Value chain improvement of fresh sweet potato through the utilization of mechanical harvester

Edgar D. Flores*, Renita S.M. Dela Cruz

(*Philippine Center for Postharvest Development and Mechanization, 3120 CLSU Compound Science City of Munoz, Nueva Ecija, Philippines*)

Abstract: The study determined the postproduction handling systems, losses and the needed intervention to improve the fresh sweet potato chain. Surveys were conducted among 350 sweet potato farmers in four major sweet potato producing provinces supplemented by the key informant interviews, focus group discussion and on-line search of secondary data. Actual loss assessments were undertaken adapting the tracing method and following two commercial marketing channels replicated 6 times for each marketing channel. The total average postharvest loss was 32.09%. Among the postproduction operations, quantity losses during harvesting were the highest at 15.96% and 17.94% for Bataan and Tarlac, respectively. Along the fresh sweet potato market chain, the farmer contributes the highest percentage share (41.63%) to the retail price on a per kilogram basis of fresh sweet potato. A potential technology intervention to address observed problems in harvesting operation, which contributes 53% to the overall postharvest losses, is the introduction of tractor-mounted conveyor-type digger to reduce losses and labor cost. Initial technical and financial performance indicated that the machine can reduce harvesting loss and increase farmer's income by PhP23, 408 to PhP28, 936 ha. Reducing the harvesting loss can increase the quantity of fresh sweet potato available for sale by 2076 to 2316 kg ha^{-1}. Pilot testing of the technology should be done to evaluate its technical and financial viability as well as its social acceptability among sweet potato farmers.

Keywords: Sweet potato, postproduction losses, value chain, mechanical harvester

Citation: Flores, E. D., and R. S. M. D. Cruz. 2017. Value chain improvement of fresh sweet potato through the utilization of mechanical harvester. Agricultural Engineering International: CIGR Journal, 19(4): 159–169.

1 Introduction

Sweet potato (*Ipomoea batatas* L.) is the seventh most important food crop in the world in which majority of world's production share is coming from China, followed by Nigeria and Uganda. Among the 82 developing countries, 40 countries consider sweet potato as the fifth most important food crop produced annually (Elameen et al., 2008). On the ASEAN block, Philippines also entered the list with production share of 0.50 percent which made the country as number nineteen top sweet potato producing country in the world (FAOSTAT, 2015; Flores et al., 2016). Sweet potato is usually produced in sub-tropical and tropical countries by small farmers with limited land, labor, and capital (Claessens et al., 2009). It is usually planted in less productive soils with restricted supply of water. Despite of these conditions, sweet potato contains more calories than any other major food crop like rice or wheat (Horton, 1988). The roots and leaves of sweet potato are both used for human and animal consumption as well as raw material for production of starch, organic acids, and alcoholic beverages (Woolfe, 1992). Fresh roots are also a good source of vitamins and minerals but less in protein and fats. Because of its nutritional value, sweet potato is becoming more important both in research and industrial applications (Bovell-Benjamin, 2007).

In the Philippines, sweet potato is one of the most important crops after rice and maize, in many areas. The crop is included as a priority among the root crops in the country. Currently, the Philippine government through

Received date: 2017-02-04 **Accepted date:** 2017-05-09

*** Corresponding author: Edgar D. Flores,** Philippine Center for Postharvest Development and Mechanization (PHilMech), 3120 CLSU Compound, Science City of Muñoz, Nueva Ecija, Philippines. Email: egaydulayflores@yahoo.com.

the Department of Agriculture (DA) is advocating the production and consumption of sweet potato. It is believed that sweet potato plays a major role in realizing the country's goal towards food self-sufficiency. Sweet potatoes like any other crops are exposed to post-harvest losses during harvesting, transportation from farm to market. These losses are mainly due to physical damage, weight reduction, sprouting, pests and diseases (Woolfe, 1992; Mtunda et al., 2001; Rees et al., 2001) and improper post-harvest handling systems that lead to both qualitative and quantitative losses. Freshly harvested sweet potato roots have high respiratory rate that releases both heat and moisture that would eventually soften its texture. Sweet potato is considered highly "perishable" commodity because once it is detached from the plant it can no longer be stored for a long period of time (Wagner et al., 1983; Mtunda et al., 2001; Rees et al., 2001).

Postharvest loss is a measurable quantitative and qualitative loss of a product during the postharvest chain and includes the change in the availability, edibility and wholesomeness of the product that prevents its consumption (Troger et al., 2007). Both quantitative and qualitative losses of extremely variable magnitude occur during post-harvest stages, from producers until its final delivery to the consumers. Furthermore, improper post-production practices result in losses due to spoiling and deterioration in appearance, taste and nutritional value of the product before reaching the market. Such improper practices risk the marketability of the product, lower the prices and shorten the storage period of the products (Turan, 2008 as cited by Buyukbay et al., 2011). It was reported that losses during harvest, preparation for market, transportation and marketing of fruits and vegetables vary from 15 to 50 percent (Ozcan, 2007; Nuevo and Apaga, 2010) and could be up to 65 percent due to either loss in fresh weight or root rot between one and four months of storage (Kone, 1991). Post-harvest losses have already been recognized as one of the reasons that reduce food supply to the increasing population. Though the focus of the government is more on increasing production to provide the need of the growing population, post-harvest loss reduction is another area that leads to increase food availability.

