been reported to contain up to 46 mg of ascorbic acid per 100 g tubers (on fresh weight basis) and its availability depends on the variety,

maturity status and the environmental conditions under which crop is grown (Nourian *et al.*, 2003; Han *et al.*, 2004).

Reducing sugar

The study revealed that the main effects of variety ($p < .0001$) and storage period ($p = 0.0004$) as well as the interaction of variety and storage durations ($p = 0.0183$) were significantly influenced the reducing sugar content of potato tuber. The reducing sugar content was decreased insignificantly from 0 to 30 days of storage periods but significantly decreased from 60 to 90 days of periods. In the study Jalegne (1.38 Mg/gm) and Degemign (1.18 Mg/gm) varieties had the highest and least amount reducing sugar contents respectively followed by the local “Sussallho”, Belete and Gudagne. The highest (1.26 Mg/gm) the least (0.90 Mg/gm) amount of reducing sugar content was measured prior to storage and at 90 days of storage periods respectively. In agreement to this study Ján Mareček *et al.*, (2013) reported that the lowest reducing sugar content was observed at the end of the storage. The insignificant difference in reducing sugar content at 0 and 30 days of storage probably mostly correlated with the low respiration rate and low temperature in the storage house. In this investigation as shown in table 1 the reducing sugar content was decreased with the increment of the storage periods, this is mostly as mentioned in Olsen *et al.*, (2003) due to the increased in storage temperature, and this results the decreased in accumulation of sugar due to the starch transformation. Similarly Ali *et al.*, (2017) reported that reducing sugars are used as substrate in respiration and is converted in to water and carbon dioxide. Ján Mareček *et al.*, (2013) reported the main factor that affected s reducing sugar content is the temperature in the storage area. If the temperature falls during more than 10 days to below 2°C, the decomposition of starch is accelerating. Jenny (2012) described that at low temperatures sugars are accumulated in the stored tubers. This implies that the temperature fluctuation inside the storage house would be accounted the change in the amount of reducing sugar content.

The level of sugars in potato tubers is affected by variety, maturity of at harvest, the influence of year and very important is storage temperature (Ján *et al.*, 2013). Its conversion of starch into sugars takes place while the reconversion of sugars in to starch also takes place in storage which has little effect on the quantity of total carbohydrates in the tubers in storage (Ali *et al.*, 2017).

Table.1 Descriptions of improved potato varieties used for the study.

No	Varieties	Accession code	Year of release	Breeding center	Recommended altitude (m.a.s.l.)	Remark
1	Belete	CIP-393371.58	2009	Holeta Research Center	1600-2800	
2	Jalegne	CIP-37792-5	2002	Holeta Research Center	1600-2800	
3	Gudagne	CIP-386423.13		Holeta Research Center	1600-2800	
4	Degemign		2002	HARC/EIAR	-	
4	Local	-	-	-	-	Locally available

Source: Plant Variety Release, Protection and Seed Quality Control Directorate, Crop Variety Register Issue No. 16, pp. 161-164 (MoA, 2013, June, Addis Abeba, Ethiopia); m a.s.l = meters above sea level

Table.2 The effect of storage durations on Starch, Carbohydrate, Vitamin C, Reducing sugar and Crude protein content of potato tubers

Varieties	Starch (%)	Carbohydrate (%)	Vitamin C (Mg/100gm)	Reducing Sugar (Mg/gm)	Crude protein (%)
Sussallho	38.13 ^d	74.68 ^b	38.32 ^c	1.06 ^b	1.27 ^d
Jalegne	46.43 ^a	87.1 ^a	44.64 ^b	1.38 ^a	3.04 ^a
Belete	42.32 ^c	76.83 ^b	37.47 ^d	1.05 ^b	2.06 ^c
Degmeign	44.95 ^b	71.45 ^d	45.32 ^a	1.18 ^b	1.27 ^b
Gudagne	34.94 ^c	68.13 ^d	35.06 ^c	0.80 ^c	0.77 ^c
LSD at α 5%	*	*	*	*	*
Storage Durations					
0	47.68 ^a	86.44 ^a	44.77 ^a	1.26 ^a	1.26 ^a
30	44.62 ^b	79.89 ^b	41.82 ^b	1.14 ^a	1.14 ^a
60	39.14 ^c	74.84 ^c	38.87 ^c	1.07 ^b	1.07 ^b
90	33.96 ^d	62.04 ^d	35.19 ^d	0.90 ^c	0.90 ^c
LSD at α 5%	*	*	*	*	*
R-Square	0.98	0.90	0.99	0.72	0.97
Interaction					
Significance Level					
V \times SD	*	*	*	*	*

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, R²=Coefficient of determination, V \times SD=interaction of variety and storage duration

Figure.1 Warehouse, for storage of potato tubers



Jenny (2012) reported increased storage temperature results in decreased accumulation of sugar.

