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Review Article

Prospects and Challenges of Postharvest Losses of Potato (*Solanum Tuberosum L.*) in Ethiopia

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Abstract

Potato is known as a semi-perishable commodity and storage of both seed and ware potatoes which is problematic for most producers and consumers. The losses could be occurred during harvesting, sorting, cleaning, handling and packing, transportation, storage, distribution or marketing and processing. In Ethiopia most of the potato produced is mainly consumed as boiled, salad and stew preparations. Use of alternative recipes like french fries, crisps, flakes, flours, starches, pre-peeled potatoes and various snack food items has not developed well. Thus, the study was conducted to evaluate improved seed and ware potato storage, local farmers' practices such as; storing under bed, storing in pit and extended harvesting for resource poor potato growers in central highlands of Ethiopia. The experimental design was complete randomized design (CRD) with three replications using two improved potato varieties. Improved ware potato storage diffused light store (DLS) were demonstrate to farmers through farmers field school (FFS) and farmers research group (FRG) participatory research approaches. FFS and FRG were organized from four districts and regular assessments were done for 105 days of storage period. From this study non-significant storage losses were observed. However, for the qualitative data, there were significant difference between the improved and the farmer's/local storage practices in terms of taste, color change, sprouting and pest infestation.

The result revealed that storing potato on the ground under beds exposes the tubers for rapid sprouting, color and taste changes within few days. Especially in Haramaya district the tubers stored in the ground pits, according to the farmers practice, have rotten and excessively sprouted almost totally unlike the ones put in improved structures. On the other hand, extended harvesting has exposed the tubers for pest infestation. Even though, it is possible to use potato for ware through extended harvesting for some months, the losses due to pest infestation was extremely high. Thus, extended harvesting and other farmers' practices are not effective for handling ware potato for long-term storage. It seems that the introduced improved seed and ware potato storage were the only effective option for potato grower farmers in central highlands where the temperature and relative humidity are suitable using locally constructed storage structure. Therefore, it was with great enthusiasm that the participated farmers highly interested with this improved practice and accepted to use the improved seed and ware potato storage structures for prolonged time and exploits the potential of this crop for food and nutrition security.

Keywords: Postharvest; Farmers field school; Farmer research Group; Ware potato storage

Introduction

Potato (*Solanum tuberosum L.*) ranked as the third most important food crop following rice and wheat and is consumed by over a billion people throughout the world [1,2]. Potato serves as a food and income security source and provides important nutrients. Potato has a high content of carbohydrates, significant amounts of quality protein, and substantial amounts of vitamins, especially vitamin C [3]. Potato production is expanding strongly in many developing countries accounting for more than half of the global harvest [4]. In Ethiopia, root and tuber crops are the third largest national food commodity, after maize and wheat, in terms of production [5,6]. Potato promises higher calorie per unit area production potential than any grain and can be produced, stored, and consumed without major technological inputs. Recent trends indicate that potato production in densely populated developing nations is on the rise [7]. According to [1] half of the total production occurs in developing countries that makes potato the third most important food crop globally [8,9] suggested that the high yield potential of potato per hectare of arable land, good nutritive value, and cooking versatility have resulted in a threefold per capita potato consumption in the developing world, from 6 kg capita_1 year_1 in 1969 to 18 kg capita_1 year_1 in 2009. The crop's short cropping cycle allows it to serve as a hunger-breaking crop, and makes it suitable for intercropping and double cropping, especially in cereal-based production systems in Africa and Asia [10,11].

However, production of potato tuber is constrained by pre-harvest factors and postharvest losses, which in turn limit the volumes of good quality, produce reaching consumers [12] reported that potato is a source of food and cash income, playing an important role in the rural livelihood system of the densely populated highlands of sub-Saharan Africa. Ethiopia is one of the major potato producing countries in Africa as 70% of its arable lands in the highlands are suitable for potato production [13]. Potato being cultivated for more than 150 years in Ethiopia, it grows dominantly in the Northern Central and Eastern highlands of the country [12] and the recent reports of [14] stated that its production area has reached about 0.3 million ha producing more than 3.66 million tons in both Meher and Belg seasons.

According to [15], in 2017, potato yielded up to 20 tons/ha worldwide on average, whereas maize, rice and wheat had an average yield of 5.7 tons/ha, 4.7 tons/ha and 3.5 tons/ha, respectively. Potato is one of the most productive food crops, producing more dry matter (food) per hectare than cereals or any other cultivated plant. As such, it can significantly contribute to food and nutrition security. A hectare of potatoes provides up to four times the calories of a grain crop and up to 85% of the plant is edible human food, compared to around 50% in cereals. Potato produces more food per liter of freshwater used through irrigation than cereals and thus is more sustainable to mitigate the effects of climate change. Over the past 20 years, potato production has significantly increased in developing countries in Asia, Africa and Latin America by 89, 14.5, and 4 million tons, respectively. In Africa, the potato production and harvested areas more than doubled over the last 20 years. Average potato consumption in East Africa has grown by approximately 300% over the past two decades, yet yields are low. The major bottlenecks to higher potato yield and reliable supplies in Africa are limited or no access of farmers to high quality seed tubers of improved varieties, poor crop husbandry practices (e.g. disease and soil fertility management), and poor post-harvest management [16]. A promising alternative to traditional clonal propagation of tetraploid potatoes is the production of hybrid true potato seeds: planting 10 hectares, for instance, takes just 200 grams of easily transported true seeds, compared with 25 tons of perishable seed-tubers. It was introduced in Africa at the end of the 17th century by Christian missionaries through the formation of small plantations. Soon after, potatoes quickly became part of the feeding habits of both rural and urban populations. As in Europe, potato production could contribute in the fight against food insecurity in the sub-Saharan African countries [17].