Currently, there is no information on the post-harvest loss of fresh sweet potato in the Philippines. In addition, there are no available data on the specific points in the post-harvest system of fresh sweet potato where majority of losses occur. Hence, this study was designed to assess the losses in post-harvest handling of sweet potato as basis for providing appropriate loss reduction technology to enhance the supply chain of fresh sweet potato. Specifically, the study sought to determine and describe the post-production handling systems of fresh sweet potato; assess the nature and magnitude of post-production losses from farm to retail market level; determine the cost and net income shares of different stakeholders; determine the potential technology intervention that can reduce the magnitude of loss in the most problematic sweet potato post-harvest operations; and determine the potential effects of the proposed intervention in improving the post-harvest operation of fresh sweet potato.

2 Materials and Method

2.1 Framework of the study

Figure 1 shows the schematic diagram of activities undertaken to attain the objectives of the study. Identification and development of post-harvest and mechanization interventions that are appropriate to the needs of concerned farming actors require information on the specific constraints/gaps in sweet potato production.

The required preliminary data were gathered following the value chain framework and since sweet potato is a highly perishable commodity, post-harvest losses in every segment of post-harvest operation were also assessed. The immediate outputs of the study are recommendations on strategies that will reduce post-harvest losses as means of improving the fresh sweet potato chain as well as knowledge products that will be used in education and extension activities. The potential effects of proposed interventions and/or strategies will be more availability of sweet potato for sale and increased income due to reduce losses.

2.2 Postharvest handling system of fresh sweet potato

The data and information were obtained from both primary and secondary data sources. A total of 350 farmer-respondents were randomly selected and interviewed from sweet potato producing provinces of Albay (110), Bataan (100), Northern Samar (80) and Tarlac (60). Other needed information was also obtained through online search of secondary data, key informant interviews (KII) and focus group discussions (FGD). Interviews were done with selected respondents who are very much familiar, knowledgeable and immersed in the production of sweet potato such as the farmer-leaders, key officials of Department of Agriculture (DA), Local Government Units (LGUs) and traders (i.e. wholesaler, retailers, viajeros, agents/middlemen).

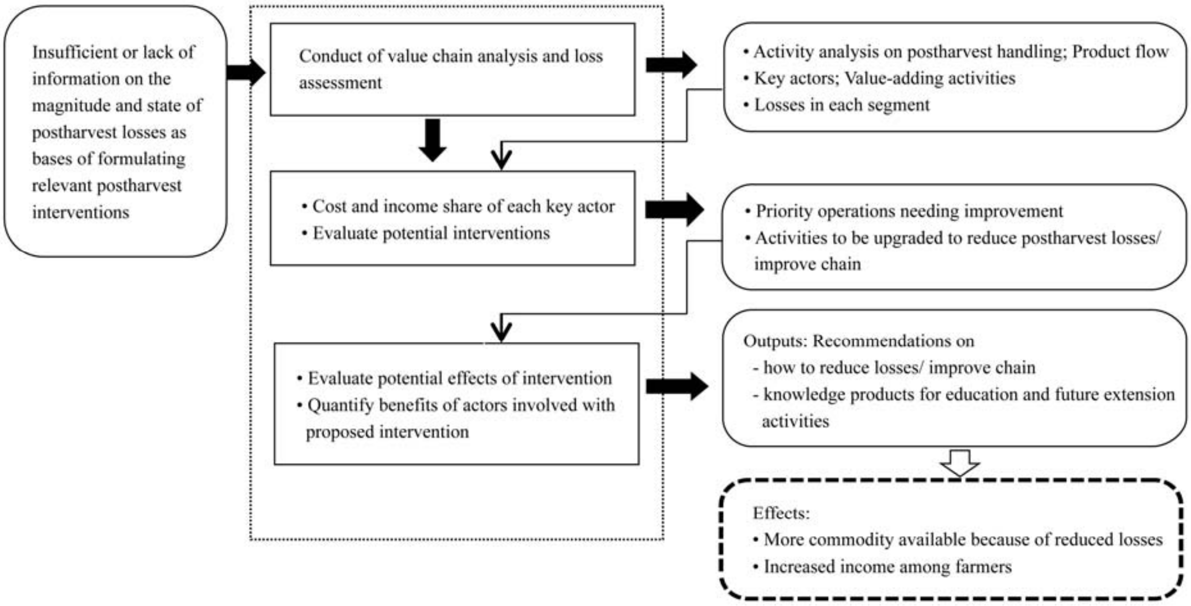

Figure 1 Schematic diagram of the activities undertaken to generate the objectives of the study

2.3 Qualitative and quantitative post-harvest loss assessment

Actual loss assessment studies for sweet potato were done in the provinces of Tarlac and Bataan where majority of sweet potato is grown for commercial market. A one shot run of loss measurement per identified sweet potato route was conducted with 6 samples per operation per route. Loss assessments were done following two routes, treating the routes as replicate for a given post-production operation. The assessment of losses of sweet potato (both qualitative and quantitative) began from harvesting in the farm to marketing at retail market level.

Qualitative losses due to physiological changes that make the appearance, taste or texture of the sweet potato less desirable to the consumers were determined. Visual quality rating (*VQR*) and quality profile (*QP*) were used in determining the quality loss at the determined points of the commodity flow. Five to ten percent of the stocks were subjected to *VQR*. The *VQR* scales and its description are summarized in Table 1. Rating scale and descriptions were based on the quality standards set by Bureau of Agricultural Statistics (BAS, 2014) and Fishery Products Standards (BAFPS) and validated with traders and retailers. The average rating for the samples monitored was calculated using Equation (1) (PhilMech and UPLB, 2009).

$$VQR = \frac{(Wc)(Rc) + ...(Wc) + (Rc)}{Total\ weight\ of\ \ the\ samples} \quad (1)$$

where, Wc = weight of the commodity per rating scale and Rc = rating of the commodity.

