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FACULTY OF AGRICULTURE

SWEETPOTATO [*Ipomoea batatas* (L) Lam] ROOT QUALITY: ASSESSMENT OF PACKAGING CONTAINERS FOR TRANSPORT IN GHANA

BY

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DECLARATION

CANDIDATE'S DECLARATION

I hereby declare that this thesis is the result of my own original work and that no part of it has been presented for another degree in this University or elsewhere.

Candidate's signature…………………………... Date…….……………………..

Name: Mr. Sampson Alhassan

SUPERVISOR'S DECLARATION

I hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the University for Development Studies.

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ABSTRACT

Sweetpotato root packaging and transport are very important value chain activities in the marketing of the fresh produce. This study investigated the sweetpotato storage root packaging and transportation from aggregation centres to urban markets in Ghana. A structured questionnaire was administered to sweetpotato root aggregators at Bawku (Upper East regions) and Afram Plains (Eastern region). A follow-up transport experiment was conducted to compare two proposed containers (50 kg-polypropylene sack and 50 kg-wooden crate) with existing packaging containers (polypropylene and jute sacks packed about 130 kg) for the transportation of sweetpotato roots from major aggregation sites (Bawku and Afram Plains {Adawso}) to distant urban markets (Bittou, market centre in Burkina Faso and Accra respectively). Root mechanical quality indices (breaks, bruises and cuts), impact, visual acceptance and benefit cost ratio (BCR) were evaluated. Polypropylene and Jute sacks were the commonly used packaging containers to transport sweetpotato in Ghana. Most aggregators (81 %) in Bawku transport their sweetpotato roots to Bittou. Tricycles (Motorkings) and donkey-drawn carts are the common mode of transport of sweetpotato for the Bawku-Bittou route whiles market trucks are used for the Afram Plains (Adawso)-Accra route. A paired-sample t-test comparison showed a significant increase in major ($p = 0.028, 0.016$) and minor ($p = 0.001, 0.034$) breakages in the existing polypropylene before and after transport for both year one and two for the Afram Plains (Adawso)-Accra route in a hired truck. The 50 kg-packaging containers delivered much higher percentage of *None* broken roots to the urban market compared with the existing containers. Apart from 50 kg-wooden crates that

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delivered about a quarter of none-bruised roots to the urban market, the other containers resulted in total bruised roots. The average impact recorded at both loading and offloading sites was significantly ($p = 0.006$) lowest in 50 kg-wooden crate, a fifth for the impact of the roots in the existing polypropylene (75 g), being the highest. Rank means for visual assessment by consumers for the roots contained in the 50 kg-wooden crates ($p < 0.0001$) was highest in year one; and the 50 kg-polypropylene ($p = 0.003$) in year two and lowest for existing polypropylene in both years. Although the wooden crate was superior in protecting roots from impact and bruising, it was less profitable, hence it was not included in year two study. Transporting roots in 50 kg-sized sacks (BCR = 1.44, 1.28) may lead to higher profit for aggregators and delivery of more wholesome roots at the urban market.

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DEDICATION

I dedicate my achievement through this research to my lovely wife, Mary Alhassan and my parents, Rev. and Pastor (Mrs). David Alhassan Zakaria. I really appreciate your support and encouragement.

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ABBREVIATIONS AND ACRONYMS

BCR: Benefit cost ratio

Major_agg. Site: Major breaks, bruises or cuts at aggregation site

Major_mkt: Major breaks, bruises or cuts at market centre

Minor_agg. Site: Minor breaks, bruises or cuts at aggregation site

Minor_mkt: Minor breaks, bruises or cuts at market centre

None_agg. Site: None occurrence of breaks, bruises or cuts at aggregation site

None_mkt: None occurrence of breaks, bruises or cuts at market centre

OFSP: Orange-fleshed sweetpotato

WFSP: White-fleshed sweetpotato

PFSP: Purple-fleshed sweetpotato

YFSP: Yellow-fleshed sweetpotato

TR: Total revenue

TC: Total cost

IN: Internal necrosis

Nd: Not defined

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Organization of chapters

Chapter One consists of the background of the study, problem statement and justification, overall objective and specific objectives. Chapter Two contains the review of relevant literature related to the study. Chapter Three explains the methodology employed for the study. It emphasizes the study location, and specifications of tools used, methods used and data analysis. Chapter Four consists of all the findings of the transport survey and the transport experiment, results are presented in graphs and tables. Chapter Five is made up of the discussion of the results, both transport survey and experimental results generated from the study. Chapter Six contains the summary, conclusions, recommendations for future study and the limitations drawn from the research.

1.2 Background

Sweetpotato (*Ipomoea batatas* L. Lam) is an important root crop capable of mitigating food insecurity in the sub region because of its relatively ease of cultivation (van Oirschot *et al*., 2003). It is a hardy crop that can give good yields even under marginal soil conditions (Agbemafle *et al.*, 2014). Sweetpotato exist in varied fleshed colours, ranging from; white, cream, yellow, purple and orange. The white and cream-fleshed cultivars are mostly cultivated and consumed in Ghana. However, the purple and orange-fleshed cultivars possess superior health

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benefits. Owing to this, the production of sweetpotato, particularly the orange-fleshed is being encouraged in Ghana (Teye *et al*., 2011a).

In terms of production areas and output, slightly over a third and a quarter of total sweetpotato production (132,000 metric tonnes per year) comes from Upper East and Eastern Regions, respectively (MOFA, 2012). Fresh storage roots from these major production areas are transported to the national capital, Accra, in the case of Eastern region and in the case of the Upper East region production, sweetpotato storage roots are exported to neighbouring country, Burkina Faso ('Bittou' market).

Meanwhile, farmers and aggregators incur huge losses due to transport and poor post-harvest handling undermining the market value of the product. Postharvest losses of food crops in Ghana are estimated at 30% annually (Nyanteng & Asuming-Brempong, 2003). Such losses occur at harvest, handling, transportation, storage and processing (Affognon *et al*., 2014). For sweetpotato storage roots, losses resulting from post-harvest handling, and transport were reported to be 20 and 86% respectively (Tomlins *et al*., 2000). Although these losses appear to be inevitable during handling and transportation, considerable care must be taken to minimize them to ensure extensive utilization of food crops (Atanda *et al*., 2011) such as sweetpotato.

Sweetpotato storage roots are highly susceptible to mechanical damage once they are harvested or when not harvested timely (Owori & Agona, 2003). Mechanical damage to sweetpotato storage roots during handling may include cuts, abrasions, and bruises, depending on the physics and configuration of the surfaces involved (Edmunds *et al.*, 2008). As skinning damage occurs, the underlying cells of a skinned area desiccate and die (Legendre, 2015). Furthermore, desiccated and depressed areas are unappealing to consumers thereby reducing the market value of the product.

During loading and off-loading of sweetpotato storage roots, sacks are often dropped resulting in high impact which causes breakages (Tomlins *et al.*, 2000). This can result in the loss of more than half of the harvested sweetpotato storage roots before they reach the consumers (Chaitali *et al.*, 2017). Furthermore, transport alone resulted in about 9% loss due to breaks and about 52% in skinning injuries (Tomlins *et al.*, 2000). The size (160 kg) and nature of the packaging containers have been fingered for these losses. As a result of the heavy weights associated with the current packaging containers, sweetpotato storage roots may not be handled properly leading to breakages and bruises (Tomlins *et al.*, 2000) that may compromise storage root quality and shelf life (Truong *et al.*, 2011). Weights not exceeding 100 kg per bag have been recommended for the delivery of good quality storage roots at the market (Tomlins *et al.*, 2010). Kitinoja and Kader (2002) also emphasized the significant role packaging plays in reducing losses in Africa.

The packaging of sweetpotato storage roots is an industrial operation that should be dedicated to delivering the highest quality product to the consumer. Because of the enormous nutritional benefits of sweetpotato storage roots, it is important to secure it after harvest and transport so that it maintains its nutritional value. For

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many reasons which include the haphazard / uncontrolled packaging, the size of packaging containers used and the manner of transport, sweetpotato storage roots are exposed to various degrees of mechanical damages which often leads to the heavy loss of quality (Ray & Ravi, 2005). However, there is a dearth of information in Ghana regarding the effect of transport and packaging containers on the quality of sweetpotato delivered at the urban market centres.

Therefore, this study seeks to assess alternative packaging containers (50 kg polypropylene and 50 kg wooden crate) relative to the existing packages (160 kg polypropylene and jute) in the sweetpotato value chain in Ghana. An economic analysis of the various packaging containers was also considered as aggregators' willingness to adopt any packaging container for the transport of storage roots depends on its profitability (Schuur, 1988). For optimum utilization of sweetpotato storage roots, as well as any other fresh agro-produce, there should be effective methods for minimising losses associated with packaging and transport (Atanda *et al.*, 2011).

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1.3 Problem statement and justification

Inappropriate transportation has accounted for huge post harvest losses in sweetpotato roots. It is known that sweetpotato produced from the major production region in Ghana is exported to the neighboring Burkina Faso (FAO, 2005; Peters, 2013). Accra, which is the hub of sweetpotato root consumption in Ghana is supplied from the Eastern and Central regions (Peters, 2013). Though these have been stated categorically, the information regarding the transportation system of sweetpotato roots in Ghana is still very scanty and cannot be relied on

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for any technical planning and exploration. It is however imperative for an investigation to be conducted to deduce more information concerning the transportation linkages, packages used and handling of the commodity within Ghana. This information will be the basis for any industrial reforms for the government and other private agencies that may be interested in conducting business in relation to the crop.

According to Rees *et al.* (2003b), postharvest losses of sweetpotato range from 35% to 95% in developing countries. In Ghana such losses in food crops are estimated at 30% annually (Bond *et al*., 2013; Nyanteng & Asuming-Brempong, 2003). The factors responsible for this extent of losses in developing countries are not hidden. Conditions during transportation and marketing of sweetpotatoes are not favorable, largely due to the type of packages, heavier weights of the packaged roots, high temperatures and low humidity. These factors result in mechanical root damage and a reduction in shelf life (Rees *et al*., 2003b). Sweetpotato is considered a perishable crop because once the roots are detached from the plant; they cannot be stored for a long time (Woolfe, 1992). In Ghana, roots are packaged and transported in polypropylene sacks weighing about 160 kg (Peters, 2013). The fresh sweetpotato roots contain high moisture contents with low mechanical strength and high respiratory rate (Ray *et al*., 2010). The resultant heat produced within packages softens the texture which leads to damage (Ray *et al*., 2010). The inappropriate postharvest handling practices lead to skin injuries, cut or broken roots, and invariably accelerating metabolic activities, high ethylene

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production that is associated with root perishability and poor market value (Buescher *et al*., 1975; Rees *et al*., 2001a; Teye *et al.*, 2011b).

Marketability is reduced when sweetpotato roots are shriveled, cut, bruised or even broken into two or more pieces. Sweetpotato being an important source of vitamins and other nutrients, it is important to secure it after harvest and transport it safely to the market in order to reach the consumer with all nutrients and physical characters intact. For many reasons which include the haphazard / uncontrolled packaging, the size of packaging containers used and the mode of transport, sweetpotato roots are exposed to various degrees of mechanical damages which often leads to the heavy loss of quality (Ray & Ravi, 2005). This study seeks to explore the postharvest packaging, handling and transport of sweetpotato roots from the major production and aggregation sites to the urban market centres in Ghana. It will also suggest an appropriate packaging container for sweetpotato in order to maintain the quality to urban market centres in Ghana. Size of packages is a matter of concern as heavier packs of sweetpotato bags are uneasy to handle. For ease of handling, size must be reconsidered. In view of these, the study will investigate the sweetpotato packaging and transport from the major production centres in Ghana and as well evaluate alternative packaging containers for safe delivery of sweetpotato to the urban market. Though a particular packaging option may safely transport high quality sweetpotato roots to the urban market, it is imperative to convincingly tell how economically beneficial it will be as well for adoption.

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1.4 Main objectives

As an overall aim of the study, it will investigate packaging options for safe delivery of quality sweetpotato roots to urban markets in Ghana.

1.4.1 Specific objectives

- To identify the sweetpotato packaging and transport options from production sites market centres to urban markets in Ghana
- To identify appropriate containers for long distance transport of sweetpotato in Ghana.
- To determine the Benefit Cost Ratio of current and proposed packaging containers for sweetpotato transport.

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CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

This chapter contains relevant literature of the study. It begins with a review of the origin and distribution of sweetpotato, its production in Ghana, utilization and economic importance, nutritional and health benefits, planting, pests and diseases, harvesting mechanical root quality factors, extent of postharvest losses, packaging, improvement of quality and shelf life, storage and marketability.

2.2 Origin and distribution

Sweetpotato, a dicotyledonous plant, was first described by Linnaeus as *Convolvulus batatas* in 1753. However, in 1791 Lamarck classified this species within the genus *Ipomoea* on the basis of the stigma shape and the surface of the pollen grains. Therefore, the name was changed to *Ipomoea batatas Lam*. The systematic classification of the sweetpotato indicates that it belongs to the family *Convolvulaceae*, tribe *Ipomoeae*, Genus *Ipomoea*, Sub-genus *Quamoclit*, Section *Batatas* (Nedunchezhiyan & Ray, 2010).