So far, different attempts have been made to come up with an appropriate agronomic and pre-harvest management to increase potato tuber productivity in Ethiopia [18-20]. The major constraint of potato production in Ethiopia includes poor quality seed, poor agronomic practices, poor pre and post-harvest handling, marketing and transportation systems. The percentage losses of potato due to post harvest handling are estimated to be 20-25% [21]. Potato production is seasonal, and it lack proper storage methods such as cold storage. In agriculture sector, a lot of emphasis has been put on research and development of agriculture production and fewer resources in post-harvest development. Potato is a bulky and fleshy crop with a short storage life therefore needs careful handling, packaging and storage. In Ethiopia, post-harvest losses of horticultural crops may be estimated for about 15 to 70% at various stages [18]. Potato is known as a semi-perishable commodity and storage of both seed and ware potatoes which is problematic for most farmers, as storage losses can reach 50% and sometimes higher [22]. Lack of proper storage systems are among the main factors contributing to the low yield of potato in the region, which is the case at the country level also [23]. Furthermore, market price of the product and marketing systems are also problematic [24]. According to [25] unavailability of proper potato seed storage forces the farmer to sell immediately during harvest with low price, whereas availability of proper storage facilities allow farmers to sell their potato tuber as a seed during planting or in the later season with higher price compared to the immediate sell.

Farmers stored potato either for seed or ware using various traditional storage mechanisms. These traditional storage facilities do not allow the growers and consumers to store potato not more than three and half months without deterioration [24]. However, farmer requires good storage either to use tubers of their own harvest as a seed source to postpone sales to get better market price and for household consumption in the later season. Hence, improving food security requires a comprehensive approach towards post-harvest managements using new strategies and/or technologies to ensure the higher value of post-harvest produces. Therefore, the major post-harvest losses of potato and its strategy to mitigate the problem were described.

Major potato post-harvest losses

In the absence of storage technologies for seed and ware potatoes, farmers keep potato harvest in the field for extended period in Ethiopia. This practice exposes the tubers for insect attack which reduces tuber yield and quality significantly. A study on extended harvesting period in Alemaya revealed that yield of marketable tubers was reduced by 60% when tubers were harvested at 210 days after planting as compared to a harvest at 120 days [26]. Similarly,

[27] reported significant yield reductions (70-100%) when harvesting was delayed from about 125 days to 230 days after planting. Estimates of the production losses in developing countries are hard to judge; but some estimate the losses of potatoes, sweet potatoes, plantain, tomatoes, bananas and citrus to be very high. About 30-50% of the total produce (1.3 million tons) is lost after harvest. Globally, horticultural crops postharvest losses have been reported at 19% for the USA at an estimated annual loss of $18 billion [28]. Higher losses have been reported for African countries ranging between 15%-30% of the harvested product [29].

Post-harvest losses are mainly caused by different physical, environmental and biological factors which include mechanical injuries, extreme temperatures and pathogens [30]. According to [31], the causal factors enhance post-harvest losses through changes in the chemical composition and physical properties of the tuber in the process of respiration, loss of moisture from the tuber, sprouting, and spread of diseases. In the light of the little information generated on the major factors of post-harvest losses in Ethiopia, some of the principles in post-harvest management and the basic environmental and physiological causes of post-harvest loss are discussed as below.

Physical, biochemical and physiological losses

Physical losses include the various responses of tuber to excessive or insufficient heat, cold, or humidity. Proper storage is required to allow ventilation and heat exchange to maintain proper temperature level, to reduce the air and gas exchange (oxygen, carbon dioxide, and ethylene) and to minimize water loss. Losses caused by mechanical injury are usually overlooked. Physical injury is a loss by itself, and it can result in secondary physiological and pathological losses. Mechanical injury can occur at hilling, harvesting, and handling operations such as grading, transporting and marketing. Among tubers from the same cultivar, the degree of damage is influenced by the dry matter content and turgidity of the tubers [32]. High dry matter content causes higher braising. Good level of care is needed during harvesting and handling operations to minimize damage caused on tubers. The damaged tuber always has a shorter post-harvest life than the undamaged tubers [32].

