DOI: 10.15613/sijrs/2014/v1i1/53853
ISSN (Print): 2349–8919
ISSN (Online): 2350–0999
ScieXplore: International Journal of Research in Science, *Vol 1(1), 16–29, January–June 2014*

Assessment of Post-harvest Losses of Ware Potatoes (*Solanum tuberosum* l.) in Chelia and Jeldu districts of West Shewa, Ethiopia

Misrak Urge[1], Mulugeta Negeri[1], Thangavel Selvaraj[1*] and Girma Gebresenbet[2]

[1]Department of Plant Sciences and Horticulture, College of Agriculture and Veterinary Sciences, Ambo University, Ambo, P.O. Box 19, Ethiopia, East Africa; tselvaraj_1956@yahoo.com

[2] Divisions of Transport and Logistics, Department of Energy and Technology, Swedish University of Agric Sciences, SLU, Box7032:750 07 Uppsala, Sweden

Abstract

Potato is one of the most important food and cash crops in Ethiopia, mostly grown in the Central, Southern and North-Western and Eastern highlands of Ethiopia that accounts for about 83% of the potato production in the country. In Ethiopia, post-harvest losses of horticultural crops may be estimated for about 15 to 70% at various stages. Potato is 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. These losses are also occurred during harvesting, sorting and cleaning, handling and packing, transportation, storage, distribution or marketing and processing in Ethiopia. Therefore, the present study was undertaken to identify the factors responsible and potential losses occurred in the supply and marketing chain of ware potatoes production in Chelia and Jeldu districts of West Shewa Zone, Ethiopia. As the survey results indicates that the post-harvest losses of potato at household (2.5% and 3.79%), transportation (3.83% and 3.98%), sorting loss (5.31% and 4.92%), storage loss (6.07% and 10.08%), restaurant loss (6.88% and 7.14%), retailer loss (8.02% and 7.16%), harvesting loss (13.81% and 10.77%), wholesaler loss (18.65% and 14.78%), and marketing loss (19.41% and 22.21%) in Chelia and Jeldu districts, respectively. Those post-harvest losses of ware potatoes occurred due to infectious diseases and insect pests which mainly initiated due to improper harvesting and handling of potatoes. The collected samples from both districts, the fungal and bacterial pathogens were isolated and identified from infected potato tubers. The fungal and bacterial pathogens were identified into Fusarium solani, F. oxysporum, Penicillium notatum, P. digitatum, Aspergillus flavus, Alternaria solani, Bacillus pumilus, Ralstonia solanacearum, Erwinia caratovora, Pseudomonas aeruginosa and Streptomyces scabies. The insect pests associated with potato tubers were also identified into cut worms and red ants. In order to reduce this all above losses, mechanical harvester should be introduced for proper harvesting of potatoes, so this technology, the harvester should be afforded for the producers by Government within their financial capacity and reduce the harvesting loss. The awareness of the farmers should be also increased, by providing adequate training, so they can produce proper operation during harvesting, transportation, storage and distribution to avoid the contamination of the tubers by bacterial and fungal pathogens.

Keywords: Post-harvest Insect Pests, Post-harvest Diseases, Post-harvest Loss, Ware Potato

1. Introduction

Potato is one of the most important food crops grown in more than hundred countries in the world. The world total production of potato was 321 thousand tons. China ranks 1st while Russia and India ranks 2nd and 3rd in potato production, respectively [13]. Potato is an excellent food source in which the tuber provides high energy and quality protein as well as substantial amount of vitamins and minerals. The protein of potato has high biological value

*Author for correspondence

than proteins of cereals and even better than that of milk. Potato is one of the most important food and cash crops in Ethiopia, mostly grown in the Central, Southern and North-Western and Eastern highlands of Ethiopia that accounts for about 83% of the potato production in the country. Now, Ethiopia is one of the major potato producers in Africa.

Farmers get lower yield mainly due to diseases, pests and sub-optimal fertilization. However, there are many factors which limit potato yield in Ethiopia, which includes: the lack of improved well performing varieties, poor fruit setting due to heavy rains and excessively high temperatures, pests and diseases, of which fungal, viral and bacterial wilt diseases appear to be significant constraints [1], [5]. Many factors other than disease cause yield instability in developing countries. These losses occur during harvesting, sorting and cleaning, handling and packing, transportation, storage, distribution or marketing and processing. In Ethiopian markets wholesale prices at times of peak supply can drop to as little as US $10 per tons. When supplies become excessive, farmers in more remote locations facing high transport costs might be forced to dump their potatoes [8]. Losses after harvest are a major source of food loss in Ethiopia. Agriculture analysis of food aid, food import and food security figures versus post-harvest losses suggest that addressing storage losses could have a significant impact on food security. It has been estimated that losses due to physical wounding, such as cuts and bruises can be as high as 40% in potato. In addition, this facilitates the infestation of potato by diseases and insect pests. *Phytophthora infestans*, *Erwinia* spp. and *Fusarium* spp. are among the microorganisms that cause post-harvest rot in potato (Mayea *et al.*, 1980; Piplani *et al.*, 1983). Potato tuber moth, (*Phthorimaea operculella*) also a major pest of potatoes either in fields or storage, potentially a cause of total crop loss in the form of discards or unfitness of tubers for seed. Farmers also suffered losses of reduced prices for damaged potatoes, or indirectly when they are forced to sell potatoes at low prices to avoid damage [25].

In Ethiopia, post-harvest losses of horticultural crops may be estimated for about 15 to 70% at various stages. 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 [8]. These losses could be occurred during harvesting, sorting, cleaning, handling and packing, transportation, storage, distribution or marketing and processing. 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. Despite the importance of the potato in Chelia and Jeldu districts of West Shewa, the information on post-harvest assessment has not been done so far to estimate the percent losses and their causes. Since the potato is used as main food in these two study districts as part of breakfast, lunch and dinner, therefore, the present study was definitely add value in determining the main factors that causing losses at various stages and for further designing an appropriate management and for the fulfillment of the gaps. Now-a-days, increase in potato farms and potato demands in Ethiopia, need improvement of the quality of seed and ware potatoes production systems which require better information about biotic and abiotic stresses that affect potato yield. This is also important to give advises for the local farmers and/or producers to use the best technological practices that reduces the post-harvest losses in potato. Therefore, the assessment of factors that causes potato post-harvest losses is a paramount and the present study was undertaken to identify the factors responsible and potential losses occurred in the supply and marketing chain of potato production in Chelia and Jeldu districts of West Shewa, Ethiopia and to identify the microorganisms and insect pest losses, the physiological deterioration and mechanical damage of potato tubers in ware houses and also to quantify post-harvest losses of potatoes at different post-harvest operations due to different factors.