Sweetpotato is a crop that has been reported to originate from either Central or South American lowlands (Woolfe, 1992). The dried roots, the oldest remain so far discovered are those from the caves of Chilca canyon of Peru (Engel, 1970), which have radiocarbon dated at 8000-10000 years old (Ugent *et al.*, 1983). Ugent *et al*. (1983) further reported the archaeological discovery of actual remains

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of cultivated sweetpotato from the Casma valley of Peru, dated at approximately 2000 B.C.

Sweetpotato spread in historic times was by two lines of transmission: (1) the *batatas* line, which followed on from the Spanish introduction into Europe continuing after 1500 AD (Woolfe, 1992). By the transfer of European grown clones to Africa, India, and the East Indies through Portuguese exploration, and (2) the *kamote* line whereby Mexican clones were carried to the Philippines by Spanish trading galleons (Woolfe, 1992). Woolfe (1992) further stated that sweetpotato was introduced into Africa by the Portuguese.

According to Yamakawa (1997), Sweetpotato is grown in the geographical locations from 40° N to 32° S and from sea level to almost 3000 m above mean sea level. In South America, it is grown in the Andes Mountains, in the Amazon jungle, on the great sub-tropical and temperate plains of the Southern zone and under irrigation in the desert on the Pacific coast. In the Caribbean and the Pacific, it is grown on small tropical islands, in Africa at mid elevations and in parts of the tropical low lands; and in Asia at a wide range of altitudes and from temperate to tropical zones. These ecosystems on which the sweetpotato is grown have poor degraded soils that support very few other crops (Yamakawa, 1997). However, over 95% of global sweetpotato production is from developing countries (Bovell-Benjamin, 2010).

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2.3 Sweetpotato production in Ghana

2.3.1 Major production areas

Ghana is located on the southern coast of West Africa, between latitudes 4˚ 44‟ N and 11˚ 11‟ N and longitudes 3˚ 11‟ W and 1˚ 11‟ E (FAO, 2005). It is one of the West African countries with its economy largely driven by agriculture. Nearly 60% of the Ghanaian population are in the rural sector and are predominately farmers (FAO, 2005)

There are six agro-ecological zones in Ghana, these are: Sudan Savannah, Coastal Savannah, Rain Forest, Deciduous Forest, Guinea Savannah and the Transitional Zone (FAO, 2005) as shown in Figure 1.

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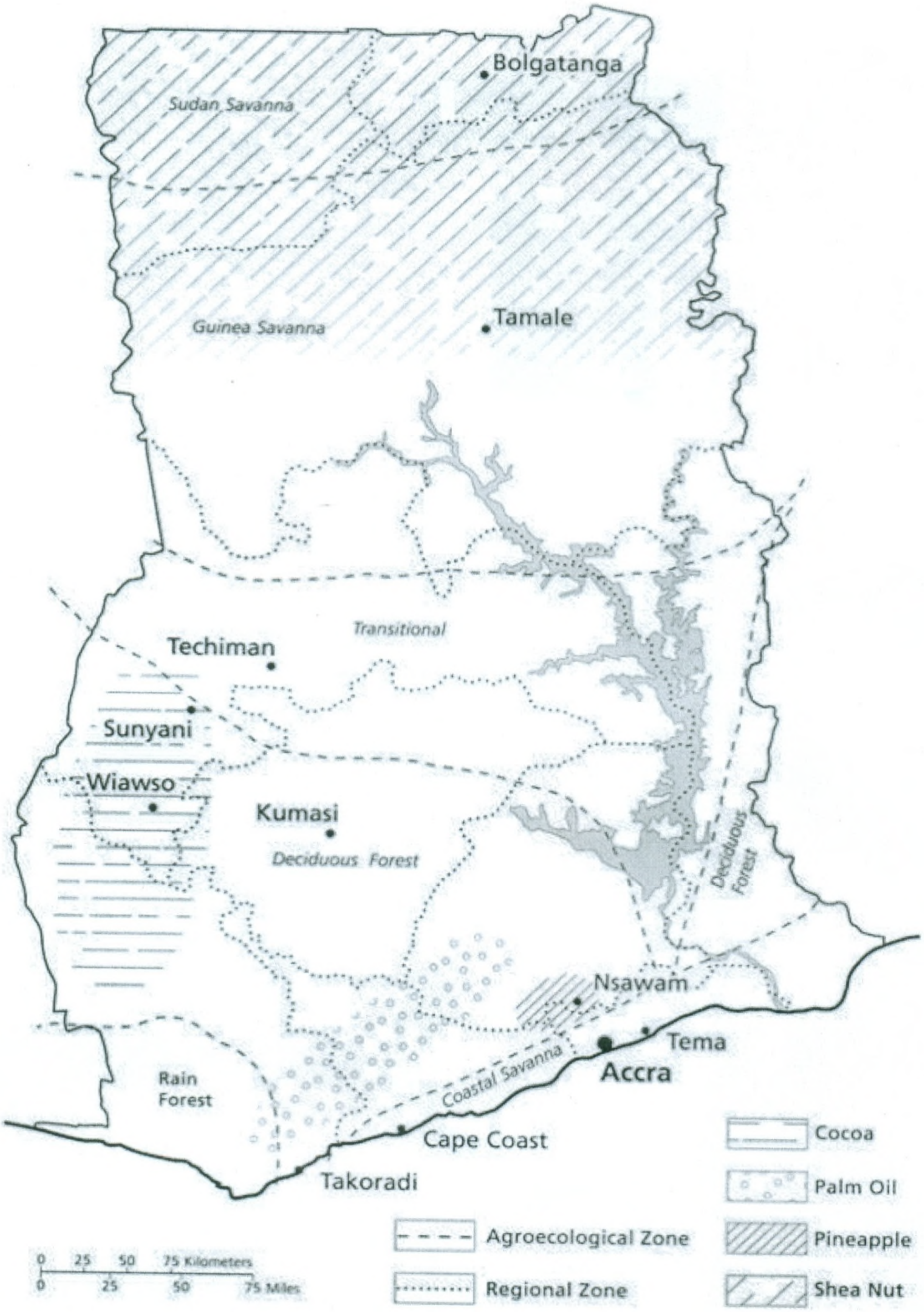

Figure 1: Agro-ecological zones in Ghana. Source: Fold, 2008

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Table 1: Crops grown in Ghana

Group	Crop
Cereals	Maize, Millet, Sorghum, Rice
Industrial crops	Cocoa, Oil-palm, Coffee, Cotton, Tobacco, Sheanut, Cola nut
Legumes	Cowpea, Bambara nut, Groundnut, Soybean
Fruits	Papaya, Avocado, Mango, Cashew, Watermelon, Plantain, Banana
Vegetables	Tomato, Eggplant, Onion, Pepper, Okra, Cabbage, Lettuce, Carrot
Roots and Tubers	Yam, Cassava, Cocoyam, Sweetpotato

Source: FAO, 2005

With reference to the Table 1, sweetpotato is one of the four widely cultivated root crops in Ghana. According to Ofori *et al.* (2009), the crop is mainly grown by farmers scattered around the three Northern regions and some parts of the Volta region of Ghana.

Currently, the production of sweetpotatoes is scattered across Ghana with large scale production available in few areas around the Upper East and Eastern regions of Ghana as shown in Table 2. In Ghana, almost all the regions cultivate sweetpotato in larger quantities except the Western region which is in the southern sector of the country. Sweetpotato is mainly planted in pure stand in the southern sector whilst in the northern sector, it is sometimes intercropped with

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yam or other crops (MOFA/SRID, 2012). Also, the crop is either planted on mounds or on ridges depending on the location.

It was estimated that, a total of 9,622 hectares of sweetpotato was cultivated during a cropping season in Ghana at the time of data gathering (MOFA/SRID, 2012). The Table 2 below indicates the scale of production in the various regions in Ghana.

Table 2: Regional scale of sweetpotato storage root production in Ghana

Region	Area (Ha)	% Contribution	Production (mt)	% Contribution
Central	371	3.9	6,490	4.9
Volta	880	9.1	15,340	11.6
Eastern	1,030	10.7	34,910	26.4
G. Accra	38	0.4	640	0.5
Ashanti	37	0.4	620	0.5
BrongAhafo	145	1.5	2,390	1.8
Northern	414	4.3	6,070	4.6
Upper East	5,550	57.7	46,000	34.9
Upper West	1,157	12.0	19,530	14.8
Total	**9,622**	100.0	**131,990**	100.0

*Source: MOFA/SRID, 2012

According to the MOFA/SRID (2012) statistics shown in Table 2, Upper East region is the highest sweetpotato producing region in Ghana with a share of about 35% and Greater Accra and Ashanti regions being the least of 0.5% each.

The Upper East region cultivated 5,550 hectares representing 57.7% of total area cropped while Upper West and Eastern regions cultivated 1,157 hectares (12.0%)

and 1,030 hectares (10.7%) respectively. An estimated total output of 131,990 metric tons of sweetpotatoes was produced.

2.3.2 Released varieties of sweetpotato in Ghana

Sweetpotato production and research was not given the much needed attention in the past, but with the inception of the National Root and Tuber Crops Improvement Project (NRTCIP) in 1988, research attention has been devoted to increasing the production of sweetpotato as a source of dietary energy, vitamins, minerals, proteins and its use as animal feed (FAO & IFAD, 2005). In view of the recent efforts in the development of sweetpotato root production and utilization, some varieties have been released by researchers as shown in the Table 3.

Table 3: Sweetpotato varieties in Ghana

Name	Year released	Original Name	Origin
Okumkom	1998	TIS 8266	IITA
Sauti	1998	Tanzania,Kenya	Malawi
Faara	1998	TIS 3017	IITA
Santom Pona	1998	TIS 84/0320	IITA
HI-Starch	2005	Hi-Starch	Japan
Ogyefo	2005	Mugande	Rwanda via CIP
Otoo	2005	Mogamba	Burundi via CIP
Apomuden	2005	Kamala Sundari	Bangladesh via CIP
Tek Santom	2003	Tib 2	IITA

Source: Victor, 2012

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2.4 Utilization and economic importance

World statistics revealed that sweetpotato is the seventh most important food crop in the world in terms of production (Loebenstein, 2009). Sweetpotato is grown on about 8.2 million hectares yielding about 102 million metric tons with 12.1 metric tons / ha as an average yield (FAOSTAT, 2010).

Sweetpotato has become a valuable food security crop for its producers, because it enables them to combat shortages and provide security in the event of natural disaster (Woolfe, 1992). Sweetpotato production still remains very concentrated in specific regions, 82.3% of global production being in Asia. According to Low *et al.* (2009), China produces about 80% of global production but Africa is coming up. Root yield of sweetpotato in Sub-Saharan Africa appears to be static, between 4 and 5 metric tons / ha and more than 80% of the total production is consumed by man directly and the rest is processed into starch, glucose syrup or used as animal feed (Kenyon *et al*., 2006). Uganda is one of the most important African sweetpotato producing countries with a harvest that increased from around 2 million metric tons in 1999 to 2.83 million metric tons in 2010. The expansion in sweetpotato production in Africa is explained by an increased demand linked to a high human population growth (FAOSTAT, 2012). Economically, sweetpotato plays a significant role in improving upon the living standard of people across the world. According to Degras (2003), even though sweetpotato has not gained much popularity in the international trade, it has by far improved the economy of some countries. For example, a Chinese province have experienced a tremendous economic transformation due to the relatively high

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production level of sweetpotato and have been elevated from subsistence farming to agro-industrial level of production. In Japan, there have been major changes in the usage of the crop as a forage and consumption on the farm to starch production (Degras, 2003). Agro-industrialization is not the same in all parts of the world. In most parts of the Sub-Saharan Africa, sweetpotato is mainly consumed directly from the farm and does not undergo any industrial processing before use (Degras, 2003). There is high consumption of sweetpotato in Africa (Degras, 2003). This means that, the crop is capable of improving food security. However, harvesting period, good storage practices and processing the roots of most cultivars are not known (Pillai, 1997).

Even though sweetpotato is yet to be given much industrial attention in Africa, it does not in any way mean that Africans are not enjoying its economic benefits. Many sweetpotato farmers have been able to improve their income level through the sale of vines (sweetpotato planting materials) as reported by Mwanga & Ssemakula, (2011). A single farmer can earn up to an amount of 400 US$ per month from the sale of planting materials and sweetpotato products at the beginning of the rainy season (Mwanga & Ssemakula, 2011). According to Kenyon *et al.* (2006), root crop production including sweetpotato in the developing world's economy, is estimated annually to be more than 41 billion US$. The income these farmers gain will definitely support them to meet their household obligations such as their children educational and health needs as well as clothing and providing shelter for them.

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Sweetpotato is one of the most widely grown root crops in Sub-Saharan Africa (SSA) (Low *et al*., 2009). Despite its importance, it has not realized its full potential as a mainstream food in human and animal systems. The reasons for this under-exploitation of the sweetpotato are: (i) it is often grown by small farmers on marginal soils with limited yields; and (ii) its production is often concentrated in countries with lower per capita incomes (Vinnings, 2003). In Ghana, sweetpotato is an important crop and hence rated the third most impotant root crop (FAOSTAT, 2010). Over 80% of the sweetpotato produced in Sub-Saharan Africa is consumed fresh (Woolfe, 1992). Evidence has also shown its proficiency as animal feed (Bovell-Benjamin, 2010). Awareness of sweetpotato as a healthy food crop is increasing, especially the orange-fleshed sweetpotato (OFSP) which is rich in provitamin A carotenoids (Bovell-Benjamin, 2010). Sweetpotato is a nutritious crop which contains also a good source of potassium. Vitamin C, vitamin B6, riboflavin, copper, pantothenic acid and folic acid are also contained in sweetpotato (Woolfe, 1992).