Respiration

Potato tubers respires using sugars converted from starch. Therefore, respiration reduces the starch content of the tuber. During respiration, the tubers use oxygen from the air and produces water, and carbon dioxide and heat. The most important effect of tuber respiration is the production of heat and its subsequent effect on storage temperatures and the action required to control it [32]. If the respiratory heat is not removed, the temperature of the potatoes rises by 0.25 °C per 24 hours. The rate of respiration is dependent on the temperature and is minimum at about 5 °C. Tubers that are stored at relatively higher temperature lose their moisture after some time and become unfit for consumption or for prolonged storage as seed for the coming season planting. The problem was observed in seed potatoes stored in diffused light store (DLS) at Shashemene area. Fresh weight of tubers is considerably reduced in storage both due to respiration and water loss. It was observed that mean tuber weight loss as high as 23% was recorded when potatoes were stored in naturally ventilated storage for 120 days (Table 1). The tubers were dry due to excessive moisture loss and they were not suitable for planting after 6 months. This was due to relatively higher temperatures and dry air that enhances respiration and consequently desiccates the stored tuber.

Table 1: Mean weight loss of tubers of four cultivars stored in naturally ventilated ware storage.

Days in Store After Harvest	Mean Fresh Weight Loss (g/kg)	%Loss on Fresh Weight Bases
30	33.5	3.4
60	133.2	13.3
90	183.5	18.3
120	233.7	23.4

Loss of moisture

Water is lost from tubers by evaporation. The rate of loss of water is highly affected by the weather condition of the location and it is proportional to the water vapour pressure deficit, i.e. the drying power of the surrounding air [32]. The potato can lose moisture rapidly if it is immature, wounded and unhealed and sprouted. Immature tuber loses water more rapidly because of its more permeable skin and increase in water loss when sprouting starts because the surface of sprouts is more permeable to water vapour.

Loss in dry matter content

Tuber respiration during storage results in dry matter losses. This amounts to 1-2% of fresh weight in the first month and about 0.8% per month thereafter until sprouting is well advanced when dry matter loss will amount to 1.5% per month [32]. Temperature and humidity of storage have an effect on the dry mater in relation to the water content and changes in specific gravity of the tubers. Potatoes stored at relative humidity of 83-84% show increase in specific gravity during storage at both 4.4 and 12.8 °C. At 90% relative humidity, however, the specific gravity of tubers remain practically unchanged in storage up to 6.5 months at 4.4 °C and 10 °C [33]. Similar result was obtained in ventilated ware storage with internal temperature for 120 days ranging between 3.6 and 7.8 °C and relative humidity of 86.6-87.0% at Holetta (Table 2). Nevertheless, respiration, sprouting, loss of moisture from the tuber and pathogenic losses have mostly a direct influence on the dray matter content and thus on the use or processing quality of the tuber [34].

Table 2: Change in specific gravity after 120 days in naturally ventilated ware potato storage at Holetta.

Days in Ventilated Ware Store	Potato Varieties					
	Jalenie	Tolcha	Zengena	Menagesha	Gorebella	Mean
0	1.095	1.098	1.09	1.071	1.09	1.09
45	1.096	1.103	1.102	1.071	1.088	1.092
120	1.103	1.099	1.102	1.086	1.095	1.098
Mean	1.098	1.1	1.098	1.076	1.091	1.093

Sprouting

Generally, tubers are dormant at harvest. A very important point related to successful storage is an understanding of dormancy and sprouting. The tuber has a definite life cycle. Following field maturity, the tuber remains dormant for a specific period of time which varies with variety and the influence of the crop growing and storage conditions. Maturity at harvest time influences the degree of sprouting. Stresses at any of these stages reduce tuber natural dormancy. Damaged and diseased tubers sprout sooner than healthy ones. It has already been noted that once dormancy ends, sprout growth leads to increased respiration and moisture loss from the tuber via sprout tissue. The higher the temperature over a range of about 4°C to 21°C, the shorter the dormancy period. The most critical temperatures are between 4°C and to 10 °C. However, it is possible that tubers stored first at low temperature followed by storage at 10 °C, could have a shorter dormant period than following continuous storage at 100°C.

The number of sprouts per tuber, which determines the number of main stems per plant, is influenced by variety, tuber size and the degree of apical dominance [35]. In a given variety, the degree of apical dominance is influenced by storage conditions, particularly temperature (Table 3). Sprouting directly affects quality of ware potato presumably due to its enhancing effect on water and respiratory loss.

Table 3: Estimated storage life of ware and seed potato.

Storage Temperature (°C)	Storage Life (no. of months)		
	Ware		Seed
	Dark	Dark	Indirect Light
4	10	10	11
10	5	6	9
15	4	5	8
20	3	4	6
25	2	3	5
30	1.5	2	3
35	1	1	2

Pathogenic losses

Post-harvest attack by microorganisms can cause a serious loss. Post-harvest diseases can start prior to harvesting in the field, at or following harvesting through wounds. Insects and rodents may cause additional pathogenic losses. The potato tuber moth causes the most serious damage in the store. The larval damage causes direct weight loss and the wounds lead to secondary infection by microorganisms. During storage, aphids can attack the young sprouts and shoots, and they can disseminate certain virus diseases, especially potato leaf roll virus (PLRV). Quantitative pathogenic losses result from the frequently rapid and extensive breakdown of tissue for example, fungal and bacterial attack which is followed by massive attack by secondary organisms. This mostly is the prime importance in storage and can cause substantial damage.