2. Materials and Methods

2.1 Description of the Study Areas, Sampling Size and Data Collection

The post-harvest losses of ware potatoes experimental study was conducted at two administrative districts viz. Chelia and Jeldu of West Shewa zone, Oromiya Region of Ethiopia, during the main cropping season on 2012/2013. The altitudes of the surveyed areas, Jeldu and Chelia were between 2800 and 3200 m. a. s. l. and the geographical positions of N08°43.423–N10°12.082 and E037°28.902–040°62.590, respectively. The annual rainfall and the temperature of these two districts, Chelia and Jeldu were 1200–1500 mm and 9–24 °C and 700–1270 mm and 18–32 °C, respectively. In each district, the assessment of post-harvest losses of ware potatoes were conducted at

three localities and totally, six localities were selected viz. Chilanko, Edensa Gelan and Kolu Gelan at Jeldu District and Rafiso Alenga, Ale Hula Dabi and Bilof Keku at Chelia District. The study was carried out between July and May, 2012/13. The data and information's were collected from potato farmers, traders and consumers. The selected respondents and sample size are given in Table 1.

2.1.1 Data Collection from Farmers

In each district, three localities were selected by using purposive data sampling based on farmers' high productivity, wide coverage of farm area, nearest to main road and town. A total of 54 farmers were selected by using randomly data sampling from both districts. From both districts, 9 farmers from each locality were selected by using randomly data sampling. The farmers were selected at 1 km intervals of the road side of potato fields. After potato farms were selected, the samples of potato tubers were sampled randomly by peaking sacks which were full of potato tubers. This occurred, when farmers collect his/her potatoes in 100 kg sacks. By chance the sacks were peaked at 5 m intervals of the potatoes collected in 100 kg sacks and distributed in farm depending on the shape of those fields. For example, W or U shaped sampling was used in the square shaped field. In long narrow field, a zigzag or Z sampling pattern was used. By moving in such like pattern, from the sampled sacks, the losses of potatoes through mechanical and physiological damages with pathogens and insect pests were calculated from 100 kg sacks depending on their weight by using weight balance. Additionally, the information was collected using structured questionnaire which includes: personal information, family size, years of experience and level of education, insect pest and diseases, input used, method, time and stage of harvesting, loss during harvesting, type of packing materials, method of transportation, loss during transportation, loss during marketing, crop storage awareness, type of storage, structures used and for how long stored, loss during storage and degree of post harvest loss of potato. Regarding post-harvest, the causes of the losses were identified from taken samples by the help of Ambo University, Holleta and Ambo Plant Protection Research Center, Ethiopia.

Table 1. Selected respondent of all the studied areas

No	Respondent Category		Number of Respondents		
			Each Locality	Each District	Total
1	Potato farmers		9	27	54
2	Potato Traders	i. Whole sellers	….	6	12
		ii. Retailers	….	6	12
3	Potato Consumers	i. Restaurant owner/ manager	….	6	12
		ii. Household	….	6	12
Total sample size					**102**

2.1.2 Data Collection from Traders

Additionally, losses were assessed in potato storages of the trader's in both districts by using structured questionnaire and personal observation. A total of 24 potato traders were selected using purposive data sampling based on capacity of their storages by taking: 12 wholesalers and 12 retailers. They were interviewed for gathering data and information regarding potato marketing and post-harvest losses. Information were collected using structured questionnaire which include the following information: personal information, family size, years of experience and level of education, insect pest and diseases in storages, method of transportation, loss during transportation, loss during marketing, crop storage awareness, type of storage, structures used and for how long store, loss during storage and degree of post harvest loss of potato.

2.1.3 Data Collection from Consumers

Interviews were held with potato consumers both at household and restaurant levels for assessing post-harvest losses of potato. Hence, a total of 24 potato consumers were selected from both districts using purposive data sampling based on their buying or utilization capacity by taking 12 households and 12 restaurants from both districts and interviewed. Information was collected using structured questionnaire which include the following information: personal information, family size, and level of education, insect pest and diseases in temporary storage, quantity of potato bought, From whom potato bough, how did they consume, how much loss after bought, how much potato rejected during cutting, peeling etc.

2.2 Method of Estimation of Different Post-harvest Losses

In each level of operations, the losses of potatoes were assessed and ranked quantitatively. Field data from different respondents (farmers, traders and consumers)

were collected on quantity basis and post-harvest losses obtained at different operations. The sampled potato farmers were asked through direct interviewing what quantity of potatoes they produced and lost during 2012–13 and also different losses calculated based on their weight in 100 kg sack. Regarding post-harvest losses, farmers were asked how much quantity of potato was lost during each operation (harvesting, curing, sorting etc.).

For example, during harvesting, per-cent of potatoes cuts was estimated as:

Potato cut/total potatoes × 100 = % of potato cuts at harvest.

Farm level storage loss was estimated on the basis of the quantity of potato stored during the storage periods. Different types of storage losses were estimated similarly in terms of quantity of potato stored. Losses were estimated what quantity of potato lost during storage period in terms of total quantity of potato stored. Traders' level losses were estimated by quantifying the quantity of potato loss during one week of trading in terms of potato bought in the same period. During interviewing, the traders were asked what quantity of potato bought and sold in one week. The different types of losses occurred during marketing of potato was estimated in terms of quantity bought in one week. Then the losses at different levels of traders at different marketing operations (transportation, handling etc.) were estimated in terms of quantity bought. Losses at consumers' level were also estimated on the basis of quantity lost in one week in terms of quantity bought in one week. Losses were quantified in weight (kg) and percentage (%) level. Secondary data were also considered and gathered from different reports (Zonal and District level reports, Journal articles, research reports, and internet etc.).

3. Isolation and Identification of Fungal and Bacterial Pathogens

Isolation and identification of fungal and bacterial pathogens were conducted at Ambo Plant Protection Research Center (APPRC) Laboratory, Ambo, Ethiopia. For isolation of fungal pathogens, diseased potato tubers were thoroughly washed in tap water to remove the surface soils and then dried. After dried, the samples were taken from both healthy and diseased potatoes by cut into small portions (about 2mm) and then surface sterilized with 70% alcohol for 1 min. and serially washed in three changes of sterile distilled water and then the four pieces were placed only in each Petri dish of Potato Dextrose Agar (PDA) medium [20]. The plated potato pieces were incubated at 25 °C for 3–7 days. The fungal organisms that grew from them were also sub cultured and further purified on the same medium. The identification of fungal isolates was made by using the Manual for the identification of Fungi [3] and Dematiceous and More Dematiceous; Hyphomycetes [12].

For isolation of bacterial pathogens from diseased potato tubers, about 1 g of the diseased sample was surface sterilized by 1% hypochlorite and macerated in sterile distilled water. Finally, the filtrate was diluted using sterile distilled water and an appropriate dilutions, 0.1 ml aliquots were spread plated in triplicates on pre-dried surfaces of Nutrient Agar Medium and incubated at 36 °C for 48h [4] and the organisms that grew from them also sub-cultured and further purified through repeated streak plating on the same medium. The pure cultures of the isolates were preserved by sub-culturing on nutrient slants at 4 °C for further use. The isolated bacterial strains were identified using various morphological and biochemical methods. Identification was done on the basis of their colony and cellular morphology and culture characteristics on different media, Gram reaction of the isolates was tested by using KOH test [26], motility test [10] and the biochemical tests viz. Cytochrome oxidase [10], Catalase, KOH solubility test [14], Tween 80 hydrolysis [14], Starch hydrolysis [24] and Indole production [24] which were used subjected to various bacterial isolates for their identification [18]. The bacterial isolates were designated as JB_n and CB_n where 'J' represent Jeldu, 'C' Chelia, 'n' numbers and 'B' Bacterium, respectively.