QP is a method of evaluation where the general quality of the harvested produce is described by its frequency or percentage of defects or damage present. The degree, extent or description of the quality defects or damage, e.g. bruises, compressions, rotting, etc. were evaluated and classified as pre-harvest and postharvest defects (Table 2).

Table 1 Rating scale used in *VQR* of samples for sweet potato

Scale	Description
5	Excellent condition, fresh, minor defects (which will include insect infestation, physical damage, injury)
4	Fair moderate defects
3	Minimum level of marketability
2	Minimum limit of edibility
1	Non-edible

Table 2 Quality traits used in describing quality profile (*QP*) of sweet potato

Stage of occurrence	Sources of damage	Defects
Pre-harvest (damage manifested during harvest)	• Wireworm • Weevil • Fertilizer	• Wireworm infested • Weevil infested • Fertilizer damage
Postharvest	• Mechanical • Pathological • Physiological	• Bruises, cuts, skinning • Soft rot, skin • Shriveling, sprouting

Quantitative losses due to the reduction in weight (e.g. spillage, moisture loss, etc.) of the total produce from farm to retail market were determined. The measurements of losses were determined from differences of the initial and final weight of the whole sample produce stock. Weight loss (*WL*) at the end of each postharvest operation was calculated using Equation (2) (PHilMech and UPLB, 2009).

$$WL(\%) = \frac{Initial\ weight - final\ weight}{Initial\ weight} \times 100 \qquad (2)$$

where, *WL* is the weight loss in percent; initial weight and final weight are the sample weights before and after a period of observation, respectively. Period may refer to time or operation.

Farm level. Observations and documentations were conducted during harvesting of sweet potato roots and its sub-operations (e.g. field gathering, sorting, etc.). Harvest compositions and losses were determined from the three sampling areas representing 10 percent of the total harvested area. Assessment of produce such as marketable, non-marketable and rejects was immediately done after field gathering. Each observation samples were randomly selected from the marketable stocks and labelled for *VQR* and *QP* analysis in the succeeding chain until it reached the retail market level. The packing techniques, practices, distances travelled and the road conditions were observed. Prior to trading, the hauling of harvested sweet potato roots from farm to the farmer's house or near access road for picking-up by the trader was done using a tractor-trailer with capacity of 20 bags (90 to 100 kg bag^{-1}) per load.

Trader level. From the farmer's house, sweet potato roots were hauled and transported using forward truck in an ambient condition. The quantity and quality of the observation samples was determined immediately after transporting to the intended market to assess losses during loading, transportation and unloading of sweet potato.

Wholesale level. Upon reaching the wholesale level, the samples were unloaded manually from the truck. The observation samples were weighed and subjected to visual quality (*VQR* and *QP*). Sweet potato at the wholesale level can be marketed 3 to 15 days after harvesting (DAH) or 1 to 12 days of stay at the wholesale level. At the wholesale level, the sweet potato roots were temporarily stored in the warehouse at an ambient condition before it is brought to the retail market stall.

Retail level. The quantity and quality assessments were undertaken on the observation samples upon reaching the retail level and on subsequent days of retailing until samples were completely disposed. At the retailer level, the sweet potato roots were displayed in an ambient condition.

2.4 Costs and net income shares

The information on the production cost and returns of sweet potato were based on the prevailing cost of inputs and labor and the price of sweet potato in 2015. The value addition undertaken by each actor along the chain was highlighted. The cost and income share of each actor was determined adapting the work of Lantican et al. (2011).

2.5 Evaluation of potential technology intervention

Potential technology intervention was evaluated for the identified postharvest operation where the highest losses occur. Partial budget analysis was used to determine and quantify the benefits and cost associated in adopting the new technology versus traditional or existing method.

3 Results and Discussion

3.1 Commodity Flow and Key Actors Involved in Production

Figure 2 shows the flow of fresh sweet potatoes from the farmers of the four major producing areas to the retail markets in Metro Manila and other adjacent regions. Among the sweet potato producing provinces, Tarlac and Bataan commercially produce sweet potato which reaches central markets like Divisoria, Balintawak, Tanauan-Batangas and Pasig City. Most of the sweet potatoes from Albay and Northern Samar are sold within the province. This study assessed the production of sweet potatoes in commercial scale considering the Bataan-Divisoria and Tarlac-Tanauan City market channels.

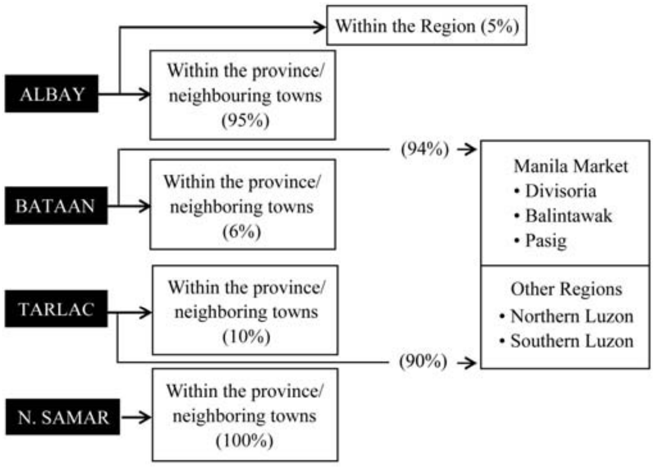

Figure 2 Commodity flow/handling route of sweet potato produced in Albay, Bataan, Tarlac and Northern Samar, 2014-2015

The activities undertaken by the major actors involved in the commercial type of sweet potato production are shown in Figure 3. Generally, harvested sweet potato passes many intermediaries from farmers to consumers. In the production of fresh sweet potato, farmers are the main producers, having the time, land and inputs to plant, grow, harvest (vine removal, soil digging, gathering and piling), sort and grade, haul harvested sweet potato to nearest area accessible for pick-up and sell sweet potato to the traders (e.g. agent, assembler, wholesaler, retailers).