Storage Methods

Traditional storages

In Ethiopia potatoes are basically stored for two reasons: ware and seed. Farmers use different traditional potato storage system depending on the use. However, these storage facilities are not proper to keep the quality of tuber for more than 1-2 months. As a result, farmers are forced to sell their potatoes at low prices during harvest. They buy seed potatoes at a very high price at planting. Some farmers store seed potatoes either in burlap sacks or in dark rooms, which result in the formation of long and etiolated sprouts that break easily while handling and during planting. Storing seed potatoes in diffused light stores (DLS) results in the formation of shorter and sturdier sprouts than storing in the traditional dark storage method or in burlap sacks. Potato seeds stored in DLS have better emergence, more uniform growth and better plant establishment, resulting in higher tuber yield than seed stored in the traditional storage.

At Holeta, potatoes stored in burlap sack produced smaller sprouts and lost higher weight than those stored in either 2, 3 or 4 layers on shelves of DLS. Potatoes stored in multi-layered burlap sacks produced less number of sprouts per tuber. These results were confirmed by research carried out at Alemaya where storage of seed tubers in dark resulted in a higher weight loss than storage in DLS. Field (underground) storage is commonly used in the highland area. Farmers leave their potatoes underground for prolonged use by piece-meal harvest which also helps regulate the low market price they often encounter at peak times and improve their use for consumption. This is the most common storage system of farmers both for ware and seed potatoes, but it is preferred most for ware due to high dry matter. It can keep up to 4 months in cool highlands. However, this extended method is challenged by untimely rainfall that hastens tuber rotting, tuber moth problems causing considerable yield loss, and tuber infectious diseases that degenerate the tubers. Floor storage (piling potatoes in the room on the floor) is used both for ware and seed purpose which helps to keep the potato up to 2-3 months in cooler areas. Storage on raised bed, locally called ko't or alga, is usually used to keep potatoes for seed. Storing potatoes in pit in which the wall is made from mud and roofed with straw is exercised to keep ware potato for 1-2 months.

All the methods used by farmers had considerable quantity and quality loss (Table 4) to ware and seed potatoes. Nearly all the major physical, physiological and disease problems that cause loss were not effectively controlled or regulated adequately. The problem is very critical in affecting seed quality and subsequent performance of the crop in the field. The seed quality is thus the most pressing factor in the potato enterprise. In general, farmers have no appropriate facility for package, transport, and storage. Thus, they cannot keep stock to reduce post-harvest loss and reduce price fluctuation in order to obtain better price.

Table 4: Effect of extended harvest on yield of potato, average of three years.

Treatments (Days in Ground After 1st Harvest)	% Unmarketable Tuber (3 Years Average)
Harvest at maturity (control)	-
15	65.7
30	71.1
45	78.7
60	83.1
75	84.5
90	81
105	88.1

Diffused light stores (DLS)

The potato tuber which is to be used as seed has to be stored and prepared for planting so that it retains its vigor, remains healthy and in insect-free condition up to the time of planting. Although this can be done in costly refrigerated storage, the need of the household and small-scale producer or enterprise demand a low -cost alternative technology. After complete growth of the potato crop in the field and before ready for planting, the tuber enters a period of rest known as dormancy. During dormancy the tuber is relatively easy to store. However, once dormancy ends and sprouts growth commences, unless planting is done shortly after wards, sprouting must be controlled to protect the tuber from becoming exhausted, infecting with virus and damage by insect. Seed tuber storage must include, therefore, a way of controlling the growth of the sprouts and other pests.

The diffused light storage is a very simple and low cost structure which allows the diffusion of daylight and free ventilation (air circulation) inside the storage that helps to suppress the elongation of sprouts as opposed to dark storage. It helps to maintain seed quality for a long time in areas where prolonged storage is a must. Observations made at Holetta indicated that tubers could be stored a long as 7 months without considerable depreciation of seed quality. The storage performance, however, was noted to vary depending on variety [36]. According to the results, tuber weight loss, time of dormancy break (sprout initiation), sprout number and length varied depending on variety (Tables 5&6). In general, decisions and actions on whether or not to store potatoes and how to store them must depend up on circumstances of individual cases. Therefore, the choice or recommendation of a given method should better be made using research information and knowledge on the influence of storage variables on the quality of the stored potatoes and on storage losses in the desired storage time. Therefore, the low-cost diffused light store (DLS) for seed tubers developed by CIP has been evaluated under the Ethiopian condition. It was found to be very useful and efficient storage technique. Consequently, it has been adopted by many potato farmers' in many parts of the country [37] reported that, 87% of the central part and 25% in the north and western are using DLS to store their improved potato variety seed. The authors reported that, in DLS tubers can be stored 8-9 months without much loss. It can also produce 3-4 sprouts, which are green and strong consequently that will produce high yield.

Table 5: Performance of improved potato cultivars after storage for 216 days in diffused light storage.

Variety	Time to Sprout Initiation (Days)	No. of Sprout Per Tuber	Sprout Length (Mm)	Tuber Wt Loss (%)
Sissay	39	5.2	10.04	25.3
AL- 624	16	8	9.9	32.5

Tolcha	28	4	8.9	12.4
Wochecha	38	5	7.4	33.1
Awash	44	5.5	11.1	27.8
Menagesha	25	4	6.3	19
Genet	52	5.1	13.9	32.9
Local	19	8.6	6.7	22.6
Mean	32.6	5.68	9.3	25.7

Table 6: Effect of storage days and tuber size on sprout growth in diffused light store, Holetta.