4. Pathogenecity Test for the Selected Fungal and Bacterial Isolates

The healthy potato tubers were obtained from Holleta Research Institute, Holleta, Ethiopia. Initially, tubers appearing healthy and uniform in size (100–120 g) were selected and washed to remove excess soil, surface sterilized in 0.5% sodium hypochlorite solution for 10 min and rinsed in 3 changes of sterile distilled water [22] and air dried. Then the tubers were wounded with a cork borer with a diameter of 4 mm to a depth of 4 mm [23] and inoculated with all of the bacteria cultured on nutrient

broth and incubated at 28°C for 48–72 h. At the first step those bacteria were used for serial dilution preparation. After serial diluted, the bacterial suspension was taken at 10^{-8} level for growing on solid media, by pouring 2 ml of bacterial suspension on nutrient agar through streaking by "L" shaped wire glass rod and incubated at 28°C for 24–48 h. The bacteria grown on nutrient agar medium were added with 10 ml of distilled and sterilized water and bacterial suspension at a concentration 2 ml of 10^{8}cfu/ml inoculated into wound created by means of a cork borer. Each inoculated tuber was placed in polythene bags and incubated at 25°C for 24 h at dark room. After 24 h, it placed at room temperatures for three weeks and examined for rot. Two un inoculated wounded, two un wounded health potato tubers and two wounded and inoculated with 0.5 ml sterile water were used as control. Koch's postulate was performed randomly from infected potato tubers for the isolation of bacterial and fungal pathogens. Finally, the re isolated pathogens were checked by comparing with the initially inoculated pathogens through its cultural, color of spore produced, observation under microscope by using manual, performing biochemical tests namely, oxidase, catalase and KOH solubility test.

4.1 Identification and Determination of Insect Pests Losses of Potato

Information on post-harvest losses of potatoes due to insect pest was collected from selected respondents (farmers, traders and consumers) by using structured questionnaires. Visual assessment for the damage of insect pests were taken randomly at regular interval of 5 km along the main road sides and small roads were also used in order to cover the areas from selected locations in each district and examined for tuber damage. Number of insect pests encountered from each sample was counted by assessing the surface of the tubers and dissecting the tubers those with the insect damage symptoms. 2–3 kg was sampled from each locality or sample sites for examining the insect pests associated with post harvest produces of potato. Some materials such as knife, forceps, killing jars, small boxes, vials and alcohol were used for collection and preservation of specimens and also hand lens and microscopes were used to assist the identification processes. The collected specimens were identified at Ambo University with the help of my main advisor up to genus level.

5. Data Analysis

For the statistical data analyses, SAS version 9.0 was used. The data collected from different sources were analyzed using descriptive statistics (mean, frequency etc). The mean comparisons of the parameters were tested by LSD-test and significance difference level and probability at 5% and simple correlation analysis were made. The results were summarized and presented in tabular and graphical forms.

6. Results and Discussion

6.1 Socio-economic Characteristics of Potato Farmers

6.1.1 Age, family size and level of education

Most of the farmers (55–77) in Chilanko, Edensa Galan and Rafiso Alenga were relatively young and falling in age group of 31–40 years. But in Ale Hula Dabi, Bilof Keku and Kolu Galan, the age group of producers (44–66%) were in the range of 41–50 years. Relatively the higher numbers of old producers (above 41 years) were engaged in potato farming in Chelia than in Jeldu districts. But the higher number of young producers (31–40) was found in Jeldu than Chelia district. The average family size of the sampled potato producers of all the study areas was found to be 6, which is less than of Ethiopia. There were significant differences of the family size among the study areas. Most of the farmers in Ale Hula Dabi (89%), Refiso Alanga (78%), Bilof Keku and Chilanko (67%), Kolu Galan(56%), and Edensa Galan (33%) areas were completed primary level of education up to class 3 to 8. The farmers of Edensa Galan (56%) and Bilof Keku (22%) areas were completed secondary level of education (Class 11–12). The same level of illiterate farmers were found in only Chilanko , Kolu Galan and Rafiso Alenga (11%). The notable number of higher educated producers (Class 9–12) engaged in potato farming in Jeldu (41%) than in Chelia (19%) district, because of relatively, young farmers cultivated potato commercial in this area.

6.2 Ware Potato Production and Productivity in Chelia and Jeldu Districts

6.2.1 Ware potato production seasons and productivity

There are two main potato production seasons in Ethiopia: belg (January to June, short rainy season), meher

(June to December, long rainy season), residual moisture and irrigation based production systems [6]. The majorities of the producers prepared the land in February to March; plant it in April to May and harvest it during July (after 20 days) to September. Thus July (after 20 days) to September is the peak of potato production and marketing seasons which also characterized by low price in Chelia district. But in the case of Jeldu district, the majorities of the producers prepared the land in March to April; plant it in May and harvest it during August to September. Thus August to September is the peak of potato production and marketing seasons, which also characterized by low price in Jeldu district. In Chelia district, due to the producers are only produce the potato in garden, the land size is small compared to the land holding potatoes in Jeldu district. Hence, the area located to potato production is small. During the year 2011/12, the farmers in Chelia district, on average, allocated 0.28 ha to potato, whereas the area allocated to potato in Jeldu district is 1.5 ha. Moreover, the average potato yield is higher in Jeldu (i.e. 38500 kg (38.5 tons/ha)) as compared to 20400 kg (20.4 tons/ha) in Chelia district. Under farmers' conditions, the average yield was reported in Ethiopia for improved seed was between 19 and 38 tons/ha for different varieties at different locations [6].