The buyer or trader of sweet potato roots from the farmer-producer can be a "viajero", wholesaler or assembler/consolidator. Most traders usually have the time, access to vehicle, connections to wholesaler and financial capital. Among the traders, the assemblers/ consolidators usually have permanent stalls in the market where wholesalers pick-up the products for distribution to retailers. The wholesaler buys the produce from the trader and usually has a warehouse near or within the market where the retailers pick-up the sweet potatoes for market to local buyers/consumers. Commercial farmers with their own trucks bypass the traders and bring sweet potatoes directly to assemblers or to wholesalers. In Bataan, freshly harvested sweet potato are picked by the traders (agents) from the farms and brought to assemblers/wholesalers in central markets (e.g. Balintawak, Divisoria).

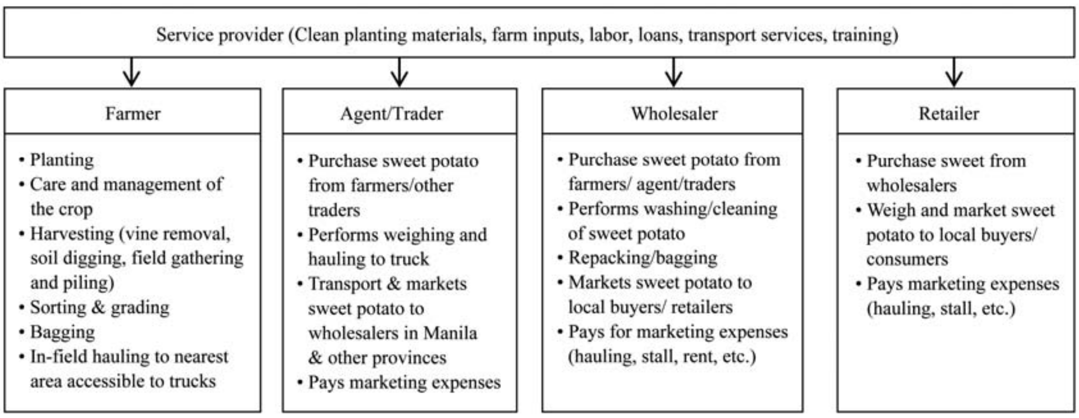

Figure 3 Major actors involved and their functions in commercial type of sweet potato production, 2014-2015

3.2 Postproduction Handling of Fresh Sweet Potato

At the farmer level, the postproduction operations of sweet potato for commercial purposes involves the cutting of vines, digging of roots, field gathering and piling, sorting, bagging, in-field hauling and marketing.

Harvesting

Harvesting is one the most critical part of the postproduction and marketing operations of sweet potato. Harvesting of sweet potato for commercial purposes involves vine cutting, digging of the roots, and field gathering and piling. Harvesting of sweet potato is by digging the roots, requiring 30 to 50 laborers to harvest one hectare in a day. Harvesting can be done in two ways: staggered and single harvesting. Single harvesting involves the harvesting of sweet potato farm in one batch where the vines are totally removed and the production area is plowed or dug. In staggered harvesting only marketable size roots are collected on the first three harvesting before the vines are finally removed and plowed at the fourth harvest while one-time or single harvesting is practiced by farmers selling sweet potato in commercial scale.

The percentage of farmers practicing the two methods of harvesting is shown in Table 3. Across the four provinces, 46 percent of the farmer-respondents practice staggered harvesting. Almost all of the farmers from Albay (90%) and Northern Samar (95%) practice staggered harvesting while all the farmers from Bataan and Tarlac practice one-time harvesting.

Table 3 Type of harvesting sweet potato by farmers in four producing provinces, 2014

Type of harvesting	Albay	Bataan	Tarlac	N.Samar	All provinces (N=350)
Staggered	90.00	-	-	95.00	46.00
Single	10.00	100.00	100.00	5.00	54.00

Vine removal.

Vine clearing is the removal of sweet potato vines prior to soil digging. This is commonly done manually to facilitate soil digging. The labor requirement for vine clearing is estimated to be 11 person-days/ha. About 18.0 tons of fresh sweet potato vines can be recovered per hectare.

Soil digging

Soil digging is exposing the roots from the soil through digging. This can be done by using any sharp or hard rod or stick; or by passing once or twice with single plow drawn by animal or two plows drawn by tractor (commonly done in single-type harvesting).

In Tarlac and Bataan, sweet potato farmers are using moldboard plow that can be dragged by an animal or a four wheel tractor with the laborer holding and guiding the direction of the plow. The Sapang Multipurpose Cooperative (MPC) in Moncada, Tarlac tried to fix the two moldboard plows at the hitch of the four wheel tractor to exclude the laborers following the plows. However, the system did not materialize because the tractor-operator tends to look back and check if the ridges for digging are hit or not. As such, more roots are cut and left under the ground. Under this condition, improvement in digging efficiency can be done by mechanizing planting. The furrows served as guide for the tractor-operator to dig the sweet potato rows. It was observed that more damage occurs when the farmers plow or dig tubers manually during harvesting. Aside from being time consuming, manual digging can cut and even splits sweet potato roots into pieces.

It was observed that existing moldboard plow used in digging/uprooting of sweet potato did not expose all the roots and could not remove buried sweet potatoes in the soil. This limitation in the present practice can be a potential entry point to reduce loss.