Crude Protein Content

The study showed that the main effects of variety and storage durations as well as the interaction effects variety and storage durations were significantly ($p < .0001$) influenced the crude protein content of potato tubers. The crude protein content was decreased significantly and insignificantly from 0 to 60 and 60 to 90 days of storage durations respectively. The crude protein content was highest (2.19%) and least (1.59%) prior to storage and at 90 days of storage periods respectively. In this study Jalegne (3.04%) and Gudagne (0.69%) had the highest and least amount crude protein content respectively and followed by Degemign, the local “Sussallho”, and Belete varieties. In agreement to this study Chemedu *et al.*, (2014) reported that potato varieties differed significantly over the storage durations.

Total carbohydrate content

The study showed that the main effects of variety and storage durations as well as the interaction effects of variety and storage durations were significantly ($p < .0001$) influenced the carbohydrate content of potato tubers. The study showed that the total carbohydrate content was decreased significantly from 0 to 90 days of storage durations with increment of storage periods. The total carbohydrate content was highest (86.44%) and least (62.04%) prior to storage and at 90 days of storage periods respectively. In this study Jalegne (87.91%) and Gudagne (68.13%) had the highest and least amount of reducing sugar contents respectively followed by Belete, the local “Sussallho” and Degemign varieties. Similar results were reported by Shujaat *et al.*, (2017) but in the contrary to the study they found that the mean values of varieties were not statistically significant. In this study the decrease in total carbohydrate content are most probably attributed with the decreased in starch and reducing sugar content with the increase of storage durations.

Similarly Shujaat *et al.*, (2017) explained that carbohydrates are composed of reducing sugars (glucose +fructose), sucrose and starch, the decrease in reducing sugars and starch content is accounted for the decrease in total carbohydrate content potato tuber. In the similar studies Erdogan and Taskin (2016) reported that the storage period led to differences on the protein content among the potato varieties (Zoran *et al.*, 2020).

Conclusion and Recommendation

Potato farming and production is a very common activity in the mid and highland areas of Ethiopia, specifically in Gamo zone, potato farming highly linked with the livelihood of Chenchu farmers. Among root and tuber crops, potato is a well-known major cash income and food security crop for many farmers in the study area. However, the increment of potato farming from time to time in the study area, studies showed that unavailability of improved storage facilities in Ethiopia is one of among major limiting factors to potato productivity. No studies have been tried to see the storage life of potato tuber in the study area using different storage techniques. Diffused light store (DLS) is a commonly used techniques in some cooperatives in the study area and storage methods most commonly used are on the floor (*wolel*) up to three months with minimal losses in that time in highlands areas, Bed (*kot/alga*), wooden beds used to keep potatoes for seed, sometimes covered with straw to promote sprouting, granary (*gotta/kefo*) rarely practiced, usually small structures of mud walls covered in straw.

Since, the present investigation performed with the objectives biochemical characteristics and storage duration major potato varieties cultivated in the study area stored under modified dark room storage for 0, 30, 60 and 90 days. The biochemical characteristics were assessed at each 30 days end of storage. The study reported highest and least vitamin C was obtained for Degemign (45.32 Mg/100gm) and Gudagne (35.06 Mg/100gm) varieties respectively. In this study Jalegne (3.04%) and Gudagne (0.69%) had the highest and least amount crude protein content whereas total carbohydrate content was highest (86.44%) and least (62.04%) prior to storage and at 90 days of storage periods respectively. Therefore, the study showed that farmers can store their tubers in same way as possible in the warehouse used in this study. Further research should focus on improving the potato warehouse ventilation, aeration, light interference as well as temperature and relative humidity control mechanism.

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Conflict of Interest

The authors declare no conflict of interest

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