Days in Storage	Sprout Growth (Mm)			Mean
	25-35	35-50	50-60	
15	11.5	9.1	10.3	10.3
30	15	24.7	27.6	22.4
45	19.7	31.8	38.5	30
60	48.5	64.7	70.6	61.3
75	36.1	46.3	58.3	46.9
90	40.1	55.8	60.8	52.2
105	70.9	88.4	113	90.8
120	75	104.1	93.5	90.8
Mean	39.6	53.1	59.1	

Ware potato storages

The effect of sun and radiant heat on the storage interior should be avoided by including resistance to these effects so that the desired cool condition is maintained. This is because consumption potatoes (ware potatoes) must be kept in dark to prevent greening of tubers. The high-water content and rich carbohydrate is conducive for spoilage through respiration and pathogen attack. Therefore, the inside temperature is maintained at low level. All specialized stores or storage structures should have a roof space of not less than 1 m wide to shade walls from high hot sun. Buildings should be placed, if possible, with the long axis east to west. This can be modified by the need to place a long side across the prevailing night wind so as to allow natural ventilation.

The above describe naturally ventilated ware potato storage has two compartments. Potatoes are stacked at the height not exceeding 1.5m. The wall is made up of mud with a thickness of not less than 10cm. To avoid crack formation, the mud must be well fermented and stabilized with straw. Following the night wind direction, the stores are constructed with air inlet and outlet openings. These are opened during the night from sunset to sunrise to allow air circulation, exhausting the day's heat due to respiration of the stacked potatoes and cooling it with the lower night temperature. The roof slope in one direction and covered with straw.

Matured potatoes are much more desirable for home consumption as well as processing than less matured ones. Therefore, ware potato should be harvested at full maturity stage when the soil is slightly moist to prevent tuber abrasion and to avoid tuber damage. All potatoes showing greening, any decay or damage are rejected for storage. Tubers showing disease symptom and any other mechanical damage are unfit for storage; therefore, such tubers are carefully separated and avoided. The harvested potatoes must be cured to repair any skin injuries and to promote the formation of stronger epidermis to reduce water loss. Good quality potato tubers, that are suitable for storage can then be kept and stored. Evaluation of ware quality of potatoes stored in locally made household level naturally ventilated ware potato storage with 2m x 1.5m x 2m size was made for eight potato varieties with stack height (1.5m) recommended for naturally ventilated ware potato stores at Holetta. The walls were made up of mud having a thickness of not less than 10 cm and roofed with grass to protect temperature build-up and direct sunlight. The cool night wind of the highland is employed using an air inlet and outlet openings which remained opened at night (from sun set to sun rise) to avoid the entrance of hot air into the stored potatoes.

The result (Table 7) showed that potatoes from both main and off-season production could be stored for about four months (120 days) with losses ranging 5-17.5% depending on the potato variety and the internal and external storage temperature and relative humidity. At Holetta, with temperatures and relative humidity presented (Table 8), potatoes could be stored for four months. Variety Digemegn had got the minimum and Menagesha the maximum storage weight losses (Table 9). The other potatoes varieties showed storage weight losses between 10-15%. Potato produced in the off-season and stored from May to August showed the lowest storage weight loss. The evaluation included quality changes in terms of tuber firmness, emaciations, crisp quality and sprouting from storage sample every 15 days. The results related to processing and utilizations are discussed in the following section.

Table 7: Percentage tuber weight loss of different potato varieties in naturally ventilated storage at two different seasons.

Variety	Weight Loss (%)	
	Nov-Feb storage	June-Sep storage
Jalenie	12.5	10.0
Wechecha	15.0	12.5
Digemegn	10.0	5.0
Tolcha	12.5	10.0
Zengena	15.0	12.5
Guassa	12.5	10.0
Menagesha	17.5	15.0
Gorebella	15.0	10.0
Mean	13.7	10.6

Table 8: Environmental conditions of naturally ventilated stores for ware potato stored for 120 days at Holetta.

Environmental Factor	Storage Period			
	Main-Season Harvest (Nov -Feb)		Off-Season Harvest (Jun-Sep)	
	Internal	External	Internal	External
Temperature (0C)	3.6	22.7	7.83	19.84
RH (%)	86.6	53.8	87.09	75.81

Table 9: Mean tuber weight loss of four cultivars in naturally ventilated ware storage at Holetta.

Treatments (Days in Ground After 1st Harvest)	Mean Fresh Weight Loss (G/Kg)	% Loss on Fresh Weight Bases
30	33.5	3.35
60	133.25	13.32
90	183.5	18.35
120	233.7	23.37

Processing and Utilization

In Ethiopia most of the potato produced is consumed as boiled potato and frequently prepared in local dishes sauced or mixed with other vegetables and spices. The per capital consumption of potato in Ethiopia is probably the lowest in Africa [38]. The main reasons for the low consumption of potato are poor post-harvest handling and supply, unavailability of processing industries, lack of improved varieties with appropriate processing quality (chips, crisps, dehydrated potatoes and several potato-based snack food products), and lack of awareness of the different uses of the crop [39].