Field gathering

Field gathering is the collection of exposed sweet potato roots and piling them at central location for sorting. This is done after soil digging or uprooting operation. Spacing of piles depends on the number of assigned laborers.

Sorting and grading

Preliminary sorting is the separation of good and removal of rejects from the harvested roots while grading is classifying the collected roots according to the present market grade. This operation is done in the farm by laborers hired by the trader. Sweet potatoes are graded according to size of the diameter. The Philippines has a size classification standard for sweet potato by PNS-BAFPS. These are: 1st tier (*primera* or good) are those roots classified as large (7.1 to 9 cm dia) and extra-large (7 to 10 cm dia), 2nd tier (*segunda* or medium) are those roots classified as medium (5.1 to 7 cm dia), third tier (*tersera* or small) are those roots classified as small (3 to 5 cm dia) and the fourth tier (*imut-imut* or *kalatong*) are those classified as very small (less than 3 cm diameter).

Bagging

In farm, sweet potatoes are bagged or packed in polypropylene woven sacks before hauling. The weight of a bag of sweet potato varies per study sites. In Bataan and Tarlac, the usual weight of bag is 100 kg with some farmers opting to have 50 kg per sack.

In-field hauling/transportation

Pre-sorted/pre-graded sweet potatoes in bags are transported from farm to more accessible roads for pick-up by traders. Hauling is usually done by trucks. Sweet potato farms that are not accessible to four-wheel transport, used carabao-drawn sled, single motorcycle, hand tractors, or four wheel tractor-drawn trailer.

Washing

Washing of sweet potato is done at the wholesale level. It is usually done within the vicinity of the warehouse. Washing is done twice. The first washing removes the soil from the surface by soaking and with the aid of both feet (with or without rubber boots) loosen the soil from roots. Water replacement is done after three sacks or when around 300 kg of sweet potato roots have been washed. The second washing is done in concrete tanks (usually on warehouses that is distant from the intended market support). The roots are brushed manually to remove remaining dirt. Warehouses are either within the market such as in Tanuan Public Market and on case-to-case basis in Divisoria Public market.

Packaging

At the wholesale level, washed and graded SP roots usually packed in 10-kg capacity polyethylene (PET) bag before trading.

3.3 Qualitative and Quantitative Loss Assessment

Table 4 shows the quantitative loss of sweet potato for Bataan-Divisoria and Tarlac-Tanauan routes. The total average postproduction system's loss of fresh sweet potato from harvesting to 7 days of retailing was 32.09 percent. Highest loss was observed at the farmer-producer level (17.77%) followed by the retailer (10.39%) and wholesaler (3.93%). From producer, fresh sweet potato was directly traded and delivered by the agent-trader to the wholesaler. Thus, losses at the agent-trader level were nil.

Table 4 Quantitative loss in the postproduction handling system of fresh sweet potato, Bataan-Divisoria and Tarlac-Tanauan, Batangas routes, 2014-2015

Supply market route	Percentage of fresh weight				Total loss
	Farmer-Producer	Agent/Trader	Wholesaler	Retailer (7 days)	
Bataan-Divisoria	17.12	0.00	1.89	12.20	31.21
Tarlac-Tanauan	18.42	0.00	5.97	8.58	32.97
Average	17.77	0.00	3.93	10.39	32.09

At the farmer-producer level, majority of the total losses came from the roots that were uncollected and those that were mechanically damaged during harvesting. Table 5 shows the harvesting loss at the farmer-producer level in Bataan and Tarlac with 15.96% and 17.94%, respectively. Bataan farm has comparatively higher uncollected roots (14.60%) compared to Tarlac (7.19%). The potential contributing factor to the gap might be the difference in soil type. Bataan has a sticky clay loam type, while Tarlac has a sandy loam type of soil. In terms of mechanical damaged during harvesting (roots that were cut and/or plow during harvesting), Tarlac has higher mechanical damage (10.75%) than Bataan (1.36%). Differences might be due to the variation in harvesting practices and size of harvested sweet potato roots. Sweet potatoes in Tarlac had bigger sizes than Bataan which could be due to the soil type and crop management practices. It was observed that bigger sizes of roots were easily hit by the pointed tooth of the plow especially when the implement could not cut the soil deeper than the roots of the sweet potato plants.

Table 5 Harvesting loss at the farmer-producer level in Bataan and Tarlac, 2014-2015

Type of losses	Bataan	Tarlac
	Percentage of Fresh Weight	
Uncollected roots	14.60	7.19
Mechanically damaged roots	1.36	10.75
Total Harvesting loss	15.96	17.94

The quality of sweet potato samples for Bataan-Divisoria and Tarlac-Tanuan City routes are shown in Figure 4. The observation was done until all the sweet potatoes are disposed by the retailers to consumers.

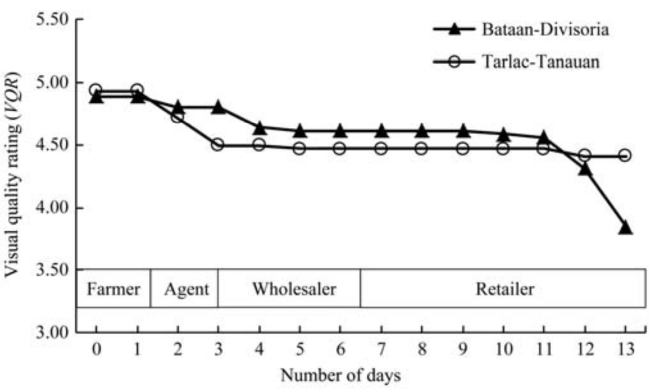

Figure 4 Visual quality rating (*VQR*) of fresh sweet potato from farm to retail level, 2014-2015 (Scale of 5, excellent condition; 3, minimum level of marketability)

For Bataan-Divisoria route, the observed *VQR* rating decreased from 4.89 to 3.85 (7 days of stay at the retail level). The reasons of quality deterioration were due to skinning, bruising and shriveling. Skinning and bruising of the samples were initially monitored in the farm and on the wholesale level during hauling, loading and unloading. Shriveling of the samples was monitored 5^{th} to 7^{th} days on the retail level. At this period, sprouting with two or more sprouts was already observed. There were no pathological defects observed.