6.3 Post-harvest Losses of Potatoes at Different Stage of Operations

6.3.1 Post-harvest losses at producers level

Potatoes are semi perishable commodity, which contain more than 70% of moisture. The post-harvest losses of potato at different stages of post-harvest operations at producer level in all the study areas are shown in Tables 2 and 3. Average harvesting loss of all areas was found to be 12.29% of total production, which was 13.81% and

Table 2. Average proportion losses of potatoes at producers' level in different post-harvest operations at Chelia district

	Chelia district			
Particulars	**Bilof Keku**	**Refiso Alanga**	**Alle Hula Dabi**	**Total average mean**
1. Harvesting loss	**15.2**	**12.54**	**13.7**	**13.81**
a. Rotten loss	$2.61^{ghijklm}$	$2.44^{ijklmnop}$	$2.83^{ghijklm}$	**2.63**
b. Insect damage	3.04^{ghijk}	2.99^{ghijk}	3.36^{fghij}	**3.13**
c. Cutting loss	3.50^{efghij}	2.87^{ghijkl}	$2.78^{ghijklm}$	**3.05**
d. Remain under soil	$2.21^{jklmnopq}$	$1.63^{lmnopqr}$	$1.79^{klmnopqr}$	**1.87**
e. Other loss	3.84^{cdefgh}	$2.61^{ghijklmn}$	2.94^{ghijkl}	**3.13**
2. Sorting loss	**5.82**	**4.86**	**5.25**	**5.31**
a. Rotten	1.02^{qr}	1.50^{mnopqr}	1.35^{nopqr}	**1.29**
b. Mechanical damage	$1.89^{klmnopqr}$	1.03^{qr}	1.30^{nopqr}	**1.41**
c. Insect damage	$1.91^{klmnopqr}$	1.30^{nopqr}	$1.60^{lmnopqr}$	**1.60**
d. Greening	1.00^{qr}	1.03^{qr}	$.00^{qr}$	**1.01**
3. Transportation loss	**3.39**	**3.84**	**4.25**	**3.83**
a. Bruise	$2.56^{hijklmno}$	$2.64^{ghijklmn}$	3.03^{ghijk}	**2.74**
b. Tear	0.83^{r}	1.20^{pqr}	1.22^{opqr}	**1.08**
4. Storage loss	**6.23**	**5.98**	**6.02**	**6.07**
a. Rotten	4.98^{abcd}	4.48^{bcdef}	5.02^{abcd}	**4.83**
b. Others (insect, rodent, etc)	1.25^{opqr}	1.50^{mnopqr}	1.00^{qr}	**1.25**
5. Marketing loss	**21.35**	**20.76**	**16.11**	**19.41**
Lack of customer	5.72^{ab}	5.56^{ab}	4.56^{abcdef}	**5.28**
Lack of facility	5.83^{a}	5.17^{abc}	3.94^{cdefg}	**4.98**
Poor handling	4.94^{abcd}	5.31^{ab}	3.67^{defghi}	**4.64**
Lack of information	4.86^{abcd}	4.72^{abcde}	3.94^{cdefg}	**4.51**
Total loss	**51.99**	**47.98**	**45.33**	**48.43**
Mean ± MSE			**0.51**	
CV%			**24.98**	
LSD(0.05)			**1.35**	

Source: Computed from producers survey data.
Means with the same letter(s) are not significantly different for each other and different letters showed significantly difference (P<0.05) by using Tukey's grouping analysis.

Table 3. Average proportion loss of potato at producer's level in different post-harvest operations in Jeldu district

	Jeldu District			
Sampled kebeles	**Chilanko**	**Kolu Galan**	**Edensa Galan**	**Total average mean**
1. Harvesting loss	**9.89**	**10.95**	**11.48**	**10.77**
a. Rotten loss	$1.89^{lmnopqr}$	$2.44^{ijklmnop}$	2.89^{ijklm}	**2.41**
b. Insect damage	$2.22^{jklmnopq}$	$2.11^{jklmnopq}$	$2.11^{jklmnopq}$	**2.15**
c. Cutting loss	$2.00^{lmnopqr}$	$2.06^{klmnopq}$	$2.00^{lmnopqr}$	**2.02**
d. Remain under soil	$2.56^{ijklmno}$	2.78^{ijklmn}	2.89^{ijklm}	**2.74**
e. Other loss	1.22^{pqrs}	1.56^{opqrs}	1.59^{nopqrs}	**1.45**
2. Sorting loss	**4.57**	**4.98**	**5.21**	**4.92**
a. Rotten	1.25^{qrstu}	$2.00^{klmnopqrs}$	$1.80^{lmnopqrt}$	**1.68**
b. Mechanical damage	1.33^{pqrstu}	$1.48^{nopqrstu}$	1.00^{stu}	**1.27**
c. Insect damage	0.99^{stu}	0.50^{u}	1.11^{rstu}	**0.87**
d. Greening	1.00^{stu}	1.00^{stu}	1.30^{qrstu}	**1.10**
3. Transportation loss	**3.31**	**4.65**	**3.98**	**3.98**
a. Bruise	$2.53^{jklmnop}$	3.28^{ij}	2.80^{jkl}	**2.87**
b. Tear	0.78^{tu}	$1.37^{opqrstu}$	1.18^{rstu}	**1.11**
4. Home storage	**10.23**	**10.11**	**9.91**	**10.08**
a. Rotten	7.56^{a}	7.00^{abc}	7.24^{ab}	**7.26**
b. Others (insect, rodent, etc)	2.67^{jklmn}	3.11^{jk}	2.67^{jklmn}	**2.82**
5. Marketing loss	**21.11**	**23**	**22.5**	**22.21**
Lack of customer	6.78^{abc}	6.33^{bcde}	6.44^{abcd}	**6.52**
Lack of facility	5.56^{defg}	5.56^{defg}	6.00^{cdef}	**5.71**
Poor handling	4.33^{hi}	6.00^{cdef}	5.17^{efgh}	**5.17**
Lack of information	4.44^{ghi}	5.11^{efgh}	4.89^{fgh}	**4.81**
Total loss	**49.11**	**53.69**	**53.08**	**51.96**
Mean ± MSE			**0.40**	
CV%			**20.75**	
LSD(0.05)			**1.21**	

Means with the same letter(s) are not significantly different for each other and different letters showed significantly difference (P<0.05) by using Tukey's grouping analysis.

10.77% at Chelia and Jeldu districts, respectively. Average harvesting loss comprised of insect damage (3.13% and 2.15%), rotten loss (2.63% and 2.41%), cutting loss (3.05% and 2.02%), potato remained under soil during harvesting (1.87% and 2.74%), and other losses (3.13% and 1.45%) at Chelia and Jeldu districts, respectively. The average post harvest loss of potato at different stages of post harvest operations at producer level in Chelia district was found to be 48.43% of total production, which is 51.99%, 47.98% and 45.33% at Bilof Keku, Rafiso Alenga and Ale Hula Dabi respectively. Highest and lowest post-harvest loss of potato encountered in Bilof Keku, and Ale Hula Dabi respectively in chelia district. The rank of average harvesting loss was found to be at transportation (3.83%), sorting (5.31%), and storage (6.07%) harvesting (13.81%) and marketing (19.41%) operation starting from the lowest to highest in Chelia district. The average post-harvest loss of potato at different stages of post harvest operations at producer level in Jeldu district was found to be 51.96% of total production, which is 49.11%, 53.69% and 53.08% at Chilanko, Kolu Galan and Edensa Galan, respectively. Highest and lowest post-harvest loss of potato encountered in Kolu Galan and Chilanko respectively in Jeldu district. The rank of average harvesting loss was found to be at transportation (3.98%), sorting (4.93%), and storage (10.08) harvesting (10.77%) and marketing (22.22%) operation starting from the lowest to highest in Jeldu district. Most post-harvest loss was encountered at marketing operation in both districts.