Sweetpotato storage roots are utilized primarily as human food after boiling or baking (Nedunchezhiyan & Ray, 2010). Roots can also be utilized for animal feed, starch production, as an ingredient in a variety of food and drink products and in protein and enzyme production (Nedunchezhiyan & Ray, 2010).

Although Ghanaian farmers have grown sweetpotato for a long time, production specifically for cash income is a relatively new phenomenon that has developed on its own due to influences by market forces, just within the past ten years (Peters, 2013). For a ready market and higher economic benefit, most of the

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sweetpotato produced in the Upper East region of Ghana are exported to Burkina Faso (FAO, 2005).

Sweetpotato in developing countries ranked fifth in economic value, sixth in dry matter production, seventh in energy production, ninth in protein production and it has tremendous flexibility of utilization as food and industrial products (Loebenstein, 2009). The greens (leaves) of sweetpotato are edible and provide an important source of food in Africa (Sierra Leone, Guinea, and Liberia) as well as East Asia (Thottappily, 2009). According to Scott *et al*. (2000), consumption of potato as food increased at 4.1 percent per year and consumption of cassava increased at 2.1 percent annually. However, sweetpotato use as animal feed increased rapidly, at 3.4 percent per year during 1983–96, and it contributed the most to animal feed in 1996.

According to Kenyon *et al*. (2006); Padmaja (2009) and Woolfe (1992), the crop is mostly eaten as boiled or roasted. It can also be processed into flour for bread baking (Low & van Jaarsveld, 2008), ice-cream or chips which is widely consumed in Asia (Padmaja, 2009).

In the case of Japan, 5% of the total production of sweetpotato starch is fermented and distilled into a spirit called "shochu" (Woolfe, 1992) and in Uganda, it is being processed into juice, cake, chapattis and also chips as it is done in Japan (Padmaja, 2009). According to Ezeano (2010), 70.8% of sweetpotato farmers in Nigeria use the crop for the preparation of "foo-foo" (pounded yam), flour and other beverages like "kuru" and "burukutu". Additionally, sweetpotato could also be used to prepare complementary foods for infants, mostly those in the low

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income countries (Amagloh *et al*., 2012a). It could also be processed into "gari" which many people prefer in Ghana (Amoaful, 2001). Due to the attractive colour of the crop, especially the purple-fleshed sweetpotato (PFSP), a lot of people around the world consume it (Woolfe, 1992). Culturally, countries like the United States use the crop and its products as festive foods and when it is absent, their "Thanksgiving meal" would be incomplete (Woolfe, 1992). In Tonga, it is also used in the traditional feasts for high ranking personalities (Woolfe, 1992). All these suggest that, sweetpotato is not only used as food to combat hunger in Africa, but also a very relevant traditional crop across the globe. According to Padmaja (2009), sweetpotato roots and vines together with its waste products from starch and alcohol are used to feed livestock in China, Japan, and Taiwan.

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2.5 Nutritional and health benefits

Even though cereals, legumes and fruits provide good yield and nutrients, roots and tubers are as much needed to meet the dietary requirement in Africa and other parts of the world at large (Dayal *et al*., 1991), Cassava, yam and sweetpotato are notably the major root and tuber crops produce in Sub-Saharan Africa in fighting hunger and improving the income level of farmers (FAO, 2005).

Sweetpotato's role as an important health food is recognized due to high nutrient content with its anti-carcinogenic and cardiovascular diseases-preventing properties (Yoshinaga *et al*., 1999). Awareness of sweetpotato as a healthy food crop is increasing, especially the orange-fleshed sweetpotato which is especially rich in provitamin A carotenoids (Loebenstein, 2009). All varieties of sweetpotato are good sources of Vitamins C, B2 (Riboflavin), B6 and E as well as dietary fibre, potassium, copper, manganese and iron, and are low in cholesterol (Loebenstein, 2009). Regardless of the name “sweet” it is a good food for diabetics as it helps to stabilize blood sugar levels and to lower insulin resistance (Loebenstein, 2009).

In terms of human health, the contribution of sweetpotato cannot be over-emphasized. The human nutritional need is paramount and has been improved significantly due to the β-carotene content, the precursor for vitamin A availability of the orange-fleshed sweetpotato (OFSP) cultivars. Millions of children under five years of age have been saved from acute malnutrition and eventual death as a result of consuming the OFSP cultivars of the required quantities (Low *et al*., 2001; Low & van Jaarsveld, 2008; Mwanga & Ssemakula, 2011).

According to Woolfe (1992), sweetpotato is a good medicinal crop and has been very effective in preventing kidney problems, constipation, and its consumption increases blood platelet levels, reduces blood sugar level and as well stimulating the immune system to function effectively. Due to the high nutritional content of the crop, it is also used in the oral rehydration therapy to improve upon the nutritional imbalances in children (Woolfe, 1992).

The Purple Fleshed Sweetpotato (PFSP) cultivars contain anthocyanins which have been found to be effective in inhibiting cancer cell growth in mice and humans (Jawi *et al*., 2012). People who are diabetic could improve upon their health through the consumption of anthocyanins concentrated foods like the PFSP (Jawi *et al*., 2012). Additionally, the excess production of free radicals such as

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superoxide anion radical, hydroxyl radical and alkylperoxyl, influences damage such as aging, cancer and other lifestyle related diseases to human (Suda *et al*., 2003). These diseases could be prevented through regular consumption of these anthocyanin rich-foods such as the PFSP (Jawi *et al*., 2012; Suda *et al*., 2003).

According to Kapinga *et al.* (2000), most sweetpotato varieties grown in Africa, including Ghana, are white or yellow-fleshed (W/YFSP) and these supply little vitamin A when incorporated into a diet. However, the orange-fleshed sweetpotato (OFSP) has been identified as a variety that can make a major contribution in the alleviation of vitamin malnutrition in Sub-Saharan Africa (Hagenimana *et al*., 1999). This is due to its association with high content of provitamin A carotenoid – notably β-carotene. The potential of the leaves as a source of nutrients also appears to be largely unexploited.

Sweetpotato-based complementary food blends such as *ComFa* could be used as infant food in Ghana (Amagloh *et al.*, 2012b). This is low in phytate and high in β–carotene which is necessary for the availability of micronutrients such as vitamin A, calcium, iron and zinc (Amagloh *et al.*, 2012b). Sweetpotato competes well with other root and tuber crops in terms of their chemical composition. The Table 4 shows the levels of chemical composition for some important root crops in Sub-Saharan Africa.

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Table 4: Chemical composition of sweetpotato roots with other tubers

	Sweetpotato	Cassava	Yam	Irish potato	Taro
Water	70	63	76	78	72
Protein (%)	1.5	1.0	1.8	2.1	1.7
Glucose (%)	26.1	32.4	21	18.5	23.1
Iron (mg)	0.7	1.1	0.5	0.8	1.2

Source: Woolfe, 1992

Sweetpotatoes has a good source of vitamins necessary for human growth and development (Woolfe, 1992). It has high levels of β-carotene than many root and tuber crops. The Table 5 is a clear indication of the higher contents of β-carotene in sweetpotatoes.

Table 5: Contents of major vitamins of root and tuber crops

	Sweetpotato	**Cassava**	**Irish potato**	**Cocoyam**	**Yam**
β- carotene (µg)	0 – 20,000	0 – 120	Nd	43	108
Thiamine (mg)	0.09	0.05	0.11	0.03	0.05
Riboflavin (mg)	0.03	0.04	0.04	0.03	0.03
Niacin (mg)	0.60	0.60	0.20	0.76	0.41
Pantothenic acid (mg)	0.59	-	0.30	-	0.13
Pyridoxine (mg)	0.26	-	0.25	0.08	Nd
Folic acid (µg)	14	-	24	-	Nd
Ascorbic acid (mg)	24	20	30	15	20

Source: Woolfe, 1992. Nd means not defined.

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2.6 Cultivation of Sweetpotato

2.6.1 Planting of sweetpotatoes

Sweetpotato requires warm days and nights for optimal yields. It is sensitive to low temperatures and grows best in the tropical and warm temperate regions wherever there is sufficient water and sunlight. It grows favourably under well aerated and moderate to slightly acidic sandy to sandy-loam soils but has the ability to tolerate harsh soil and climatic conditions and still give a satisfactory yields (Van den Berg & Laurie, 2004).

Sweetpotato is usually propagated through vine cuttings obtained either from freshly harvested plants or from nursery (Nedunchezhiyan & Ray, 2010). Vines obtained from nursery are found to be healthy and vigorous. A healthy and vigorous growing vine produces maximum storage root yield (Nedunchezhiyan & Ray, 2010). Sweetpotato cut vines with intact leaves stored under shade for 2-3 days prior to planting in the main field promoted better root initiation and established the vines quickly (Nedunchezhiyan & Ray, 2010).

The specific time frame for planting sweetpotato has not been well defined (Rukundo *et al.*, 2013). Different geographical locations have different rainfall patterns, which is the main reason for the unspecific time frame for planting sweetpotato (Woolfe, 1992). However, it is always good to plant within the early rains to enable the crop meet maximum rains in the season for proper growth, development and yield production (Woolfe, 1992). The season for planting sweetpotato may depend largely on the "ecosystem". Within the tropical zones, the crop is mostly planted once in a year unless of course the specific

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geographical area experiences two rainy seasons or being irrigated. In Ghana the sweetpotato are mostly planted at the beginning of the rainy season at the time when most crops are planted. Sweetpotato cuttings of desirable length (20 cm) are planted in the soil with both ends exposed and the middle portion buried in the soil (Nedunchezhiyan & Ray, 2010). Vines are also planted in an inclined position with half of its length buried in the soil. Sweetpotato cuttings are also planted horizontally to the soil surface with 5 or 6 nodes (Nedunchezhiyan & Ray, 2010). However, sweetpotato can also be propagated vegetatively from the sprouts produced by bedding mother roots (Van den Berg and Laurie, 2004).

Maturity period in Ghana varies from under 3 to 5 months depending on variety (Otoo *et al*., 2000). Sweetpotato is most commonly grown on mounds or ridges, and occasionally on raised beds, or on the flat. Deep cultivation enhances root growth and bulking of the sweetpotato roots. Mounds and ridges promote adequate drainage and ease of harvesting (Low *et al*., 2009). It requires from 500-1250 mm rainfall in West Africa. A high rainfall leads to excessive vine development (Low *et al*., 2009). Compact and poorly aerated soils prevent satisfactory development of storage roots resulting in poor shapes, low yield and difficulty in harvesting. Optimum pH for sweetpotato is 5.8-6.0 and the crop can be cultivated in an elevation as high as 1500 m above sea level (Obigbesan, 2009).

2.6.2 Production constraints

According to Low *et al*. (2009), there are five major constraints to improved productivity and incomes from sweetpotato among the smallholder sector in Sub-

Saharan Africa which includes, the lack of timely access to clean planting material, lack of improved varieties adapted to local environments, damage due to the sweetpotato weevils particularly in drier production areas, insufficient knowledge and use of better agronomic practices and lack of markets.

2.6.3 Pests and diseases

Nematodes and insect pests attack sweetpotato storage root and vine. *Meloidogyne spp*. (root-knot) and *Rotylenchulus reniformis* are the major known nematode pests of sweetpotatoes in the tropics (Nedunchezhiyan & Ray, 2010). They attack the fibres as well as fleshy roots and reduce yield and quality. They also allow other pathogens to penetrate through the wounds. Nedunchezhiyan and Ray (2010) further reported that nematodes can be controlled by applying neem cake 500 kg / ha in the last ploughing before ridge and furrow making. Sweetpotato weevil, *Cylas formicarius* Fab. is one of the major pest in most sweetpotato growing countries (Ray & Ravi, 2005). Larvae and adult feed on the roots, causing extensive damage both in field and storage in many parts of the world (Nedunchezhiyan & Ray, 2010). The weevil infestation can be effectively managed by following the integrated pest management (IPM) strategies (Nedunchezhiyan & Ray, 2010). According to Nedunchezhiyan and Ray (2010), virus diseases may attack the root or the leaves. They include internal cork disease and mosaic virus. More than 12 virus diseases are identified, among them sweetpotato feathery mottle virus (SPFMV) is prominent (Nedunchezhiyan & Ray, 2010). Insect pests and diseases can really be serious constraint to increased and sustainable sweetpotato production in Ghana. Of the many pests recorded;

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Cylas spp; Acrea acerata; Bemisia tabacci; Empoasca spp; grasshoppers / crickets, termites and white grubs were all observed in more than 50% of all farms surveyed, confirming their close association with the crop (Tanzubil, 2015). Tanzubil (2015) further noted that *Cylas spp* occurred in over 90% of farms damage. Estimates revealed that *Cylas spp* caused 30.8% and 41.4% damage to vines and roots respectively. Table 6 shows the incidence and damage caused by Cylas spp on farmers' fields in the districts of the Upper East region of Ghana.