For Tarlac-Tanauan route, the observed VQR decreased from 4.93 to 4.41. As in the case of Bataan-Divisoria route, skinning and bruising of the samples was also observed in farm and on the wholesale level. Despite of the observed quality deterioration, both the sweet potato samples of the two routes were still traded as good quality by the retailer to the consumers. These observed defects did not affect the market value of the commodity because traders do not consider roots with bruises and skinning injury unacceptable. Though traders are unaware of this, the advantage of low bruises and skinning injuries would be an extended shelf life (Ndunguru et al., 2000).

3.4 Costs and Net Income Shares of Major Actors

The cost and net income shares of four players (farmer, agent-trader, wholesaler and retailer) involved along the marketing channels of Bataan-Divisoria and Tarlac-Tanauan in handling sweet potato roots were determined and summarized in Table 6. In terms of net income, the farmer-producer is the top earning actor (4.76 PhP kg^{-1}) but considered as the most vulnerable to price fluctuation (as the selling price is dependent on the agent-trader's decision) and to production-related factors such as deterioration in quality brought about by insect pest infestation and losses during harvesting. In all the players, the trader has the lowest net income (2.02 PhP kg^{-1}) but can generally be assumed as the safest player from price fluctuation and quantity loss as the selling price to wholesaler is set first before setting the buying price from the farmer. The retailer is the second top earner with 4.28 PhP kg^{-1} and net income share of 14.83% next to farmer (16.50%). Retailer shares the risk of higher postharvest loss being at the end of the chain and has the second highest cost share (15.67%).

The farmer contributes the highest percentage share (41.63%) to the end price of fresh sweet potato on a per kilogram basis. While he gets the highest share of income per kilogram, he also shoulders the highest cost of producing the commodity.

Under the situation, addressing the major constraints in postharvest operations undertaken by the farmers will improve the chain and will alleviate the financial conditions of the farmers. Reducing the harvesting loss and at the same time bypassing intermediaries will increase the profit of the farmers (Imtiyaz and Soni, 2013).

Table 6 Cost and net income shares of different chain actors along Bataan-Divisoria and Tarlac-Tanauan marketing channels, 2014-2015

All Routes	Farmer	Trader	Wholesaler	Retailer	Total
Costs, PhP kg^{-1}	7.25	1.24	1.87	4.52	14.88
Net Income, PhP kg^{-1}	4.76	2.02	2.91	4.28	13.97
Cost share, % of selling price	25.13	4.30	6.48	15.67	51.58
Net Income share, % of selling price	16.50	7.00	10.09	14.83	48.42
Total, %	41.63	11.30	16.57	30.50	100.00

Note: PhP 1.0 = 0.020 US Dollar.

3.5 Identifying of Potential Technology Intervention

Among the major operations in the postharvest handling system of fresh sweet potato, the harvesting operation at the farmer-producer level provided the highest percentage share of the total postharvest losses. To effect an immediate improvement in the chain, the identification of potential technology intervention in harvesting was prioritized. In addition to the loss due to direct effects of harvesting method such as the unrecovered and mechanically damaged roots, delayed in harvesting due to limited labor predispose the roots to weevil infestation. It is therefore imperative to mechanize to facilitate harvesting.

As a proof of concept, a tractor-mounted conveyor-type digger (Figure 5) which is being used for white potato was validated to assess its applicability and performance in addressing reduction of losses on uncollected and damaged sweet potato during harvesting.

In commercial scale farms, the most common power source during harvesting are the tractor-drawn two plows and carabao-drawn single plow in Tarlac and Bataan, respectively. Tractor-mounted conveyor-type digger can speed up the whole harvesting operation by decreasing time allocation for digging and gathering thereby reducing the labor requirement for harvesting. Since majority of the farmers in Bataan and Tarlac are using 16 to 20 hp four-wheel type tractors for their land preparation, a conveyor-type digger designed for hitching to four wheel type tractor was fabricated and used in the evaluation. The blade has 0.60 m width enough to accommodate a single ridge of sweet potato in a web conveyor with a length of 1.5 m. The depth of cut was set beyond the typical 20 cm depth of sweet potato roots to reduce mechanical damage such as cuts during harvesting. The web conveyor is made of slatted stainless round bars connected to chain on both sides which elevates the soil and sweet potato roots during soil digging. During the digging, the soil is taken off on slatted round bars while the sweet potato roots move by web rotation to the rear of the digger and drop the sweet potato roots to the ground for easy hand picking.

Figure 5 Four wheel tractor-drawn conveyor-type potato digger

3.5.1 Viability of using a mechanical root crop harvester

Tarlac case. Harvesting system in Tarlac using tractor-drawn plows guided by two laborers incur harvesting loss of 17.94% due to uncollected/unexposed and mechanically damaged roots. The use of mechanical root crop harvester as an intervention can potentially reduce uncollected roots to 2.60%. This will result to increased quantity of sweet potato that can eventually reduce the unit cost of producing the commodity. It can also reduce labor cost with the replacement of two laborers guiding the plows. The use of tractor-mounted conveyor-type digger can generate an additional income of 28,396.08 PhP/ha/season for the farmers (Table 7).