The average post harvest losses of potato at different stages of post harvest operations at farm level in all the study areas were found to be 50.20% of total production, which is 48.43% and 51.96% at Chelia and Jeldu respectively and which higher at Jeldu district. This post-harvest loss results at farm level was the same with post-harvesting loss reported in Ethiopia in earlier studies, which was 30–50 of the produce [15]. Farmers in all the study areas were used traditional tools (sharp spades, hoe and plough by oxen), to harvest and as a result a lot of loss occurs. The harvesting losses of potatoes in all the study areas were due to; potato is generally harvested manually using hoe or plough without mechanical harvester. Harvested potatoes are also not cured to heel the injuries during harvesting, handling and transportation from field to the farmer's home. Average storage loss was 6.07% and 10.08% at Chelia and Jeldu districts respectively (Table 4).

6.4 Post-harvest Losses of Potato during Transportation

Poor transportation which leads to a lot of loss prevails in all the study areas (Table 6). Average transportation loss at both study areas was almost the same, which is 3.83% and 3.98% at Chelia and Jeldu districts respectively. Means of transporting potato from farm to dwelling houses is predominantly done by pack of animal (donkey and horse), human and rarely by truck in both districts (Table 5). Major means of potato transportation to market is on donkey pack and horse pack and also by people. Transportation of potatoes by donkey and horse at this study areas facilitate for the tear and bruise of potatoes by rope. One factor that greatly affects the competitiveness of potato value chain is lack of safe transportation means and equipments [6].

Table 4. Average proportion of post-harvest loss of potato at different post-harvest operations in both Jeldu and Chelia districts at producer's level

Particulars	Districts	
	Chalia	Jeldu
Harvesting loss	13.81[b]	10.77[bc]
Sorting loss	5.31[d]	4.92[d]
Transportation loss	3.83[d]	3.98[d]
Storage loss	6.07[d]	10.08[c]
Marketing loss	19.41[a]	22.21[a]
Total loss	**48.43**	**51.96**
Mean ± MSE	**1.37**	
CV%	**11.67**	
LSD(0.05)	**3.43**	

Means with the same letter(s) are not significantly different for each other and different letters show significantly difference (P<0.05) by using Tukey's grouping analysis.

Table 5. Proportion of producers using different means of transporting and post harvest losses

Means of transportation	Chelia district and its % of respondents			
	B/Keku	R/Alanga	A/H/Dabi	Average total mean
Donkey and Horse	11.11	33.33	44.44	29.63
Human	88.89	66.67	55.56	70.37
Truck	0	0	0	0
Means of transportation	**Jeldu district and its % of respondents**			
	K/ Galan	E/Galan	Chilanko	Average total mean
Donkey and Horse	88.89	66.67	77.78	77.78
Human	11.11	22.22	0	11.11
Truck	0	11.11	22.22	11.11

Source: Computed from producers survey data.

6.5 Post-harvest Losses of Potato during Marketing

Marketing problems cited by farmers in all the study areas. The major problems including, high seed potato price and ware potato sold by low price and lack of cold storage.

6.5.1 Potato Marketing Channels

Marketing channels refers to the routes taken by products from producers to consumers. Potato passes through various channels until it reaches the final consumers in all the study areas.

Channel 1: Producers – Consumers
Channel 2: Producers – Retailers – Consumers
Channel 3: Producers – Wholesalers – Retailers – Consumers

6.5.2 Farmers

Farmers are referred as potato growers in this study. Farmers sell their potatoes to other farmers, wholesalers, retailers and consumers. As the survey result indicates that, the farmers are influenced to sell their potatoes at the peak time by low price due to they lack suitable storage to stay their products for long time to get high profit.

Due to these poor marketing, the average post-harvest losses of potato 19.41% and 22.21% at Chelia and Jeldu districts, respectively (Tables 2 & 3). Additionally, as Jeldu Agricultural Office had been reported in 2008/09, post-harvest loss of seed and ware potatoes encountered approximately, 60% due to lack of marketing.

6.6 Post-harvest Losses of Ware Potatoes at Wholesalers

In both Chelia and Jeldu districts, the majority of the producers directly sold potato to wholesalers. The second larger group of farmers sold the product directly to consumers and retailers. The wholesalers are generally purchased quality potatoes from farmers at primary markets. Generally, the wholesalers have unable to store their potatoes for long time in the cold storage. They simply, store on the ground of their storage warehouse, for one week to one month. In these poor storages, which results post-harvest loss of potatoes? As the survey result indicates that high quantity of ware potatoes loss within four months during distribution (Table 6).

Table 6. Average of post-harvest losses of potatoes in both districts study areas within four months at wholesalers' level (Figures in 100kg sacks)

Particulars	Chelia district	Jeldu district	All areas
A. Quantity bought from farmers within 4 month	1721.02(100)	2073(100)	1897.01
B. Quantity sold	1400(81.35)	1775(85.62)	1587.5
C. Quantity lost (1 + 2)	321.02(18.65)	298(14.78)	309.51
1. Storage loss (a + b + c + d)	**282.02(16.39)**	**245(11.82)**	**263.51**
a. Weight loss	70.66^{b}	68.96^{bc}	69.81
b. Rotten loss	98.95^{a}	94.79^{a}	96.87
c. greening	53.08^{cd}	35.79^{ef}	44.44
d. Bruise	59.33^{bcd}	45.46^{de}	52.40
2. Transportation loss (a + b + c + d)	**39(2.26)**	**53(2.56)**	**46**
a. Weight loss	5.00^{hi}	7.00^{ghi}	6
b. Rotten loss	2.00^{i}	5.00^{hi}	3.5
c. greening	20.00^{fgh}	23.00^{fg}	21.5
d. Bruise	12.00^{ghi}	18.00^{ghi}	15
Mean ± MSE		64.86	
CV%		20.82	
LSD(0.05)		16.48	

Figures in the parenthesis indicates loss as percentage of total quantity bought.

Means with the same letter(s) are not significantly different for each other and different letters show significantly difference (P<0.05) by using Tukey's grouping analysis.

6.7 Ware Potatoes Distribution Channel by Wholesalers

The potato flow system in both districts of the study areas were mapped based on the survey data from producers and wholesalers. The potato flow principally starts from Gojo town for Jeldu district and distributed by Jeldu wholesalers into Dambidolo, Gimbi, Wallega, A/A, Waliso, And Dire Dawa (Figure 1). In the cause of Chelia district, the wholesalers in different rural areas, around the primary marketing place they stores the purchased potatoes and distribute it into Asosa, Wallega, Gimbi, Dambidolo (Figure 2). As the survey result indicates, during these processes, high post harvest loss of potato take places especially within four months including the peak time and temporary storage of potato tubers (Table 6; Figure 1).

6.8 Post-harvest Losses of Potato at Retailers Level

There are several types of retailers supplying potatoes to different segments of the urban population. The retail markets can be grouped into:

- Road side and open markets (gullets), supply low quantity vegetables.
- The central market place, the "Mercato" is the important centre where retailers sale larger quantities of vegetables.
- Private retail stores (Kiosks), sell relatively better quality of produce and
- Few government super markets in big urban cities.