Table 6: Incidence and damage caused by *Cylas spp* on farmers' fields

District	% farm owners aware of pests	%vine damage	% tuber damage
Kasena-Nankana west (10)	70.0	34.6	40.1
Talensi (10)	90.0	39.3	43.9
Bawku west (13)	76.9	32.4	49.8
Bongo (10)	90.0	22.7	33.0
Nabdam (15)	53.3	25.0	40.3
Mean	76.0	30.8	41.4

Source: Tanzubil, 2015. Numbers in brackets is number of farms sampled

Similar reports have been made by many others who also identified *Cylas spp* and *Acrea acerata* as the two most important insect pests of sweetpotato in West Africa (Tanzubil *et al*., 2005; West, 1977). It is estimated that severe defoliation of the crop by *Acrea acerata* combined with *Cylas spp* damage to vines and roots can result in 100% root yield loss, especially during long dry seasons (Smit *et al*., 1997) while on its own, *Cylas spp* damage can be as high as 60-97% or even 100% (Chalfant *et al*., 1990). *Cylas spp* infestation is also known to induce

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increased production of furanoterpenoids that make the tubers unpalatable thus reducing their quality and market value (Jansson *et al*., 1987).

Weevils are economic pests for which effective controls need to be developed and applied by farmers to reduce their damage. The proliferation of whiteflies and leafhoppers in surveyed fields should also be worrying as these are known to transmit virus diseases in many crops including sweetpotato. Important virus diseases of the crop such as sweetpotato mild virus, sweetpotato sunken vein virus and sweetpotato disease virus are all known to be transmitted by whiteflies (Chalfant *et al*., 1990; West, 1977). Plants showing typical symptoms of virus attack (stunting, leaf distortion, mottling, chlorosis) were as well observed in some fields where infestation rates of these insects were high (Tanzubil, 2015). In Ghana, sweetpotato is attacked by a number of insect pests which damage the foliage, vines and roots. Of these, *Cylas spp* and *A. acerata* appear to be the most important pests of roots and foliage respectively, usually causing some appreciable, visible damage in farmers' fields. The effect of diseases and pest undoubtedly reduces the quality of harvested and stored roots. It may as well result in accelerating damage of roots during handling and transport to urban market centres.

2.6.4 Harvesting of sweetpotato

Root quality of sweetpotato just like any other food crop cannot be improved after harvest, it can only be maintained. It is therefore imperative to identify an appropriate harvesting period in order to meet the optimum root quality in terms of agronomic and nutrient characteristics (Nedunchezhiyan *et al*, 2012). In some

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crops, single harvesting is done as soon as the crop gets to its maturity stage, else they are shattered as in the case of soybeans, spoiled or eaten by birds, for example rice and sorghum (Nedunchezhiyan *et al*., 2012). In root and tuber crops, for example sweetpotato, single and multiple harvesting could be carefully practiced since root yield may not immediately be affected when harvesting is delayed for a week or two (Nedunchezhiyan *et al*., 2012). Traditionally, there is no specific time for harvesting sweetpotato storage roots due to cultivar and environmental differences; also it could be harvested when needed for consumption (Woolfe, 1992). Sweetpotato roots may continue to enlarge as long as they remain in the ground with relatively good environmental conditions such as rainfall and temperature, but when over delayed, will become fibrous (Woolfe, 1992). Traditionally, sweetpotato storage roots are harvested and sorted by hand to minimize the amount of damage that is incurred during harvest (Legendre, 2015). Legendre (2015) further emphasized that the damage incurred by sweetpotato storage roots during harvest is a barrier preventing mechanical harvesting. The higher yield per acre necessitates the need to switch from the traditional method of harvesting sweetpotato storage roots. A study conducted by O'Brien and Scheuerman (1969) concluded that complete and economical mechanization of sweetpotato harvesting, with the proper adjustments to machinery, is possible. Unfortunately, sweetpotato storage roots are highly susceptible to skinning damage that can lead to desiccation, weight loss, and rot (Rees *et al*., 2003b). The combination of sweetpotato storage root susceptibility to

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skinning and the inherent damage caused by a mechanized harvest can be extremely detrimental to a grower's crop.

2.7 Mechanical root quality factors

The damage incurred during harvest is a barrier preventing sweetpotatoes from being harvested mechanically. Mechanical damage to sweetpotatoes during handling may include cuts, abrasions, and bruises, depending on the physics and configuration of the surfaces involved (Edmunds *et al*., 2008). Edmunds *et al.* (2008) further reported that most damage to roots is likely to occur from impacts between roots. While there are other types of damage that can occur such as bruising, shattering, and breakage; skinning is the most prevalent. Skinning has been well studied in potatoes and involves removal of the periderm (Lulai & Orr, 1993). This lack of the epidermal layer can lead to weight loss, root desiccation, and increased incidence of root rot due to higher susceptibility to pathogens (Rees *et al*., 1998). As skinning damage occurs, the underlying cells of a skinned area desiccate and die (Legendre, 2015). Again, Legendre (2015) noted that lignification begins to occur under the desiccated cell layers, followed by the formation of a new wound periderm. The wound periderm formation occurs best in warm temperatures (28-30° C) and with a relative humidity of more than 85%. Surface skinning can be successfully managed under these conditions. Desiccated and sunken areas are unappealing to the consumer's eye and lead to a less desirable fresh market product (Legendre, 2015). Rees *et al.* (2003b) showed that the water loss from desiccation on stored sweetpotato roots increases the amount of stress put on the root, and thus increases the susceptibility to rot and other

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forms of deterioration. The same study also compared different varieties of sweetpotato grown in East Africa and demonstrated a wide range of shelf-life. “Beauregard”, a leading variety in the United States, was considered more resistant to mechanical stress compared to African varieties. In the United States, Beauregard is considered susceptible given the mechanized nature of crop production. The wide variance in shelf-life was attributed to the amount of skinning that occurred during harvest, which leads to water loss and desiccation and rot. Beauregard produced a continuous layer of wound tissue in contrast to African varieties which produced discontinuous wound tissue.

According to Legendre (2015), research underlying attempts to increase skinning tolerance is scant. Research results have proven that pre-harvest applications of ethephon at 3-7 days before harvest were found to reduce skinning incidence. The treatment was also found to increase suberin and lignification of the skin (Legendre, 2015).

Also, pre-harvest canopy removal can reduce the total surface area skinned (La Bonte & Wright, 1993). Sweetpotato plants that were defoliated 10 days prior to harvest reduced skinning damage by 62%, while other treatments of removing the canopy 8 days and 4 days prior to harvest reduced skinning damage by 53% and 26%, respectively (Legendre, 2015).

Mechanical damage factors in sweetpotatoes have been considered in many circumstances. Cuts, abrasions and breaks have been considered in the determination of damage for transported sweetpotato cultivars (Ndunguru *et al*.,

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1998; Tomlins *et al*., 2002; Tomlins *et al*., 2000). Mechanical damage is the most important harvest factor, much of which is sustained during harvest itself, and during transport and marketing (Ray *et al*., 2010). Harvesting in the tropics is usually manual, employing a variety of tools such as digging sticks, spades, hoes and knives. Mechanical harvesting using tractors or animal-drawn ploughs or specially designed machines are confined to areas of large-scale production. Sweetpotato roots are often cut, skinned and bruised by the harvesting implements. All these damage factors accelerate deterioration in roots (Rees *et al*., 2003b). The deterioration could be weight loss, rotting, sprouting, loss of good taste and infestation by insects as illustrated in Table 7.

Table 7: Forms of deterioration for sweetpotato storage roots

Weight loss	Roots can lose weight both by losing water, and also by metabolizing the starch reserves through the process of respiration. Under normal marketing conditions most weight loss (90%) is through water loss. Water loss causes the root to become less attractive as it shrivels and also appears to make the root more susceptible to rotting.
Rotting	Rotting of tissues occurs by both fungal and bacterial pathogens. When rotting starts a root quickly becomes unsaleable.
Sprouting	When a root sprouts, it will often become sweeter as starch is converted to sugar to provide energy for the growth of sprouts. The appearance of sprouts and loss of starch reduces the root value.
Loss of good taste	Many changes can occur in the root composition after harvest, which may affect the taste and texture of the cooked root.

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Infestation by Insects	The most important insect pest of the storage root is the sweetpotato weevil (*Cylas spp*.). Even if infestation is only slight, then the root can become completely unsaleable due to the production of bitter tasting phytoalexins as part of the defence mechanism of the root.

Source: Rees *et al. (* 2003b)

The damage factors have mostly been scored based on a severity rating scale of 0 = none, 1 = minor and 2 = major (Ndunguru *et al.*, 1998). Tomlins *et al.* (2000) considered a clearer scale for the scoring of breaks after transport. The scale which was a slight modification on the method of Ndunguru *et al. (1998)* is shown in the Figure 2.

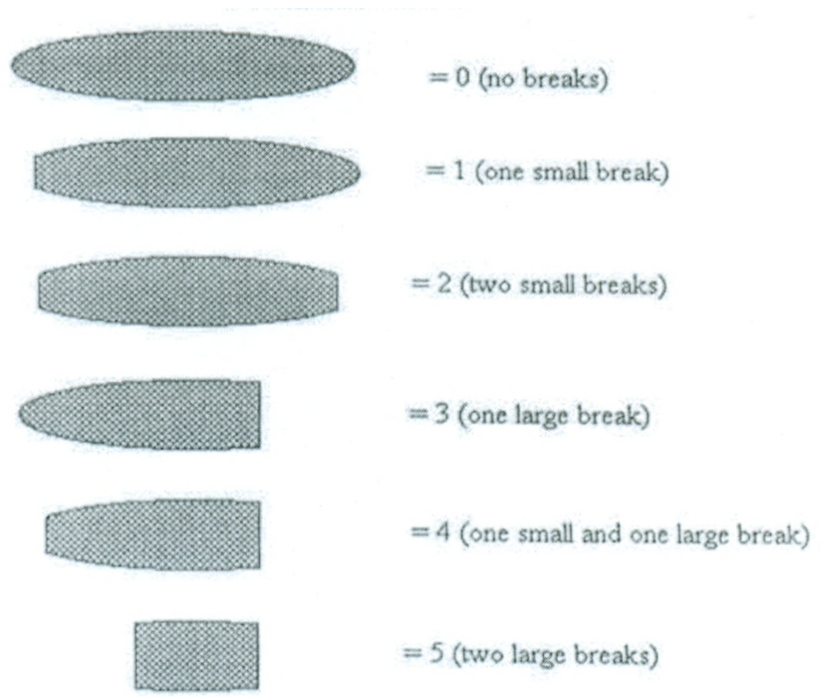

Figure 2: Scoring system for broken roots. (Source: Tomlins et al., 2000)

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Also, one mechanical damage factor might have an influence on the occurrence of another on sweetpotato storage roots. For example, cuts during harvesting are likely to increase the rate of breakage (Rees *et al.*, 2001b). Rees *et al*. (2001b) further stated that damaged roots lose water more rapidly than undamaged roots under marketing conditions.

2.8 Extent of postharvest losses in sweetpotatoes

Sweetpotatoes are harvested when tops are beginning to dry out and topple down (Kitinoja & Kader, 2002). Mechanical damage during harvest can become a serious problem, as injuries predispose produce to decay, increased water loss and increased respiratory and ethylene production rates leading to quick deterioration (Kitinoja & Kader, 2002).

Food loss occurs in production, storage, transport, and processing, which are the stages of the value chain with the lowest returns (Bond *et al*., 2013). According to Kitinoja & Kader (2002), there are three main objectives of applying postharvest technology to harvested fresh produce. These are:

1) To maintain quality (appearance, texture, flavor and nutritive value);

2) To protect food safety; and

3) To reduce losses between harvest and consumption.

The major cause of postharvest losses in sweetpotatoes in order of importance are mechanical injuries, improper curing, sprouting and rooting, water loss (shriveling), decay and chilling injury (Kitinoja & Kader, 2002). It has also been reviewed that the problems of food losses in perishable crops include the initial quality of the crop, mechanical injury, temperature, storage atmosphere, genetic factors and environmental influence (Atanda, Pessu, Agoda, Isong, & Ikotun, 2011).

Rough handling during preparation for market will increase bruising and mechanical damage even before sweetpotato roots are packaged for transport. Elsewhere, large packages (100 kg to 140 kg) are used for the transportation of the sweetpotato roots to urban markets (Rees *et al.*, 2003b). In Ghana, the market situation is not different. Sweetpotato roots after harvest are stacked by aggregators into large polypropylene and jute sacks weighing about 160 kg as reported by Peters (2013).

Sweetpotato has high moisture (60% - 70%), thin and delicate skin (Woolfe, 1992). Post-harvest losses are inevitable during postharvest handling and transport. However, considerable care must be taken to keep postharvest losses at acceptable minimum levels. Sweetpotato root loss, which could be as high as 95% in developing countries is due to the inappropriate transport and marketing (Rees *et al.*, 2003b). Such high losses accelerate root damage and a reduction in shelf-life (Rees *et al.*, 2003b). In the view of Rees *et al* (2003b), roots are exposed to many minor impacts during transport due to movement of the sacks on the vehicle which results in skinning injury.