In recent years, the demand for potato chips and crisps is increasing very rapidly in urban areas. However, the focus of the variety improvement in the last two decades was more on improving productivity. Therefore, evaluation of existing potato varieties for their processing quality like chips and crisps has since recently been an important exercise. Although the overall tendency to the processing qualities of potato is a heritable varietal character, it is also influenced by storage environment such as period of storage [40]. Quality assessment of released potato varieties for crisps, chips, dry matter content, and specific gravity was made to study seasonal and varietal effects.

The results of the study showed that potatoes produced during the off-season had higher dry matter content and specific gravity than from the main season potatoes for most of the varieties. During the main season, variety Digemegn followed by Jalenie, Zengena and Tolcha had the highest dry matter and specific gravity whereas for the off-season production, variety Digemegn, Jalenie and Tolcha showed the highest dry matter content, 25.5%, 24.7% and 23.97%, respectively. Both in the main and off-season production variety Digemegn gave the highest dry matter content and specific gravity, while Menagesha had the lowest (Table 10). The result indicated that even if there was a difference among varieties and seasons, except for Menagesha, stored potatoes from main and off-season production had acceptable dry matter and specific gravity for processing. In line with this study, high tuber specific gravity, dry matter and starch content are important for processing by enhancing chip yield, crispness and reduces oil uptake in fried products [41,42]. Potato cultivars are significantly different in tuber specific gravity, dry matter content, and starch content [43-45]. Moreover, specific gravity and tuber dry matter content are influenced by both the environment and cultivars [46]. These quality traits are genetically controlled and also influenced with growing locations and seasons [43,44,47].

Table 10: Seasonal and varietal effects on dry matter and specific gravity for improved potato varieties at Holetta.

Variety	Main Season		Off-Season		Over Seasons	
	Dry Matter (%)	Specific Gravity	Dry Matter (%)	Specific Gravity	Dry Matter (%)	Specific Gravity
Digemegn	24.93	1.105	25.49	1.107	25.21	1.113
Zengena	23.08	1.098	23.52	1.098	23.3	1.097
Jalenie	23.29	1.096	24.72	1.103	24.01	1.099
Gorebella	22.43	1.093	22.36	1.093	22.4	1.093
Guassa	22.07	1.091	22.85	1.095	22.46	1.093
Menagesha	18.87	1.078	18.97	1.075	18.72	1.076
Tolcha	22.95	1.096	23.97	1.097	23.45	1.098
Wechecha	22.91	1.094	23.44	1.097	23.18	1.096
	22.57	1.094	23.17	1.096	22.84	1.096
S.e.	0.602	0.002	0.467	0.002	0.38	

Table 11: Trained panelist evaluation of chips and crisps quality of potatoes after 120 days in naturally ventilated storage.

Variety	Evaluation (Score on 1–9 scale)*					
	Main Season		Off Season		Over Seasons	
	Crisps	Chips	Crisps	Chips	Crisps	Chips
Jalenie	6.9	6.3	7.2	6.7	7	6.5
Wechecha	6.6	5.9	6.5	6.2	6.5	6.1
Tolcha	6.6	6.2	6.8	6.7	6.7	6.5
Zengena	6.6	6.2	6.7	6.4	6.6	6.3
Guassa	6.6	6.2	6.6	6.4	6.6	6.2
Gorebella	5.9	5.9	6.2	5.8	6.1	5.6
Menagesha	5.5	5.8	6.2	5.8	5.9	5.8
Digemegn	4.5	4.2	5.6	4.6	5	4.5
s.e.	0.367	0.404	0.302	0.321	0.239	0.253

*Scores on 1-9 scale with extreme values of like or dislike.

The specific gravity of the tubers was calculated using the formula:

$$\text{Specific gravity} = \frac{\text{Weight in air} \times 100}{(\text{Weight in air} - \text{weight in water})}$$

(Table 11) Potatoes with a dry matter content of 20-24% are ideal for making French fries, while those with a dry matter of up to 24% are ideal for preparing crisps [48]. Moreover, good quality potatoes should have a specific gravity value of more than 1.080. Potato tubers with specific gravity values of less than 1.070 are generally unacceptable for processing [49]. Potatoes stored at relative humidity of 83-84% increase in specific gravity during storage at both 4.4°C and 12.8 °C. At 90% relative humidity, the specific gravity of tubers remained unchanged in storage to 6 and half months at 4.4°C and 10°C [33]. Trained panellist evaluation was also made for quality of chips and crisps using characters colour, flavour, color, flavor, texture and overall acceptability. The results indicated that in main season production variety Jalenie followed by Tolcha, Zengena, Guassa and Wechecha were highly preferred for their crisping; but all varieties had acceptable quality (Table 11). For chips in the main season production, the most preferred potato variety was Jalenie, followed by Zengena, Guassa and Tolcha. Jalenie from both main and off-season production had the most preferred crisps and chips. As noted above, Jalenie was also the second, next to Digemegn, in its dry matter content and specific gravity both in the main and off-season production. Varieties Tolcha, Zengena, Guassa and Wechecha were equally preferred for their crisping quality. Variety Digemegn, although it had the highest dry matter and specific gravity, was not preferred as much as Jalenie.