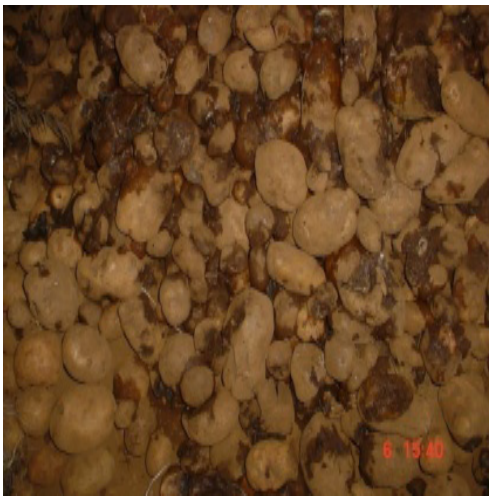

Figure 1. Post-harvest loss of potato at storage operation in Jeldu district (stored for 3 weeks).

They have fixed permanent place in the market. Survey results showed that the retailers buy potato from the producers to sell the product in smaller quantities to the consumers. They bought potatoes where they received the cheapest price because they wanted to make high profit using their small capital. They have business experience range from 1 to 11 years with an average of 5.5 years.

Table 7 showed that, the post harvest loss occurred during the marketing of potatoes by retailers. This occurred due to weight loss, rotten loss, cutting loss and greening loss. The highest loss was found in Chelia (8.02%) and the lowest loss was in Jeldu (7.16%). The average loss of all areas was found to be 7.59% of total potato bought. As the survey result shows, this loss is due to potatoes affected at producers level are easily loss at retailers' level by exposed to high temperature and storing this one at unsafe place.

6.9 Post-harvest Losses of Potato at Consumer's Level

Households and restaurants are the ultimate consumers of potato in the study areas. The loss at restaurant was higher than the loss occurred in household level at both districts. Also, the rotten loss was higher than rejected loss during cutting for both household and restaurant at all study areas (Table 8). Again, relatively the losses at Jeldu district are higher than Chelia district because of many quantities of potatoes are used by restaurants in Jeldu for preparation of potato chips and roasted potato. As the survey result indicates post-harvest loss of potato ranked as household (2.5%), transportation (3.83%), sorting loss (5.31%), storage loss (6.07%), restaurant loss (6.88%), retailer loss (8.02%), harvesting loss(13.81%), wholesaler loss(18.65%), and marketing loss(19.41%) at Chelia and household(3.79%), transportation(3.98%), sorting loss(4.92%), restaurant loss(7.14%), retailer(7.16%), storage loss(10.08%), harvesting loss(10.77%), wholesaler loss (14.78%), and marketing loss(22.21%) at Jeldu districts, respectively starting from lowest to highest. The highest and the lowest post-harvest loss of potato examined at household and marketing level at both districts.

Table 7. Proportion of post harvest losses of potatoes in one week at retailers' level in all the study areas from 100 kg

Particulars	Jeldu	Chelia	All areas
A. Quantity of bought from farmers	100	100	100
B. Quantity sold	92.84	91.98	92.41
C. Quantity lost	7.16	8.02	7.59
Weight loss	2.90[b]	3.42[a]	3.16
Rotten loss	2.30[c]	2.01[d]	2.16
Handling loss	1.20[e]	1.80[d]	1.5
Transportation loss	0.76[f]	0.79[f]	0.78
Mean ± MSE		0.01	
CV%		6.42	
LSD(0.05)		0.23	

Weight loss is the reduction of moisture from the tubers.

Means with the same letter(s) are not significantly different for each other and different letters show significantly difference (P<0.05) by using tukey's grouping analysis.

Table 8. Proportion of post harvest loss of potato at household and restaurant levels in the study areas

Respondents	Chalia	Jeldu	All areas
Household			
Potato bought in a week(kg)	32	39	30.5
Total loss(kg)	**0.8(2.5)**	**1.48(3.79)**	**1.14(3.74)**
i. Rotten loss(kg)	0.45[c]	0.75ab[c]	0.6
ii. Rejected during peeling and cutting (hollow heart)(kg)	0.35[c]	0.73[c]	0.54
Restaurant			
Potato bought in a week(kg)	92	98	95
Total loss(kg)	**6.33(6.88)**	**7(7.14)**	**6.67(7.02)**
i. Rotten loss(kg)	4.00[a]	4.83[a]	4.42
ii. Rejected during peeling and cutting (hollow heart) (kg)	2.33[b]	2.17[b]	2.25
Mean ± MSE		0.35	
CV%		30.51	
LSD(0.05)		1.11	

Note: Figures in the parenthesis indicates loss as percentage of total quantity bought.

Means with the same letter(s) are not significantly different for each other and different letters show significantly difference (P<0.05) by using Tukey's grouping analysis.

7. Isolation and Identification of Pathogenic Organisms from Ware Potatoes

7.1 Bacterial Pathogens

The bacterial isolates were isolated from diseased ware potato tubers as per Gram reaction indicates that the dominance of Gram-negative bacteria. Of the total isolates,

80% was found to be of Gram-negative and the remaining 20% belonged to Gram-positive. Out of 36 samples from 6 localities from both districts, totally, 22 bacterial isolates were recovered from diseased potato tubers. Of the 22 isolates, 14 were not grown on Nutrient Agar Medium, which comprises 4 and 10 from Chelia and Jeldu districts, respectively. Many diagnostic and identification tests were based upon structural and chemical properties of bacteria [21]. The chemical composition of certain substances in bacterial cells can be detected with specific staining techniques. Information about the presence or absence of such substances is used for identification of bacteria [2]. This reflects fundamental biochemical and biophysical differences in the bacterial cell wall.

Brown rot of potato tubers is caused by the bacterium, *Ralstonia solanacearum* was identified. Brown rot symptoms may be present in potato tubers at the later stages of disease. Cross-section of infected potato tubers may reveal a grey-brown discoloration of vascular tissues is also called the vascular ring [16]. As infection progresses, the discoloration may extend into the pith or cortex of the tuber. Milky-white sticky exudates (ooze), which indicates the presence of bacterial cells, might also be observed from freshly-cut sections of infected tubers. The bacterial soft rots of potato tubers are caused by several types of bacteria, but most commonly by species of Gram negative bacteria, *Erwinia* and *Pseudomonas* and also by Gram positive bacterium, *Bacillus pumillus*. Disease spread can be caused by simple physical interaction between infected and healthy tissues during storage or transit. The disease can also be spread by insects [2]. Potatoes experience a cream to tan colored tuber that becomes very soft and watery. A characteristic black border separates the diseased area and the healthy tissue. Only when the secondary organism invades the infected tissue does that decay become slimy with a foul odor [17].