During loading and unloading of sweetpotato roots, sacks are often dropped resulting in high impact which causes breakages (Tomlins *et al.*, 2000). Water loss is the main force responsible for the deterioration of roots under market conditions (Rees *et al.*, 2003b). According to Rees *et al*. (2003b) water loss is a

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key factor in keeping quality of the roots. However, water loss from any sweetpotato root is enhanced by wounds on the root (Rees *et al*., 2003b). The wounds therefore accelerate the respiration of the roots. In general, poor handling practices may result in the loss of more than half of the harvested sweetpotato storage roots before they reach the consumers table (Chaitali *et al*., 2017). Specifically, it could result in 20% - 25% loss during curing and storage, 5% - 15% during transport and retailing and 10% - 15% loss with the consumer (Chaitali *et al*., 2017). For full utilization of sweetpotato storage roots as well as any other perishable to be achieved, there should be proper management of temperature, humidity and effective methods for preventing these losses (Atanda *et al*., 2011).

2.9 Packaging of roots and transport

The handling of sweetpotato roots may begin just after harvest, during packaging and transport to urban market. According to a study conducted in Tanzania, transportation of sweetpotato roots in polypropylene sacks weighing more than 100 kg can account for loss of market value of 13% (Tomlins *et al*., 2000) and as well reduce shelf life of the crop (Ndunguru *et al*., 1998). The significant reduction in market value is as a result of the improper packaging and transport of sweetpotato storage roots to urban markets. In Ghana, the transported weight (160 kg) of a sweetpotato storage root sack as reported by Peters (2013) has a higher tendency of triggering various degrees of mechanical injuries to wholesome roots packaged from the production and aggregation centres. Use of appropriate

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packaging materials is of great importance in minimizing postharvest losses of sweetpotato storage roots in Africa (Kitinoja & Kader, 2002).

Kitinoja and Kader (2002) further recommended that roads leading to the market should be graded and free from large ruts, bumps and holes. Boxes must be well-secured during transport and, if stacked, not overfilled. Transport speeds must be suited to the quality and conditions of the roads, and truck and / or trailer suspensions kept in good repair. Reduced tire air pressure on transport vehicles will reduce the amount of motion transmitted to the produce (Kitinoja & Kader, 2002).

Ndunguru *et al.* (1998) in a study showed that transporting in cardboard cartons instead of polypropylene sacks and pre-harvest curing by pruning 14 days or more before harvesting will reduce skinning injuries. Tomlins *et al.* (2000) still followed with a similar research and found 20% and 86% of roots with severe breaks and skinning injury respectively when transported in polypropylene sacks of 100 kg. Tomlins *et al* (2002) as well continued this research and compared three (3) different packages for transport of roots to urban market. These packages were:

(a) Woven polypropylene with 20 kg and 100 kg roots;

(b) Wooden boxes containing 30 kg roots;

(c) Double walled corrugated fibre board boxes containing 20 kg roots;

It was found that skinning injury was lower in fibre board boxes but rather highest in polypropylene of 20 kg and 100 kg (Tomlins *et al*., 2002).

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2.10 Improvement of root quality and shelf-life

Considerable benefit would be achieved by improving handling after harvest and during transport to prevent breakage and other mechanical damage of roots (Rees *et al*., 2001b). According to Rees *et al.* (2003b), the characteristics which give a root a long shelf-life during marketing may not necessarily be the same as those which make a root more suitable for long-term storage. For instance, roots for long-term storage are not transported long distances, and are usually handled carefully (Rees *et al*., 2003b). In agreement to Rees *et al.* (2003b), it is important for sweetpotato roots mearnt for storage not to be disturbed in packaging and long distance transport as these processes causes mechanical damage to the sweetpotato roots. This will support the roots to be stored for a relatively longer period.

A reduction in skinning injury may not result in an increase in market value of sweetpotato (Ndunguru *et al*., 1998), though it has the potential of enhancing the shelf-life of the sweetpotato root (Ndunguru *et al*., 1998). The major problem resulting in most postharvest losses in developing countries are rough handling and inadequate cooling and temperature maintenance (Kitinoja & Kader, 2002). Kitinoja and Kader (2002) further explained that the lack of sorting to remove defects before storage and use of inappropriate packaging materials further add to the problem of postharvest losses in developing countries. Minimizing rough handling, sorting to remove damaged and diseased roots and effective temperature management will help considerably toward maintaining a quality product and reducing storage losses.

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Due to the fact that skinning damage incurred during harvest results in increased susceptibility to postharvest diseases (Rees *et al.*, 2003b), curing is recommended for the improvement of root quality and shelf life of sweetpotato roots (Edmunds *et al.,* 2008). It has been indicated through experimentation by Ndunguru *et al.* (1998) that pre-harvest curing by pruning 14 days or more before harvesting will reduce skinning injuries. According Edmunds *et al*. (2008), curing aids in wound healing and reduces losses due to shrinkage and disease. Edmunds *et al*. (2008) further explained that when roots are wounded, the exposed cells will quickly dry and die. Sweetpotato roots will naturally exude sticky latex from injuries, particularly at the ends of the sweetpotato. This material may dry in a few hours and appear to close the wound, but it actually provides little protection from decay organisms or weight loss. Only proper curing can result in “true” wound healing. Edmunds *et al.* (2008) added that freshly harvested sweetpotato roots have thin, delicate skin that is easily broken, scraped, or otherwise removed. Therefore, curing sets the skin of sweetpotato roots to permit safe handling.

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2.11 Conditions for storage

Successful storage starts with high-quality roots (Edmunds *et al*., 2008). In many parts of tropical Africa sweetpotato roots can only be stored for 3 weeks under uncontrolled conditions (Rees *et al.,* 2003a). Sweetpotatoes have special requirements with respect to storage, because of the high moisture content of the tubers (Hayma, 2003). On the one hand, desiccation should be avoided; and one has to guard against too much humidity around the tubers, which may cause rotting. Living tubers continue to breathe fairly intensively, and this increases at

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higher temperatures. When high tuber temperatures are combined with airtight storage, lack of oxygen occurs, which results for example in potatoes with black hearts (Hayma, 2003). For high temperature, better ventilation is necessary. According to Hayma (2003), during storage chemical changes take place in the tubers which may influence the firmness and the taste.

Hayma (2003) further explains that in order to make the Sweetpotato tubers more suitable for storage, curing is done. The tubers are stored under warm (about 30 °C) temperatures and very humid (80% - 90% relative humidity) conditions for 5-7 days. During this time a layer of cork cells, a few thick cell layers, is formed around the tubers. This layer greatly reduces the desiccation process and largely prevents infection by bacteria and fungi. Although the curing process goes faster in full sunshine, it is better to protect the tubers against the sun with big leaves, otherwise the relative humidity around the tubers decreases rapidly and the strong heating of the tubers initiates processes that reduce the keeping quality (Hayma, 2003).

Under appropriate and controlled storage conditions (temperature range of 13-15^{o}C and relative humidity of 90%) sweetpotato roots can be stored for up to one year (Rees *et al*., 2003a; Woolfe, 1992). Curing and Dark Storage of harvested tubers are recommended to ensure effective reduction of premature postharvest deterioration of the tubers during storage (Karanja *et al*., 2013). On another hand, an improved house pit (Mjinge) which is a normal dug pit under shade with the top opening plastered with mud and leaving a small hole is also recommended among other methods for keeping good quality sweetpotato (Mpagalile *et al*.,

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2007). This observation was made in a study in Tanzania using the traditional pit methods with some modifications. In the peak of the harvest season, these storage types described may be used by farmers to significantly reduce the losses that occur in sweetpotato roots in storage. An Evaporative cooling barn (Plate 1) and Modified pit storage structure (Plate 2) have also been proposed by Teye *et al.* (2011a) to enhance the preservation of roots in storage.

Plate 1: Evaporative cooling barn (Source: Teye *et al.*, 2011a)

Plate 2: Modified pit storage structure (Source: Teye *et al*., 2011a)

However, in a comparative assessment the Purposed Built Evaporative Cooling Barn (PBECB) was slightly better in reducing weight loss, weevil damage, shrinkage, decay and resulted in more wholesome roots than the Modified Pit Storage Structure (MPSS) (Teye *et al*., 2011a).

According to a study conducted in Nigeria, two storage methods, moist sawdust in wooden box and pit storage with layer of river sand have good potentials for storage of sweetpotatoes for up to five months without serious change in nutrient content and could therefore be recommended to farmers (Dandago & Gungula, 2011).

2.12 Sweetpotato marketability in Ghana

According to a review by Chaitali *et al* (2017), factors that influence the market life of sweetpotato storage roots are: the cultivar, pre-harvest growing conditions,

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curing conditions, storage temperature, relative humidity of storage environment, atmospheric oxygen / carbon dioxide and amount of mechanical injury during transport. The packaging of sweetpotato storage roots is an industrial operation that should be dedicated to delivering the highest quality product to the consumer (Chaitali *et al*., 2017). Between 41 and 93% of roots arriving at urban market are damaged which may correspond to a loss in economic value of 11 to 36% (Rees *et al*., 2001b). The major forms of deterioration that occurs under marketing conditions are weight loss and rotting (Rees *et al*., 2001b). The bulkiness and perishability are major constrains to sweetpotato root marketability and availability (Owori & Agona, 2003). Sweetpotato roots are highly perishable and so get rotten within few weeks in storage. This situation may cause farmers and aggregators some financial losses.

The sweetpotato storage roots produced in the northern part of Ghana is mainly sold in the northern urban market centers. The roots from the Upper East Region also has access to the Burkina collectors, especially during the months of August and September when Burkina Faso has little supply of sweetpotatoes to the market as the major harvest does not begin until October (Peters, 2013).

Accra is the major market for the sale of sweetpotatoes in the southern part of Ghana. Of the six major markets (Agbogbloshie, Mallam, Kaneshie, Kasoa, Makola, and Madina) in Accra, Agbogloshie is the largest depot (Peters, 2013).

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CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Introduction

The chapter reveals the materials and methods that constitute the framework for the investigation. The chapter explains the materials used and their specifications, study location, the experimental design and procedures for data collection and analysis.

3.2 Materials

These are the materials that were used in gathering the data during the study on the field.

3.2.1 Packaging materials

Polypropylenes sacks to contain 130 kg and 50 kg of sweetpotato roots, jute sacks to contain 130 kg of sweetpotato roots, and wooden crates that could contain 50 kg of roots were used for the packaging and transportation of sweetpotato from the aggregation sites to the urban market. These three packaging containers were used for the study for the three trips of the transport experiment.

3.2.1.1 Existing polypropylene sack

The existing polypropylenes which are locally called the “number 4”, were used to package 130 kg of storage roots (Plate 3) as usually done by the aggregators. It has been designated ‘existing’ because it is one of the packaging materials which the traders normally use for packaging of the sweetpotato roots in the trade. The 'existing' polypropylene sacks have dimensions 65 cm x 113 cm.

Plate 3: Existing polypropylene

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3.2.1.2 Existing jute sack

The existing jute sack which are locally called "cocoa sacks" in Ghana, were also used to package 130 kg of sweetpotatoes (Plate 4). It is also one of the packaging types normally used by traders in the sweetpotato trade. That is why it has the designation 'existing'. The existing jute sack has a dimension of 100 cm x 70 cm.

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Plate 4: Existing jute sack

3.2.1.3 Polypropylene sacks (50 kg holding capacity of sweetpotato roots)

Polypropylene sacks with the capacity of holding 50 kg of sweetpotato roots were also used as an alternative packaging container for the packaging of sweetpotato roots as shown in Plate 5. It is conveniently referred to as '50 kg polypropylene sacks' for the purpose of this study. The 50 kg polypropylene sack used for the study has dimensionsof 54 cm x 90 cm.

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Plate 5: 50 kg polypropylene sack

3.2.1.4 Wooden crates

Wooden crates (Plate 6) with the capacity of holding 50 kg of sweetpotato roots were used as an alternative packaging container for the packaging and transportation of sweetpotato roots from aggregation sites to urban markets. For the purpose of this study, the wooden crates are conveniently referred as '50 kg wooden crates'. The 50 kg wooden crates used had internal dimension of 0.5 m x 0.5 m x 0.5 m.

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Plate 6: 50 kg wooden crate

3.2.2 Vehicles used for the transport

Different vehicles were used for the transportation of sweetpotato roots from aggregation sites to urban markets in Ghana. This was done in accordance with the types of vehicles used for each of the transport routes where the study was conducted.

3.2.2.1 Market trucks

Market trucks (Plate 7) were used for the Afram Plains (Adawso) – Agbogbloshie sweetpotato transport route. These trucks locally called "Kia trucks" were two - axle vehicles with a length of 5-6 m, width of 2-3 m, 3-4 m in height when loaded with goods and a gross capacity rating of 4500 kg.

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Plate 7: Sweetpotato market truck

3.2.2.2 Tricycles

Tricycles as shown in Plate 8, which are commonly called “motorking” were used to transport sweetpotato roots from aggregation centres in Bawku to Bittou market in Burkina Faso. The model of motorkings which were used for the study was MK150ZH-F. It is 3250 mm in length including the bucket for load, which has a width of 1210 mm, a bucket height of 1350 mm, and a maximum speed of 75 km / h. This vehicle has a capacity to carry a maximum load of 500 kg.

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Plate 8: Tricycle (Motorking) for sweetpotato root transport

3.2.2.3 Donkey-drawn carts

Donkey-drawn carts (Plate 9) were also used to transport sweetpotato roots for the Bawku- Bittou route. The donkey-drawn carts used could carry a maximum load of about 400 kg with a speed of about 6 km / h.