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Conflict of interest

No conflict of interest.

References

1. Devaux A, P Kromann, O Ortiz (2014) Potatoes for sustainable global food security. Potato Research 57(3-4): 185–199.
2. Haverkort AJ, Koesveld MJ, van Schepers HTAM, Wijnands JHM, Wustman R, et al. (2012) Potato Prospects for Ethiopia: On the Road to Value Addition. Lelystad: PPO-AGV, Netherlands, Europe, pp. 1-66.
3. (2008) Food and Agriculture Organization (FAO), International year of the potato. Potatoes, nutrition and diets. In: FAO factsheets, Rome, Italy.

4. Scott G, Suarez V (2012) The rise of Asia as the center of global potato production and some implications for industry. Pot J 39(1): 1-22.
5. Ethiopia C (2018) Production Quantity of Major Agricultural National Commodities.
6. Emana B, Nigussie M (2011) Potato Value Chain Analysis and Development in Ethiopia. International Potato Center (CIP-Ethiopia), Addis Ababa, Ethiopia.
7. Bradeen JM, C Kole, Haynes KG (2011) Introduction to potato. In Genetics, Genomics and Breeding of Potato, Enfield, NH: CRC Press/ Science Publishers pp. 1-19.
8. (2013) FAO, Ethiopia: Country fact sheet.
9. Lutaladio N, Castaldi L (2009) Potato: the hidden treasure. Journal of Food Composition and Analysis 22(6): 491-493.
10. Cromme N, Prakash AB, Lutaladio N, Ezeta F (2010) Strengthening Potato Value Chains. Technical and Policy Options for Developing Countries. Food and Agriculture Organization of the United Nations and the Common Fund for Commodities, Rome, Italy.
11. Gebremedhin Woldegiorgis, Staffen Schulz, Baye Berihun (2013) Potato variety development strategies and methodologies in Ethiopia. Seed potato tuber production and disseminations, experiences, challenges and prospects. EIAR and ARARI, 12-14, Bahir Dar, Ethiopia, pp. 45-59.
12. Gildemacher P, Kaguongo W, Ortiz O, Tesfaye A, Gebremedhin W, et al. (2009) Improving potato production in Kenya, Uganda and Ethiopia. Potato Research. Ethiopia.
13. Gebremdhin Wgiorgis, Endale G, Berga L (2008) Introductory remark. In: Root and tuber crops: The untapped resources, Ethiopian Institute of Agricultural Research (EIAR). Addis Ababa, Ethiopia, pp. 1-5.
14. (2015/16) CSA (Central statistical agency), Agricultural sample survey, report on area, production and farm management practice of belg season crops for private peasant holdings. Volume V, Statistical Bulletin 578. Addis Ababa, Ethiopia.
15. (2018) International Potato Center (CIP). CIP Annual Report 2017. Harnessing potato and sweet potato's power for food security, nutrition and climate resilience. Lima, Peru. International Potato Center, p. 47.
16. Hirpa A, Meuwissen MPM, Tesfaye A, Lommen WJM, Oude Lansink A, et al. (2010) Analysis of seed potato systems in Ethiopia. Am J of Potato Res 87(6): 537-552.
17. Bradshaw JE, Bryan GJ, Ramsay G (2006) Genetic resources (including wild and cultivated Solanum species) and progress in their utilization in potato breeding. Potato Res 49: 49-65.
18. Chala G Kuyu, Yetenayet B Tola, Gemechu G Abdi (2019) Study on post-harvest quantitative and qualitative losses of potato tubers from two different road access districts of Jimma zone, South West Ethiopia. Heliyon 5(8): e02272.
19. Gebru H, Mohammed A, Dechassa N, Belew D (2017) Assessment of production practices of smallholder potato (*Solanum tuberosum L.*) farmers in Wolaita Zone, Southern Ethiopia. Agric Food Secur 6(1): 31.
20. Kolech SA, Halseth D, De Jong W, Perry K, Wolfe D, et al. (2015) Potato variety diversity, determinants and implications for potato breeding strategy in Ethiopia. Am J Potato Res 92(5): 551-566.
21. Benyam Tadesse, Fayera Bakala, Lamirot W Mariam (2018) Assessment of postharvest loss along potato value chain: the case of Sheka Zone, southwest Ethiopia. Agric and Food Secur 7: 18.
22. Borgel H (1980) Production, Marketing and Consumption of Potatoes in the Ethiopian Highlands (Holetta, Awassa and Alemaya). Centre for Advanced Training in Agricultural Development, Institute of Socio-Economics of Agricultural Development, Technical University of Berlin, Germany, Europe.
23. Gebremedhin Wgiorgis, Solomon A, Gebre E, Kassa B (2000) Multi Location Testing of Clones in Ethiopia, Ethiopian Agricultural Research Organization, Ethiopia.
24. Tewodros A, Struik PC, Hirpa A (2014) Characterization of Seed Potato (Solamum tuberosum L.) storage, pre-planting treatment and marketing systems in Ethiopia: The case of West Arsi Zone.