7.2 Pathogencity Test of the Selected Strains of Bacterial Pathogens

The pathogencity test of selected strain of bacterial pathogens was tested in two potato varieties, namely, Gudane and Jalene (Figure 2) Significant variances were obtained between potato varieties in response to infection with inoculated and spayed bacterial isolates Potato variety, Jalene was the more susceptible to isolated bacterial infection (58% soft rot severity produced).

Figure 2. Pathogenecity test in two potato varieties viz. Gudane and Jalane.

The inoculated bacteria were consistently isolated from the diseased plants again to prove Koch's postulates. After it's subjected to biochemical tests namely, oxidase test, catalase test and KOH solubility test, it gives the same results with the previous tests.

7.2.1 Fungal Pathogens

From the two districts, Out of 36 sampled potato tubers from 6 kebeles, totally six species belonging to four genera of fungi were recorded. Three species of fungi were unidentified, 17 samples were observed dry rot disease of potatoes caused by different *Fusarium* species. 11 samples were infested by different species of *Penicilium* and *Aspergillus* and 5 samples of potatoes were infested by early blight caused by *Alternaria solani* (Table 9). However the causative agents mentioned here were not the only species found on cultivation media, but the higher colony forming units of these species comparative to other fungal species, and the symptomatology of the fungal disease in these potatoes helped to designate them as the actual causative agents of the disease.

7.3 Identification and Determination of Insect Pests Associated with Post-harvest Loss of Potato Tubers

Two species of insects, which belongs to the family Formicidae and Noctuidae were found as highly caused post-harvest losses of potato tubers in different areas of Chelia and Jeldu districts (Table 10). Among these two families, Noctuidae was observed to loss and cause more

Table 9. Fungal species recorded from diseased potato tuber samples of Chelia and Jeldu districts

Type of Pathogen	Chelia district			
	B/Keku	R/Alenga	A/H/Dabi	Total
Total samples taken	6	6	6	**18**
Unidentified	–	1	–	**1**
Fusarium solani	1	2	2	**5**
Fusarium oxysporum	1	2	1	**4**
Alternaria solani	–	1	1	**2**
Penicilium notatum	1	-	1	**2**
Penicilium digitatum-	1	2	–	**3**
Aspergillus flavus	–	1	1	**2**
Type of Pathogen	**Jeldu district**			
	Chilanko	**E/Gelan**	**K/Gelan**	**Total**
Total samples taken	6	6	6	**18**
Unidentified	–	1	1	**2**
Fusarium solani	3	–	1	**4**
Fusarium oxysporum	2	1	1	**4**
Alternaria solani	2	–	1	**3**
Penicilium notatum	1	1	–	**2**
Penicilium digitatum-	1	1	–	**2**
Aspergillus flavus	–	–	–	**–**

Note: – denotes not obtained fungal species.

Table 10. Presence of insect pests associated with potato tubers in both districts study areas

District	Kebele	Habitat	Average (%) post-harvest loss of potato tubers from 100kg by insect pests.		Total
			Red ants (Dorylus spp.)	Cutworms (Agrotis spp)	
Chalia	Bilof Keku	Potato farm	1.04	2	3.04
	Ale Hula Dabi		1.36	2	3.36
	Rafiso Alenga		1	1.99	2.99
	Total average mean		**1.13**	**2**	**3.13**
Jeldu	Chilanko		1	1.22	2.22
	Kolu Galan		0.95	1.16	2.11
	Edensa Galan		0.50	1.61	2.11
	Total average mean		**0.82**	**1.33**	**2.15**

damage onto potato tubers in both two districts study areas. Red ants were widely distributed in most study areas. Almost all of the farmers in Jeldu and Chalia districts, who were interviewed during a survey, responded that the pest is very problematic in wet fertile soils. They affect potato tubers by making holes and tunneling into potato tubers (Figure 3. A, B & C). They cause economic losses due to damaged potato tubers which were not used for market purpose. Crowe et al. [11] reported that the red ants (*Dorylus spp*.) have a very serious pest on vegetable crops grown at high altitudes. The cut worms (Agrotis spp.) were widely distributed in almost all the study areas in both districts. As the survey result indicates that in Jeldu and Chalia districts, the cut worms are caused highest cause of post-harvest losses of potato tubers (Figure 3. B & C).

7.4 Post-harvest Disorders of Ware Potatoes

Hollow heart of potatoes has symptoms that range from slight brown discoloration at the centre of the tuber to larger cavities (Figure 3. D). Hollow heart is caused by cell death in response to stresses that occurred early in the tuber's development. The major stresses include inconsistent moisture levels, uneven fertility, and variable air and soil temperatures. Low potassium levels have also been linked to hollow heart [7]. Brown center and hollow heart effects likely form during tuber initiation but could also form during tuber bulking [9], 1998). As the survey result indicates, average hollow heart loss of potato rejecting during peeling and cutting at consumers level were 2.68% and 2.90% in Chelia and Jeldu districts, respectively. The growth cracks are large, irregular cracks that form on the tuber (Figure 3. E & F). It is an external non-infectious physiological disorder of the potato tuber in which the tuber splits while growing. Even though cracking does not usually predispose the tuber to rotting, growth cracks can negatively impact potato tuber quality. Growth cracks make fresh-market tubers unattractive. Growth cracks form due to fluctuating environmental conditions, such as uneven soil moisture, soil and air temperature, and rapid water uptake and tuber growth [19]. Growth cracks increase when relatively poor growing conditions are rapidly followed by relatively good growing conditions, such as prolonged moisture stress or high temperatures followed by excessive irrigation or rainfall. In both study areas the farmers are not considered the cracked potato as a loss; however, this is wrong perception, due to crack result decreases marketing value of potato. As the survey result indicates at both study areas, the average cracked of potato 9% and 12% were counted at producers level in Chelia and Jeldu districts respectively. Additionally, as Jeldu and Chelia Agricultural Office had been reported in 2011/12, post harvest loss of ware potatoes due to cracking was encountered approximately, 10% and 14.% in Chelia

and Jeldu districts respectively. The exposure of potato tubers to light either in the field, in storage, on the store shelf, or at home, will induce the formation of a green pigmentation on the surface of the potato (Figure 3. G & H) which is called "greening". Consumers associate greening with the tubers being 'poisonous'. While chloroplasts and the chlorophyll within are not themselves are poisonous, the increase with greening coincides with the production of nitrogenous steroidal triglycerides called glycoalkaloids. The two key compounds are solanine and chacocine and they are most likely present as a defense against consumption by both vertebrate and invertebrates pests [7]. As the survey result indicates, average greening loss of ware potato encountered after harvesting at sorting level were 1.10% at both districts.

8. Conclusions

The highest and the lowest post-harvest loss of potato examined at household and marketing levels at Chelia (19.41%) and 2.5%),) and Jeldu (22.21% and 3.79%) districts, respectively. The average storage loss was 6.07%

Figure 3. A. Red ants damaged in ware Potatoes. B & C. Cut worms making holes and tunneling into potato tubers.

Figure 3. D. Hollow heart and brown center loss of potato rejected during cutting. E & F. Cracked loss of ware potato.