Table 7 Partial budget analysis of harvesting sweet potato using mechanical root crop harvester as intervention, per hectare, Tarlac, 2015

Mechanical root crop harvester VS Tractor-drawn plows			
Additional Returns	Amount, PhP	Additional Costs	Amount, PhP
Recovered loss	27,796.08		
Sub-total Add Returns	27,796.08	Sub-total Add Costs	0.00
Reduced Costs	Amount, PhP	Reduced Returns	Amount, PhP
Reduced labor cost	600.00		
Sub-total Red Costs	600.00	Sub-total Add costs	0.00
Change in Benefits	28,396.08	Change in Cost	0.00
Net Change	28,396.08 PhP ha^{-1}		
Assumptions:			
Total Area, ha	= 1.00		
Yield per hectare, kg/ha	= 15,100		
Farmgate price, PhP/kg	= 12.00		
Harvesting loss			
No intervention at 17.94% loss =	2,708.94 kg ha^{-1}	valued at 32,507.28 PhP ha^{-1}	
With intervention at 2.60% loss =	392.60 kg ha^{-1}	valued at 4,711.20 PhP ha^{-1}	
Difference =	2,316.34 kg ha^{-1}	valued 27,796.08 PhP ha^{-1}	
Service fee			
No intervention =	Tractor plus 2 plow operators	3,600.00 PhP ha^{-1}	
With intervention =	Tractor – harvester	3,000.00 PhP ha^{-1}	
	Difference:	600.00 PhP ha^{-1}	

Note: PhP 1.0 = 0.020 US Dollar.

Bataan case. Similarly, harvesting in Bataan using carabao-drawn plows had harvesting loss of 15.96% due to uncollected and mechanically damaged roots. Under the Bataan soil condition, the tractor-mounted conveyor-type digger as an intervention had harvesting loss of 3.75%. With reference to the carabao-drawn source, tractor-mounted conveyor-type digger will have additional cost due to higher service fee but can be negated by the additional returns coming from reduced losses (Table 8) thereby the use of tractor-mounted conveyor-type digger can provide additional income of 23,408.40 PhP/ha/season.

3.5.2 Viability of investing and operating a mechanical root crop harvester

The viability indicators of investing and operating a mechanical root crop harvester to be used for custom hiring are shown in Table 9.

With an investment cost of 215,251.29 PhP, total annual area coverage of 67.50 ha/yr of sweet potato farms and harvesting fee of 3000 PhP ha^{-1}, the estimated net present value (NPV), Internal Rate of Return (IRR), benefit-cost ratio (BCR) and payback period (PBP) was 435,106.78, 58.08 PhP, 1.66% and 1.79 years, respectively. The estimated IRR of the technology is higher than the 12% interest rate in commercial bank for loans showing a good financial performance. A potential operator of the technology could invest borrowing the needed capital from a bank at interest rate of 12% and realize positive net benefits and eventually recover his investment in 1.79 years.

Table 8 Partial budget analysis of harvesting sweet potato using mechanical root crop harvester as technological intervention, per hectare, Bataan, 2015

Mechanical root crop harvester VS Carabao-drawn plow			
Additional Returns	Amount, PhP	Additional Costs	Amount, PhP
Recovered loss	24,908.40	Service fee	1,500.00
Sub-total Add Returns	24,908.40	Sub-total Add Costs	1,500.00
Reduced Costs	Amount, PhP	Reduced Returns	Amount, PhP
Sub-total Red Costs	0.00	Sub-total Add Costs	0.00
Change in Benefits	24,908.40	Change in Cost	1,500
Net Change	23,408.40 PhP /ha		
Assumptions:			
Total Area, ha	= 1.00		
Yield per hectare, kg	= 17,000		
Farmgate price, PhP	= 12.00		
Harvesting loss			
No intervention, at 15.96 % loss =	2,713.20 kg ha^{-1}	valued at 32,558.40 PhP ha^{-1}	
With intervention , at 3.75 % loss =	637.50 kg ha^{-1}	valued at 7,650.00 PhP ha^{-1}	
Difference =	2,075.70 kg ha^{-1}	valued at 24,908.40 PhP ha^{-1}	
Service fee			
No intervention	3 carabao plus 3 plow operators	1,500.00 PhP ha^{-1}	
With intervention	Tractor – harvester	3,000.00 PhP ha^{-1}	
	Difference:	(1,500 PhP ha^{-1})	

Note: PhP 1.0 = 0.020 US Dollar.

Table 9 Financial performance of mechanical root crop harvester, Bataan case, 2015

Financial Indicators	
Investment cost	215,251.29
Fixed cost, P/year	54,285.18
Variable cost, P/year	73,525.73
Total operating cost	127,810.91
Gross income, P/year	202,500.00
Net income, P/year	74,684.09
Payback period, years	1.79
Internal rate of return (IRR), %	58.08
Benefit - cost ratio	1.66
Return on Investment (ROI), %	46.00
Net present value @ 12% , PhP	435,106.78
Breakeven hectarage, ha/year	28.41
Breakeven service charge, PhP ha^{-1}	1,893.49

Note: PhP 1.0 = 0.020 US Dollar.