25. Mulatu E, Osman EI, Etenesh B (2005a) Improving potato seed tuber quality and producers' livelihoods in Hararghe, Eastern Ethiopia. Journal of New Seeds 7(3): 31-56.
26. Berga L, Hailemariam G, Gebremedhin W, E Hareth, D Lemma (1994) Prospects of seed potato production in Ethiopia. In: Proceedings of the Second National Horticultural Workshop of Ethiopia. Addis Ababa, Ethiopia: Institute of Agricultural Research and FAO, pp. 254–275.
27. Gebremedhin, W Giorgis, Endale G, Kiflu B, Bekele K (2001) Country Profile on Potato Production and Utilization: Ethiopian Agricultural Research Organization (EARO), Holetta Agricultural Research Centre, National Potato Research Program, Ethiopia.
28. Kantor Linda S, Kathy Lipton, Alden Manchester, Victor Oliveira (1997) Estimating and Addressing Americas Food Losses. Economic Research Service, US Department of Agriculture. Food Review 20(1): 2-12.
29. Buys EM, Nortje GL (1997) Horticultural Crops Post harvest handling, Food Industries of South Africa, South Africa.
30. Clark D, Klee H, Dandekar A (2004) Despite benefits, commercialization of horticultural crops. Californian Agriculture 58(2): 89-98.
31. Hengsdijk HW, De Boer J (2017) Post-harvest management and post-harvest losses of cereals in Ethiopia. Food Sec 9: 945-958.
32. Pinhero R (2009) Post-harvest Storage of Potatoes. Advances in Potato Chemistry and Technology, pp. 339-370.
33. Smith O (1987) Potatoes: production, storing, processing. Avi Publishing Company, USA.
34. Elazar R (2004) Marketing: International Research and Development Course on Postharvest Biology and Technology. The Volcani Center, Israel.
35. Salimi K, Afshari RT, Hosseini MB, Struik PC (2010) Effects of gibberellic acid and carbon disulphide on sprouting of potato minitubers. Scientia horticulture 124(1): 14-18.
36. Endale G, Gebremedhin WG, Bekele K, Berga L (2008) Post Harvest Management. In: Root and Tuber Crops: The untapped resources, Ethiopian Institute of Agricultural Research, Addis Ababa, Ethiopia, pp. 113-130.
37. Agajie T, Kiflu B, Chilot Y, Gebremedhin WG (2008) Socioeconomics and technology transfer. In: Root and tuber crops: the untapped resources, EIAR, Addis Ababa, Ethiopia, pp. 131-152.
38. Solomon Yilma, Godfrey SamAggrey W, Breke Tsehai Tuku (1987) Review of Potato Research in Ethiopia. In: Proceedings of first Ethiopian horticultural workshop. Addis Ababa, Ethiopia.
39. Sapers GM, JS Novak, VK Juneja (Eds.) (2003) Washing and sanitizing raw materials for minimally processed fruit and vegetable products, in Microbial Safety of Minimally Processed Foods, FL: CRC Press, pp. 221-253.
40. Fallik E, Aharoni Y (2004) Postharvest Physiology, Pathology and Handling of Fresh Produce. Lecture Notes. International Research and Development course on Postharvest Biology and Technology. The Volcani Center, Israel, p: 30.
41. Johnson SB, Olsen N, Rosen C, Spooner DM (2010) Commercial potato production in North America. American Journal of Potato Research 87: 1-90.
42. Freitas ST, Pereira EIP, Gomez ACS (2012) Processing quality of potato tubers produced during autumn and spring and stored at different temperatures. Horticultura Brasileira 30: 91-98.
43. Hassanpanah D, Hassanabadi H, Azizi Chakherchaman SH (2011) Evaluation of cooking quality characteristics of advanced clones and potato cultivars. American Journal of Food Technology 6: 72-79.

44. Kaur S, Aggarwal P (2014) Studies on Indian potato genotypes for their processing and nutritional quality attributes. International Journal of Current Microbiology Applied Sciences 3 (8): 172-177.

45. Ismail A, Abu Z, Wael AM (2015) Growth and productivity of different potato varieties under Gaza Strip conditions. International Journal of Agriculture and Crop Sciences.

46. Elfnesh F, Tekalign T, Solomon W (2011) Processing quality of improved potato (*Solanum tuberosum L.*) cultivars as influenced by growing environment and blanching. African Journal of Food Science 5(6): 324-332.

47. Dorota D, Rafal Z, Mieczyslaw N, Renata S (2011) Characterization of five potato cultivars according to their nutritional and pro-health components. Acta Scientiarum Polonorum. Technologia Alimentaria, 10(1): 73-80.

48. Wassu Mohammed (2016) Specific gravity, dry matter content, and starch content of potato (*Solanum tuberosum L.*) varieties cultivated in Eastern Ethiopia. East African Journal of Science 10(2): 87-102.

49. Kabira JN, Berga L (2003) Potato processing, Quality evaluation procedure for research and food industry in east and central Africa. Nairobi, Kenya.