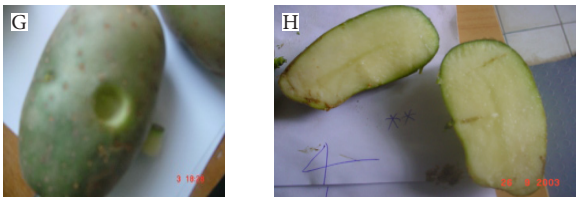

Figure 3. G & H. Greening of ware potato by exposed to sun light in field of potato farm. Figure 6 Potato damaged by red ants, cut worms and post harvest disorders.

and 10.08% at Chelia and Jeldu districts, respectively. The average harvesting loss at both districts was found to be 12.29% of total production, which was 13.81% and 10.77% at Chelia and Jeldu districts respectively. Average harvesting loss comprised of insect damage (3.13% and 2.15%), rotten loss (2.63% and 2.41%), cutting loss (3.05% and 2.02%), potato remained under soil during harvesting (1.87% and 2.74%), and other losses (3.13% and 1.45%) at Chelia and Jeldu districts, respectively. In order to reduce this all above losses, mechanical harvester should be introduced for proper harvesting of potatoes. So this technology, the harvester should be afforded for the producers by Government within their financial capacity and reduce the harvesting loss. The awareness of the farmers should be also increased, by providing adequate training, so they can produce proper operation during harvesting, transportation, storage and distribution to avoid the contamination of the tubers by bacterial and fungal pathogens.

9. References

1. Adane H., Miranda M., Willemien J. M., Alfons O.L., Admasu T., and Paul C., "Analysis of seed potato systems in Ethiopia", *American Journal of Potato Research,* vol. 21, p. 45–56, 2010.
2. George N. A., Ed. *Plant Pathology.*, Academic Press, New York, U.S.A., 2005.
3. Barnett H. L., *Illustrated Genera of Imperfect Fungi.*, Department of Plant Pathology, West Verginia University, Morgan Town, Burgess Pub. Co., Minn., 2nd Edition., 1960.
4. Bathily H., Babana A. H., and Samake F., *Laboratory of Research in Microbiology and Microbial Biotechnology*. Faculty of Science and Technology, University of Bamako, Bamako, Mali BPE 3206, 2010.
5. Bekele B., Abate E., Asefa A., and Dickinson M., "Incidence of Potato viruses and bacteria wilt disease in West Amhara Region of Ethiopia", *J. Plant Patho.l*, vol. 93, p. 149–157, 2011.
6. Emana B., and Nigussie M., *Potato value chain analysis and development in Ethiopia in case of Tigray and SNNP regions,* International potato center (CIP-Ethiopia), Addis Ababa, Ethiopia, 2011.82.
7. Pringle B., Bishop C., and Clayton R., Ed. CAB International, Potatoes Post-harvest, North America, 2009.
8. Borgel H., *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. 1980.

9. Christ B. J., *Identifying Potato Diseases in Pennsylvania,* Penn State College of AgriculturaL Sciences, Web 11 Jan 2012.
10. Collins C. H., and Lyne P. M., *Microbiological Methods: Laboratory techniques series,* UK Press, Baltimore, London, 1976.
11. Crowe J. T., and Medhin S. H., Ed. *Crop Pest Hand book*, Institute of Agricultural Research, Addis Ababa, Ethiopia, 1985.
12. Ellis M. B., *Dematitious Hyphomycetes, Common Wealth of Mycological Institute*, Kew, Surrey, England, 1971.
13. FAOSTAT, Potato World: Production and Consumption. Internal Year of the Potato 2008, Available: http://www.potato2008
14. Fahy P. C., and Hayward A. C., Media and Methods for Isolation and Diagnostic Test In: Fahy P. C. and Persley G. J. (eds.) *Plant Bacterial Disease –A diagnostic guide*, Academic Press, Sidney, Australia, 1983.
15. Endale G. W., Gebremedhin K., Bekele and Lemaga B., Post Harvest Management. In*: Root and Tuber Crops: The untapped resources,* (eds). Wolde Giorgis G. M., Endale G., and Lemaga B., 113–130. Addis Ababa: Ethiopian Institute of Agricultural Research, Ethiopia, 2008.
16. Elphinstone J. G. The current bacterial wilt situation: a global overview. In: *Bacterial wilt disease and the Ralstonia solanacearum species complex.* (eds.) C. Allen, P. Prior, and A. C. Hayward, APS Press, St-Paul, M. N., 2005**.**
17. Elphinestone J. G., "Soft Rot and Blackleg of Potato. Technical Informational Bulletin", 21 Aug 1987.
18. Goszczynska T., Serfontein J. J., and Serfontein, S. *A Manual for Phytobateriology: Introduction to Practical Phytobacteriology,* SDC, Switzerland, 2000.
19. Hiller L. K., and Thornton, R. E., Managing physiological disorders. In: *Potato Health Management: Plant Health Management Series*, (eds.) Johnson D. A., St. Paul, MN: The American Phytopathological Society, 2008.
20. Johnson M., and Sekhar V .C., *Principles of Plant pathology. Practical Manual.* Acharya N. G. Ranga Agricultural University, Kassa, Bekele and Berga Lemaga, 1993, Research on bacterial wilt of potato in Ethiopia, In: PRAPACE workshop on bacterial wilt of potato caused by *Pseudomonas solanacearum*, Bujumbura, Burundi, 2012.
21. Lelliott R. A., and Stead D. E., Methods for the Diagnosis of Bacterial Diseases of Plants. In: *Methods in Plant Pathology,* vol. 2, T. F. Preece Series, British Society of Plant Pathology, Blackwell Scientific Publications, Oxford, 1987.
22. Lui L. H., Vikram A., Abu-Nada Y., Kushalappa A. C., Raghavan G. S. V., and AlMughrabi K., "Volatile metabolic profiling for discrimination of potato tubers inoculated with dry and soft rot pathogen", *Am. J. Potato*., vol. 18, p. 34–45, 2005.
23. Peters J. C., Lees A. K., Cullen D. W., Sullivan L., Stroud G. P., and Cunnington A. C., "Characterization of *Fusarium* spp. responsible for causing dry rot of potato in Britain", *Plant Pathol*., vol. 57, p. 262–271, 2008.
24. Sands D. C., Physiological Criteria –Determinative tests, In: *Methods in Phytobacteriology* (eds.) Klement, Z., Rudolph, K., Sands, D.C. Academia Kiado and Nyomda Vallalat, Budapest, 1990.
25. Sileshi G., and Teriessa J., "Tuber damage by potato tuber moth, (*Phthorimaea operculella*) and Zeller (*Lepidoptera: Gelechiidae*) in the Field in Eastern Ethiopia". Int. J. Pest Manag., vol. 47(2), p. 109–113, 2001.
26. Suslow T. W., Schroth M. N., and Isaka M. "Application of a rapid method for Gram differentiation of plant pathogenic and saprophytic bacteria without staining". *Phytopathology*, vol. 72, p. 911–918, 1982.