Plate 9: Donkey-drawn carts for sweetpotato root transport

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3.2.3 Kitchen knife

An HMEDI stainless steel kitchen knife with a length of 160 mm was used for halving and quartering the roots in a transverse angle. The purpose of the halving and quartering of roots with the Kitchen knife was to check for internal necrosis.

3.2.4 Hanging weighing scale

A Camry hanging weighing scale of maximum recording weight of 100 kg was used to weigh sweetpotatoes before packaging was done.

3.2.5 Tuberlogs

Impact logger (PTR300 TuberLog®) of minimum detection level of 10 g was used for recording impact on roots during transport. Plate 10 shows a photo of PTR300 TuberLog®.

Plate 10: PTR300 TuberLog®

3.2.6 Venier Caliper

A Digital Venier Caliper (mm) with a maximum reading of 150 mm was used for the measuring of root diameter. Plate 11 shows the venier caliper used for taking the diameter of a sweetpotato root. The points from which measurements were taken on each of the sampled sweetpotato roots at the aggregation centre were marked. This was done to enable diameter reading from the same points at the urban market.

Plate 11: Caliper used for measuring the diameter of roots

3.2.7 Markers

Huaying permanent markers (Ref 3200) were used on the field for the identification of packages and individual sweetpotato root during the assessment.

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3.2.8 Camera

Nokia Lumia 520 mobile phone with 5-megapixel camera was used to take photos during the study.

3.3 Methodology

3.3.1 Study area

A purposive sampling was used in selecting the study area for the survey to be conducted. According to the MOFA / SRID (2012), the Upper East region and the Eastern region are the major sweetpotato root producing regions in Ghana. The sampling was also based on the major production areas within the two regions where the sweetpotato cultivation and aggregation business was high. Specifically, Bawku in the Upper East and Afram Plains (Adawso) in the Eastern regions of Ghana (MOFA / SRID, 2012). The Upper East region of Ghana shares boundaries with the republic of Burkina Faso and Togo. The Bawku area is pre-dominated by only farmers, while the Afram plains area is pre-dominated by farmers and fisher folks.

3.3.2 Questionnaire

For the preliminary survey, a structured questionnaire was developed and administered to sweetpotato root traders / aggregators in the Upper East (Bawku) and Eastern (Afram Plains) regions of Ghana. A total of fifty-seven (57) aggregators / local sweetpotato root collectors were interviewed. These "Aggregators" were middlemen and women who purchased roots from farmers and further transported them to urban market centres for wholesale.

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3.3.3 Preliminary survey

The survey investigated the sweetpotato root postharvest handling and transport from the aggregation centres to urban market centres in Ghana. The survey was conducted in December, 2014. The data gathered by the survey included the following:

- Sources of sweetpotato roots for transportation of sweetpotato;
- Type and size of packaging materials used for transport of sweetpotato roots from the production centre to urban market;
- Urban market centres where roots are transported to;
- Mode and cost of storage of roots at market centre before sale to retailers / final consumers;
- Mode and cost of transportation;
- Frequency of transportation and number of bags per trip;
- Cultivars of sweetpotato available at each location;
- The sweetpotato business season; and
- Cost evaluation of sweetpotato roots at aggregation centre and market centre;

3.3.4 Average weight per bag of sweetpotato at urban market

An assessment of the average weight of a bag of sweetpotato was also carried out at the urban markets during the time of the survey. It has already been established that a bag of sweetpotato is 160 kg as reported by Peters (2013). During the survey, three (3) different bags of sweetpotato were weighed and the average obtained. This was used as a representative average weight of a bag of sweetpotato in the urban market in Ghana.

3.3.5 Experimental design of transport experiment

For the purposes of achieving the set-out objectives, a randomized complete block design (RCBD) was used in designing the experiments. The experiment was conducted at each of these locations and each packaging option was assessed and packed three (3) times which served as replicates. However, three (3) transport trips were conducted for each of the location and each trip served as a block.

3.3.6 Transport experiment

Based on the information obtained from the preliminary survey an experiment was modeled and conducted to assess some physical quality parameters of sweetpotato roots packaged and transported in the identified packaging containers types from the aggregation points of the production centres to the urban markets.

In this experiment, two proposed containers (polypropylene sack and a wooden crate each capable of holding 50 kg of sweetpotato roots) were compared with current packaging containers (existing polypropylene and existing Jute sacks) to transport sweetpotato roots from two major production sites to urban markets. Sweetpotato farmers / marketers, and / or aggregators were involved in the packaging of the roots. They were directed to package the sweetpotato roots in the alternative packages as they usually do. In the second year of evaluation of the packaging containers, 50 kg wooden crate was dropped due to its bulkiness and

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maneuverability challenges at aggregation sites. Also, aggregators complained about its cost of transport from urban market back to aggregation sites for re-use.

Roots after packaging for each trip were transported to Agbogbloshie market in Accra from Afram Plains (Adawso). Also, sweetpotato roots were packaged and transported from Bawku to Bittou, a market centre in Burkina Faso. Packaged roots were loaded on market trucks commonly referred as Kia trucks from Afram Plains (Adawso) to Agbogbloshie market, a travel distance of about 143 km. Also, tricycle (locally called Motorking) and donkey-drawn carts were used for the Bawku-Bittou route, which has a distance of about 30 km.

3.3.7 Nature of road and time of transport

For the Afram Plains (Adawso) to Agbogbloshie transport route, roots were transported on tarred road with few bad road sections, and it is a journey made in about 4 – 5 hours by the trucks loaded with sweetpotato roots. The trucks were loaded and transported in the afternoons between 3 pm and 5 pm. Hence re-assessment of roots at the destination market was done in the morning.

On the other hand, sweetpotato roots were transported on partly graded and partly tarred road from Bawku to Bittou market. Loading and transportation of packaged sweetpotato roots for the Bawku to Bittou route was undertaken in the afternoons between 3 pm and 6 pm. Hence assessment of roots in the different packages at the Bittou market was done in the morning between 7 am and 11 am.

The sweetpotato transport experiment was conducted during the latter part of August to early October for the Afram Plains to Accra route, whilst that for

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Bawku to Bittou route was undertaken within November to December during the two-year assessment.

3.3.8 Data collection

At the aggregation sites, three (3) packaging containers each of the packaging types under study were packaged with sweetpotato roots. An initial quality (breaks, bruises and cuts) of sweetpotato roots was assessed in the packages before they were taken through the transport. Data were taken for root quality based on damage (cuts, breaks, and bruises), impact levels, visual acceptability score, root diameter, cost and revenue for each package.

3.3.9 Root quality assessment

The storage roots contained in the different packaging options were scored for damages based on the methods described by Tomlins *et al.* (2000) at both the aggregation centre and urban market centres. Damage of roots was assessed for each packaging container. Cuts, breaks, and bruises were scored based on a severity rating scale.

3.3.9.1 Bruises severity rating scale

Bruises were scored based on the severity rating scale as none bruises, minor bruises and major bruises as illustrated in Figure 3. This severity scoring of bruises was done for both aggregation and urban market sites. The procedure for the severity scoring is outlined as follows:

- 0 = (none - 0 implies no symptom of bruises);

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- 1 = (minor bruises - superficial bruises that does not cover up to 50% of the entire root area);
- 2 = (major bruises - superficial bruises that covers more than 50% of the entire root area);

Figure 3: Sweetpotato bruises severity rating scale

3.3.9.2 Breakage severity rating scale

Breaks were scored based on the severity rating scale as none breaks, minor breaks and major breaks as illustrated in Figure 4. This severity scoring of breaks was done for both aggregation and urban market sites. The procedure for the severity scoring is outlined as follows:

- 0 = (none - indicates no symptom of breakage);

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- 1 = (minor breakage - breakages of ≤ 10% of entire root length on one or both ends);
- 2 = (major breakage - breakages > 10% of the entire length of the roots);

Figure 4: Sweetpotato breakage severity rating scale

3.3.9.3 Cuts severity rating scale

Cuts were scored based on the severity rating scale as none cuts, minor cuts and major cuts as illustrated in Figure 5. This severity scoring of cuts was done for both aggregation and urban market sites. The procedure for the severity scoring is outlined as follows:

- 0 = (none - no symptom of cuts);
- 1 = (minor cuts - superficial cuts on the skin that does not extend to the flesh);

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- 2 = (major cuts - cuts that extends deep into the root flesh);

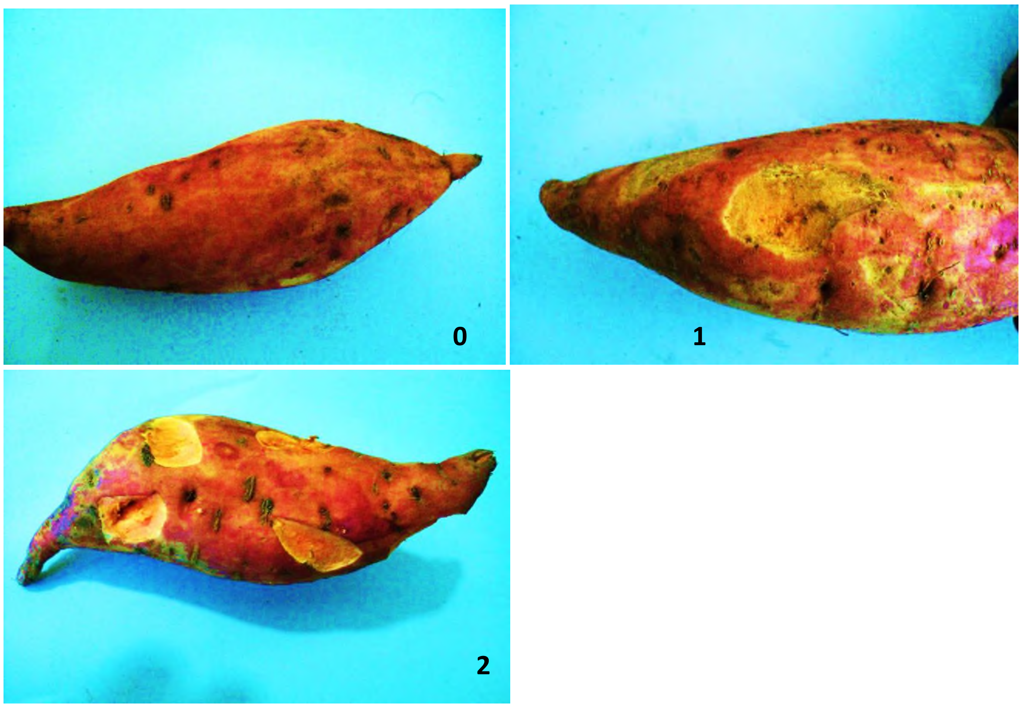

Figure 5: Sweetpotato cuts severity rating

Data were recorded by counting the number of roots for each severity rating scale. This was done at the packaging point in order to establish an initial quality level for each package before the transportation. Each packaging container after assessment at the aggregation centre was labeled with a permanent marker to ensure that same packages were re-assessed at the urban market after the transportation.

The re-assessment at the destination market centres was to determine the effect of transportation on the sweetpotatoes roots and the influence by the packaging container in which the produce was placed. Figures 3, 4 and 5 show the severity rating scales for bruises, breaks and cuts, respectively.

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3.3.10 Root shriveling

To establish the degree of shrivel as sweetpotato storage roots are transported from aggregation site market centres to the destination markets, the diameter of sweetpotato roots were measured. Within each package for each of the three (3) trips, 15 sweetpotato roots were selected randomly from the lot and the diameter of the root measured. Each of these roots was marked with a permanent marker at each side to ensure that diameter measurement is taken from the same side after transport at urban market. The instrument which was used to measure the shriveling was a digital venier caliper with its reading in millimeters. This measurement was done in accordance with Amoah *et al.* (2011) who determined sweetpotato root shrinkage by measuring the diameter of the root with a caliper and marked the points of measurement with a permanent marker. Sweetpotato roots were also stored for one week under market conditions. The diameter of sweetpotato storage roots were again measured after the one week of storage at the market. The differences in diameter were used to calculate for the root shrivels.

3.3.11 Visual acceptance

Samples of sweetpotato storage roots transported in the different packaging containers under investigation were taken out and displayed at the urban market. These samples were assessed by aggregators and consumers at the urban market centres. This afforded the aggregators and consumers the opportunity to score these samples based on its attractiveness and wholesomeness. Empty packages were taken away and only samples were displayed. This was done in order for the aggregators and consumers to do a genuine ranking of these packages based on the physical appearance of roots transported in them. The assessment was done based on a scale of 10% (least preferred) to 100% (most preferred) at the market. These assessments were done independently by consumers (*n = 48*) and aggregators (*n = 24*). About 10 kg of storage roots were randomly weighed from the different containers for the visual assessment of the storage roots.

3.3.12 Impact levels

PTR300 TuberLog® with minimum detection limit of 10 g for impact was placed in the middle of the storage roots contained in the different packaging containers to assess the impact during loading and offloading (Plate 12). Duplicate logger was placed closer to the top in the existing polypropylene and jute due to their larger sizes to monitor the impact on packages during loading and offloading. Six of the PTR300 TuberLog® were used in each trip of the study. The PTR300 TuberLog® which is shaped in the form of a sweetpotato, was placed in each of the containers. At each stage (on-loading and off-loading), the impact loggers were timed and started before the activity. The PTR300 TuberLog® logged the impact data each time the package was shaken. The loggers were activated before the on-loading at the aggregation centre. On arrival at the destination market, the loggers were again activated, while packaging containers were still on the vehicle and ready to be off-loaded. The impact recorded by the tuberlog was in grams (g).