4 Conclusions and Recommendations

Postproduction losses along the supply chain of fresh sweet potato from farm to retail level was 32.09%. This is largely contributed by the harvesting loss due soil digging inefficiency of the existing harvesting methods in the study areas. Cost and net income share analysis showed that sweet potato farmer contributes the highest percentage share to the retail price on a per kilogram basis of fresh sweet potato. The farmer gets the highest share of income but also shoulders the highest cost of producing the commodity. Addressing the major constraints in post-harvest operations undertaken by the farmers will improve the chain by reducing the unit cost of producing sweet potato. At the same time, it will improve the financial conditions of the farmers by reducing the losses thereby increasing available commodity for sale. Tractor-mounted conveyor-type digger as technological intervention can reduce losses of uncollected and damaged roots. Technical and financial analysis showed favorable results from the viewpoints of both the technology users and operators. Pilot testing of mechanized harvesting of sweet potato should be done to further assess its technical and socio-economic viability.

Overall, the results of this study would serve as guide for other researchers and concerned agencies/institutions in identifying problem areas for action and applied research. This can also guide the policy makers to provide measures/policies for loss reduction. Furthermore, this will enhance awareness on the need to provide appropriate assistance/technologies for the improvement of handling system of sweet potato production.

Acknowledgement

The authors would like to express their sincerest gratitude to the Philippine Center for Postharvest Development and Mechanization (PHilMech), Department of Agriculture, Philippines for funding this research undertaking.

References

BAS. 2014. *Production volume of sweet potato.* Philippines: Department of Agriculture.

Bovell-Benjamin, A. C., 2007. Sweet potato: a review of its past, present, and future role in human nutrition. *Advances in Food and Nutrition Research*, 52(06): 1–59.

Buyukbay E. O., M. Uzunoz and H. S. G. Bal. 2011. Post-harvest losses in tomato and fresh bean production in Tokat province of Turkey. *Scientific Research and Essays*, 6(7)1656–1666.

Claessens, L., J. J. Stoorvogel, and J. M. Antle. 2009. Ex ante assessment of dual-purpose sweet potato in the crop-livestock system of western Kenya: A minimum-data approach. *Agricultural Systems*, 99(1): 13–22.

Elameen, A., F. Siri. A. Larsen, O. A. Rognli. I. Sundheim, and S. Msolla. 2008. Analysis of genetic diversity in sweet potato (*Ipomoea batatas* L.) germplasm collection from Tanzania as revealed by AFLP. *Genetic resources and Crop Evolution*, 55(33): 397–408.

FAOSTAT. 2015. FAO Statistics Division. Available at: www.fao.org/faostat/en/ Accessed 16 May 2016.

Flores, E. D., R. SM. Dela Cruz, M. C. R. Antolin, D.O. Tesorero and G.F.Aninipot. 2016. Benchmark studies on postharvest handling system of sweet potato (*Ipomoea batatas L.*) Unpublished terminal report. Philippine Center for Postharvest Development and Mechanization, Science City of Muñoz, Nueva Ecija, Philippines

Horton, D. 1988. *Underground Crops: Long Term Trends in Production of Roots and Tubers.* Morrilton: Winrock International.

Imtiyaz, H., and P. Soni. 2013. Supply chain analysis of fresh guava (A case study). *Global Business and Management Research: An International Journal*, 3(4): 373–382.

Kone, S. 1991. Traditional methods for prolonged storage of sweet potatoes in Mali. *Gate (Eschborn)*, 2: 14.

Lantican, F., A. R. Elepano, and K. P. Quilloy. 2011. *Policy Issues: Strategies Directions for Improving Grains Supply Value.* Laguna, Philippines: College of Economics and Management, UPLB.

Mtunda, K., D. Chilosa, E. Rwiza, M. Kilima, H. Kiozya, Munisi R., Kapinga R. and D. Rees. 2001. Damage reduces shelf-life of sweet potato during marketing. *African Crop Science Journal*, 9(1): 301–307.

Nuevo, P., and A. R. M. Apaga. 2010. Technology Reducing Postharvest Losses and Maintaining Quality of Fruits and Vegetables (Philippines), In *Proceedings of 2010 AARDO Workshop.* (Philippines), 154-167. Taiwan, ROC, 3-9 October

Ozcan, M. 2007. Affects on Quality and Durability of Harvest and Post-Harvest Practices in Horticultural Products. Available at: www.carsambaziraatodasi.com Accessed 6 May 2016.

PNS-BAFNS.95-2010. ICS 67.080.01. Philippine National Standards for Fresh Vegetables-Sweet potato-Classification and grading. Bureau of Product Standards, Department of Trade and Industry.

PhilMech and UPLB. 2009. Qualitative and quantitative loss assessment of selected high value food crops. Unpublished terminal report. Munoz, Nueva Ecija: Philippine Center for Postharvest Development and Mechanization.

Rees, D., R. Kapinga, K. Mtunda, D. Chilosa, E. Rwiza, M. Kilima, H. Kiozya, and R. Munisi. 2001. Damage reduces both market value and shelf life of sweet potato: a case study of urban markets in Tanzania. Tropical Science, 41(3): 142–150.

Troger, K., O. Hensel, and A. Burkert. 2007. Conservation of Onion and Tomato in Niger - Assessment of Post-Harvest Losses and Drying Methods. In *Conference on International Agricultural Research for Development, University of Kassel-Witzenhausen and University of Gottingen*, 1-7. Germany, 9-11 October.

Turan. 2008. Post-harvest Practices on Fruits, 12: 3, July-August, (in Turkish).

Wagner, A. B., E. E. Burns, and D. R. Paterson. 1983. The effect of storage systems on sweet potato quality. *HortScience*, 18(3): 336–338.

Woolfe, J. 1992. *Sweetpotato: An Untapped Food Resource*. Cambridge, UK: Cambridge University Press.