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Plate 12: Tuberlog placed among sweetpotato roots

3.3.13 Economic analysis

An evaluation of profitability and benefit cost ratio (BCR) analysis of each packaging container was done as aggregators' willingness to adopt any packaging

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container for the transport of storage roots depends on its profitability (Schuur, 1988). Data were taken for the following cost and revenue components:

- Cost of empty packaging container;
- Cost of transport of the packaging container;
- Cost of storage at the urban market and aggregation centre;
- Loading and Offloading cost of the package;
- Market tolls;
- Value of roots contained in the package at aggregation centre;
- Value of roots contained in the package at urban market;
- Number of times a package can be re-used;

The Net profit and BCR formulae were used to compute the profit margin for each packaging option after roots were retailed at urban market.

Net profit was obtained by the difference between total revenue (TR) and total cost (TC) (Müller & Padberg, 2003) as shown in equation 1.

Net profit = TR –TC ……………………………………………Equation 1

The benefit cost ratio (BCR) was also obtained by dividing TR by TC (Müller & Padberg, 2003) as illustrated in equation 2.

Benefit cost ratio (BCR) = TR / TC …………………………..Equation 2

A packaging container is worth recommending for use if its economic benefits are greater than its cost. Using the methods of Müller and Padberg (2003), a benefit cost ratio of greater than 1 means that the packaging containers is worth

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recommending for use. It is break even if the benefit cost ratio of any packaging container is equal to 1. A benefit cost ratio of less than 1 implies that the packaging container is unprofitable.

3.3.14 Internal necrosis

After transport, 15 roots were scored for internal necrosis for each package transported. The scoring was done according to the method used by Jiang *et al*. (2015) as described in Figure 6.

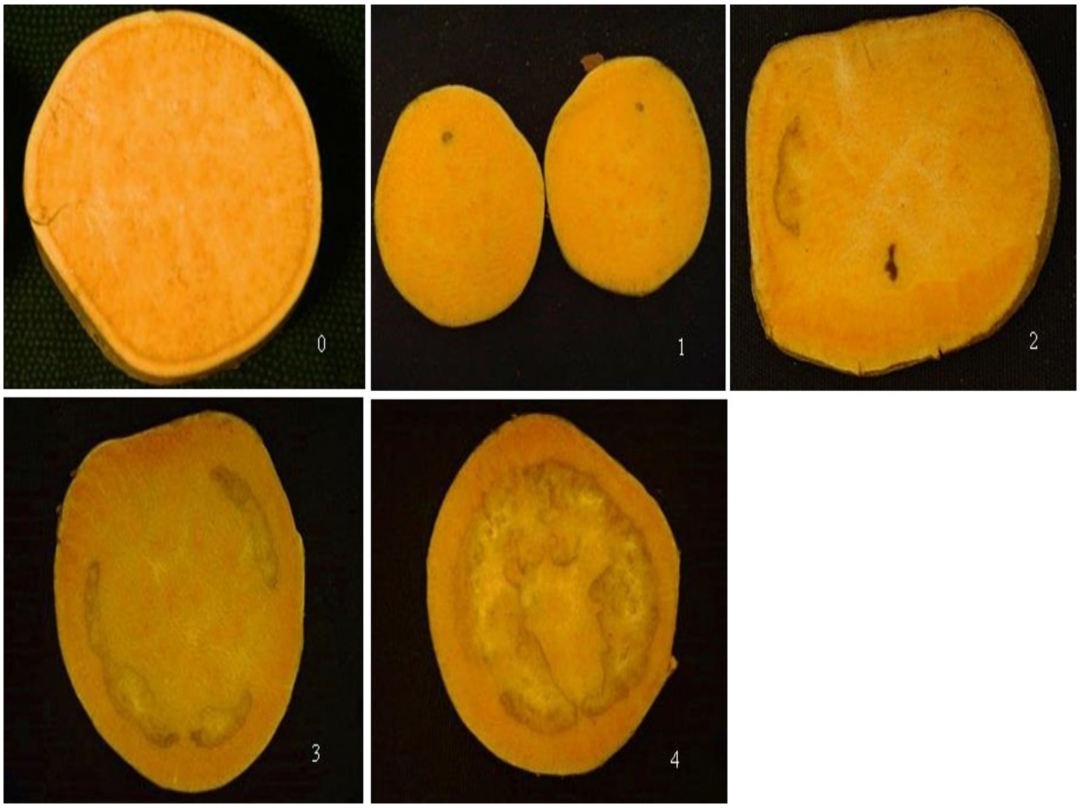

Figure 6 : Sweetpotato internal necrosis (IN) severity rating scale

0 = no symptom,

1 = negligible but visible symptoms;

2 = obvious symptoms but mainly confined to stem end;

3 = extensive symptoms that either go deeper into the root or have multiple and larger diffuse areas of the root affected and could render roots unmarketable; and

4 = extreme symptoms that go at least one-third of the way into the root from the stem end and render the root unmarketable.

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3.3.15 Data analysis

Data collected from the survey using the structured questionnaire were analyzed using SPSS version 20. Notes were also taken alongside the interviews on observations on the field at the aggregation centre and the urban market in order to gather the relevant information required.

Experimental quantitative data were analyzed using Minitab v16.2.2 statistical software. Analysis of variance (ANOVA) was done for the quality parameters (cuts, breaks, bruises) at both aggregation site and urban market. To determine whether the transport effect on packaging containers was significant, a paired sample t - test was also carried out to compare quality parameters for the aggregation centre and the urban market. For the non-parametric data generated from the visual assessment scoring, a Kruskal-Wallis test was employed. Means were considered to be significantly different at $p < 0.05$. Data were expressed as means ± standard error of means (SEM), unless otherwise specified. The results were presented in Tables and Figures.

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CHAPTER FOUR

4.0 RESULTS

4.1 Introduction

The results of this work are outlined in two fold. The reconnaissance survey data collected and the transport experimental data on sweetpotato roots. All the results are presented in Figures and Tables. The results of the reconnaissance survey have been presented in Tables 8 - 11 and Figures 7 – 11. The transport experimental results are also presented in Tables 12 – 20 and Figures 12 – 17.

4.2 A. Sweetpotato packaging and transportation in Ghana

4.2.1 Sources of roots

The sources of roots obtained by aggregators for transport to the urban markets are shown in Table 8. For the Upper East region, 65% of aggregators obtained their roots from farmers and 35% bought their roots from other retailers before transport to the urban market centre. For the Eastern region, all aggregators obtained their roots directly from farmers before they packaged and transported to the urban market.

Table 8: Sources of roots as obtained by aggregators

	From farmers	Retailers/other buyers	Total
Upper East region	65%	35%	100%
Eastern Region	100%	0	100%

4.2.2 Packages used for sweetpotato to urban markets

Two types of packages, Polypropylene and Jute sacks were identified as being used by aggregators at the market for packaging and transportation of sweetpotato storage roots as shown in Table 9. These packages had the capacity each to hold approximately 130 kg of fresh sweetpotato roots. Data in Table 9 indicate that almost 96% of the aggregators for Bawku – Bittou route used polypropylene sacks for packaging and transportation of storage roots. Also, all aggregators for the Afram Plains – Accra route used polypropylene sacks for packaging and transportation of roots to the urban market. The sacks were well filled and capped with polypropylene material (Plate 13).

Table 9: Types of packaging containers used for sweetpotato transportation in Ghana

Transport route	Polypropylene sack	Polypropylene & Jute sacks
Upper East region (Bawku-Bittou route)	96%	4%
Eastern region (Afram Plains {Adawso}-Accra route)	100%	0%

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Plate 13: Sweetpotato sack packaged and capped

4.2.3 Sweetpotato marketing chain

Before sweetpotato roots were received and utilized by the consumer, several processes were involved. The marketing chain of sweetpotato began from the local farmer after harvest through the local collectors / aggregators who transported the roots to the urban market for sale out to retailers as indicated in the flow chart in Figure 7.

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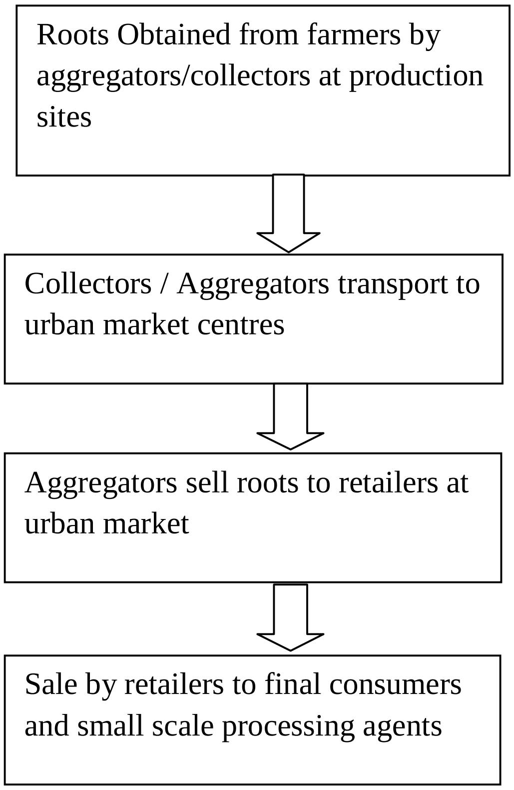

Figure 7: Sweetpotato marketing chain

4.2.4 Sweetpotato transport linkages

For the Bawku-Bittou transport route, the survey found that 81% of aggregators after purchase of roots from farmers transport to Burkina Faso for sale. Only 19% of these aggregators transport their roots towards Bolgatanga, the regional capital of the Upper East region (Figure 8). However, in the Eastern region, roots were transported from the major production centres to Agbogbloshie market in Accra where there is a hub for the retail of the sweetpotatoes. There was also transport of sweetpotato roots from Volta region (Aboteasi and Akatsi) and Central region (Kasoa) to Accra. The supplies from these areas to the Accra markets occur at different times of the year (Table 10).

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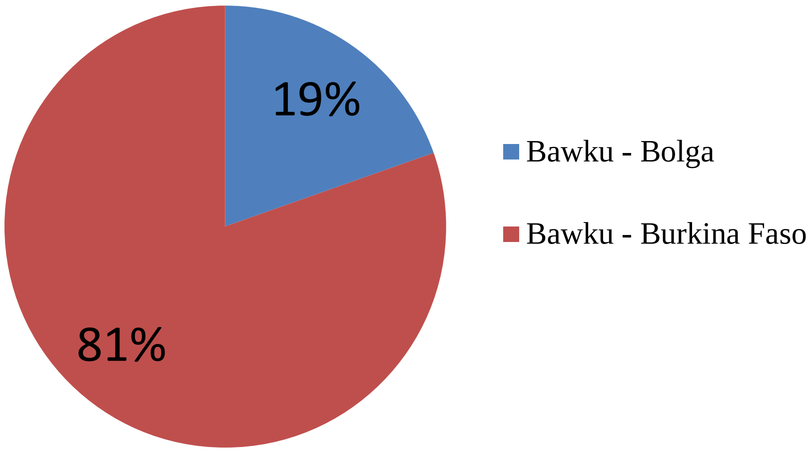

Figure 8: Sweetpotato aggregator transportation linkages from Bawku

4.2.5 Transported cultivars

Aggregators identified cultivars of sweetpotato that they transport to urban markets. Seven transported cultivars were identified by aggregators at Bawku. These cultivars were "Kufour, Samadie, Obaari, Sankansinabur, Awaal, Naakudou, and Prupru" (Table 10). These transported cultivars for the Bawku – Bittou route were all white-fleshed cultivars except "Kufour" which is an orange-fleshed cultivar. Six cultivars were also found to be transported from Eastern, Central and Volta regions to the Accra markets as shown in the Table 10. Among these transported cultivars for the southern part of Ghana, were four yellow-fleshed and two white-fleshed cultivars.

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Table 100: Transported sweetpotato cultivars from production centres in Eastern and Upper East regions.

Cultivar	Region	Skin colour	Flesh colour	Time of the year
"Fadedae"	Eastern (Afram plains)	White	Yellow	July – Nov
"Aboteasi"	Volta (Aboteasi)	White	Yellow	Sept – Jan
"Asisewa"	Eastern	White	Yellow	June – Aug
"Akatsi"	Volta (Akatsi)	White	White	Jan – Apr
"Dabo"	Central (Kasoa)	White	Yellow	Dec – Feb
"Ehiamankyine"	Eastern (Begoro)	White	White	July – Nov
"Obaari"	Upper East (Bawku)	White	White	Sept – Jan
"Kufour"	Upper East (Bawku)	Red	Orange	Sept – Jan
"Samadike"	Upper East (Bawku)	Red	White	Sept – Jan
"Sankansinabure"	Upper East (Bawku)	White	White	Sept – Jan
"Awaal"	Upper East (Bawku)	Red	White	Sept – Jan
"Naakudou"	Upper East (Bawku)	Red	White	Sept – Jan
"Prupru"	Upper East (Bawku)	White	White	Sept – Jan

Sweetpotato roots were found to be available all year round (January to December) in the Accra markets. However, there was a higher supply in the peak sweetpotato root harvest season (August to November). The major supply during this period of the year came from the Ekyiamanfrom area of the Afram plains.

For Bawku in the Upper East region, the sweetpotato root trading started from September and ended in January. The peak period when most roots were harvested by farmers and purchased by aggregators was November. The season was different in the southern part. At Afram Plains, aggregators started transportation of sweetpotato roots to urban markets in July. The transport

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continued till November when aggregators did not get enough roots for transport. The peak of the business season for aggregators who transported sweetpotato roots from Afram Plains to Accra was from August to October. During this period the supply to the urban market centre was much higher.

Though all seven cultivars are transported to urban markets by aggregators at Bawku, "Obaari" was more preferred for transport than all other cultivars (Figure 9). With reference to Figure 9, 43 out of 51 aggregators preferred to transport "Obaari" than any other cultivar.

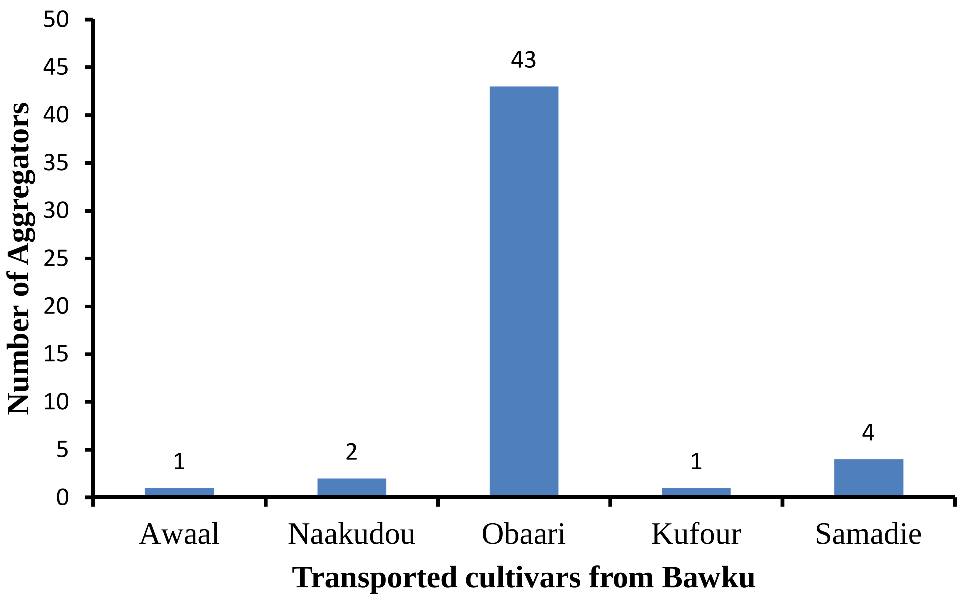

Figure 9: Aggregator preference for transported cultivars in Bawku

4.2.6 Mode and cost of transport to urban markets

The major mode of transportation of sweetpotato roots from production centres to Accra were by trucks. However, the transportation of sweetpotatoes from Upper East region (Bawku) to Bittou market in Burkina Faso were done using a tricycle

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(motoking) and donkey carts. The cost of transportation to urban market centres varied per sack at each of these locations as shown in Table 11.

Table 11: Cost of transportation per sack (about 130 kg) of sweetpotato storage roots (2014).

Transportation link	Cost/bag (GH¢)	Mode of transport
Bawku – Bolgatanga	5.00	Trucks
Bawku – Bittou	4.00	Tricycles (Motorking)& donkey cart
Afram Plains (Adawso) – Accra	29.00	Trucks

4.2.7 Grouped aggregators in relation to number of bags per transport

At Bawku, 65% of aggregators transported below 10 bags (about 130 kg each) in a single trip and the rest of the 35% transported between 10-20 bags (Figure 10). These aggregators transported about 5 trips per month at the peak of the sweetpotato storage root harvest season. However, in the Eastern region each aggregator packaged between 21 to 60 bags in a single trip (Figure 11) and transported sweetpotato storage roots weekly to Accra at the peak of the business season.

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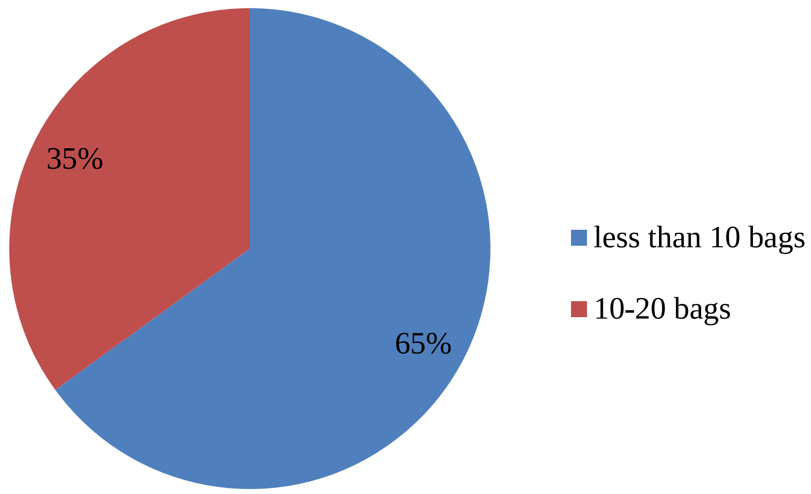

Figure 10: Grouped Sweetpotato aggregators in relation to bags per transport from Bawku to Bittou market

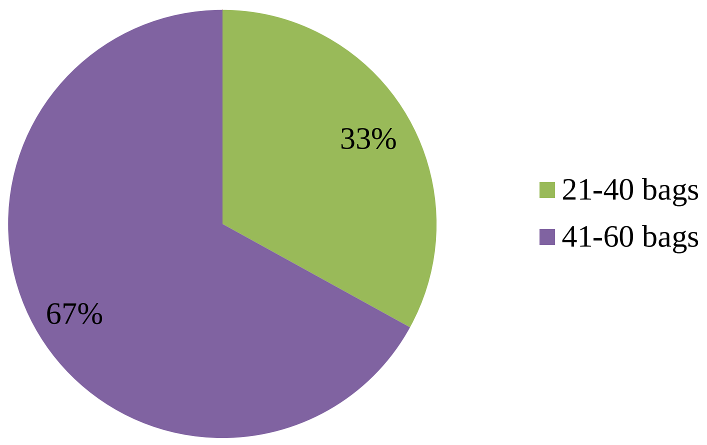

Figure 11: Grouped Sweetpotato aggregators in relation to bags per transport from Afram Plains (Adawso) to Agbogbloshie market

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4.3 B. Assessed containers for transport of sweetpotato storage roots in Ghana

4.3.1 Breaks

The level of breaks in sweetpotato packaged and transported from Afram Plains to Agbogbloshie market in Accra (urban market) is shown in Table 12. For the year one, only the existing polypropylene and jute sack packaging containers resulted in significant breaks. The roots contained in the existing polypropylene sacks showed significant increase of about 158% in major breaks ($p = 0.028$), and about 61% minor breaks ($p = 0.016$) between aggregation site and urban market. However, the existing jute sack showed significant increase of 43% in only minor breaks ($p = 0.042$). None-broken storage roots at the urban market were reduced by 10% each by both existing polypropylene and Jute in the first year of experimentation.

During the validation study (year 2), a paired sample t-test showed significant ($p < 0.05$) increase in major breaks for all packaging containers between aggregation centre and arrival at the urban market centre (Table 12). Also, both existing polypropylene and Jute in the second year of experimentation resulted in significant reduction of 11% ($p = 0.006$) and 8% ($p = 0.005$) of none-broken storage roots at the urban market.

Among packaging containers, only existing polypropylenes and jute sacks (130 kg) resulted in significant major and minor breaks for both year one and two. The size and weight of the package presented a challenge in handling during loading at aggregation site and offloading on arrival at the market. The other smaller

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weight (50 kg) packages were not significantly affected on breakage of roots in both year one and two as presented in Table 12.

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Table 12: Percent breaks before transport and after transport for Afram Plains (Adawso) – Agbogbloshie route

[illegible]y of [illegible]s	Year 1 (2015) Packaging containers					Year 2 (2016) Packaging containers			
	Existing Polypropylene sack	Existing Jute sack	50 kg-polypropyl-ene sack	50 kg-wooden crate	P-value	Existing Polypropylene sack	Existing Jute sack	50 kg-polypropylene	P-value
M[illegible]. Site	4.38±1.89	3.39±1.89	5.41±1.89	3.62±1.89	*0.874*	2.52±0.89	2.76±0.89	3.46±0.89	*0.750*
M[illegible]t	11.32±2.05	11.13±2.05	10.61±2.05	3.62±2.05	*0.062*	7.72±0.97	6.94±0.97	6.41±0.97	*0.646*
P-[illegible]	*0.028*	*0.081*	*0.209*	-		*0.001*	*0.025*	*0.001*	
M[illegible]. Site	3.69±1.89	3.41±1.89	9.43±1.89	9.50±1.89	*0.042*	1.55±0.37	2.37±0.37	3.41±0.37	*0.018*
M[illegible]t	6.08±1.89	4.87±1.98	8.87±1.98	9.50±1.98	*0.354*	7.17±1.19	5.91±1.19	3.85±1.19	*0.195*
P-[illegible]	*0.016*	*0.042*	*0.572*	-		*0.034*	*0.072*	*0.511*	
N[illegible] Site	91.9±2.83	93.2±2.83	85.16±2.83	86.88±2.83	*0.166*	95.93±1.14	94.88±1.14	93.13±1.14	*0.263*
N[illegible]	82.60±3.47	84.01±3.47	80.52±3.47	86.88±3.47	*0.629*	85.11±1.29	87.64±1.29	89.09±1.29	*0.140*
P-[illegible]	*0.011*	*0.069*	*0.292*	-		*0.006*	*0.005*	*0.057*	

Significantly different (P < 0.05). Values represent the mean ± standard error of the mean (SEM, n = 6)

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The level of breaks in sweetpotato packaged and transported from Bawku (Upper East region of Ghana) to Bittou market (Burkina Faso) is shown in Table 13. No significant differences occurred between the packaging containers and mode of transport (donkey carts *vs.* tricycles). Both modes of transport resulted in insignificant levels of major ($p > 0.05$) and minor ($p > 0.05$) breaks for both years.

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Table 13: Percent breaks before transport and after transport for Bawku – Bittou route

	ty of ks	Year 1 (2015) Packaging containers: Existing Polypropylene sack	Existing Jute sack	50 kg-polypropylene sack	50 kg-wooden crate	P-value	Year 2 (2016) Packaging containers: Existing Polypropylene sack	Existing Jute sack	50 kg-polypropylene sack	P-value
Tricycle (motorking)	N g. site	1.65±1.07	2.76±1.07	2.62±1.07	1.93±1.07	*0.635*	3.19±0.61	4.04±0.61	3.29±0.61	*0.590*
	N kt	1.69±1.07	2.90±1.07	3.03±1.07	2.34±1.07	*0.499*	3.36±0.58	4.13±0.58	3.44±0.58	*0.618*
	P	*0.423*	*0.583*	*0.244*	*0.208*		*0.067*	*0.184*	*0.423*	
	N g. site	2.29±2.36	3.13±2.36	3.47±2.36	2.17±2.36	*0.644*	6.17±0.91	4.40±0.91	6.14±0.91	*0.355*
	N kt	2.50±2.36	3.32±2.36	4.11±2.36	2.61±2.36	*0.484*	6.13±0.95	4.53±0.95	6.43±0.95	*0.377*
	P	*0.189*	*0.275*	*0.186*	*0.114*		*0.742*	*0.218*	*0.423*	
	N . site	96.07±3.17	94.11±3.17	93.91±3.17	95.90±3.17	*0.534*	90.65±0.64	91.56±0.64	90.57±0.64	*0.517*
	N :	95.81±3.17	93.77±3.17	92.87±3.17	95.05±3.17	*0.361*	90.52±0.69	91.34±0.69	90.13±0.69	*0.487*
	P	*0.209*	*0.423*	*0.186*	*0.138*		*0.238*	*0.195*	*0.423*	
Donkey Cart	N g. site	6.20±1.07	8.98±1.07	10.32±1.07	5.74±1.07	*0.122*	2.99±0.74	2.19±0.74	4.29±0.74	*0.209*
	N kt	6.20±1.07	8.98±1.07	10.32±1.07	5.74±1.07	*0.122*	4.94±0.89	2.35±0.89	4.94±0.89	*0.188*
	P	*0.189*	*0.284*	*0.423*	*0.193*		*0.394*	*0.26*	*0.186*	
	N g. site	18.79±2.36	15.74±2.36	12.81±2.36	9.10±2.36	*0.257*	6.69±1.19	4.77±1.19	12.39±1.19	*0.010*
	N kt	18.79±2.36	15.74±2.36	12.81±2.36	9.10±2.36	*0.257*	8.05±0.14	8.02±0.18	8.06±0.23	*0.992*
	P	*0.224*	*0.434*	*0.423*	*0.423*		*0.417*	*0.656*	*0.184*	
	N . site	75.01±3.17	75.28±3.17	76.87±3.17	85.16±3.17	*0.357*	90.33±1.79	93.05±1.79	83.32±1.79	*0.021*
	N :	75.01±3.17	75.28±3.17	76.87±3.17	85.16±3.17	*0.357*	88.57±0.22	88.33±0.29	88.59±0.34	*0.771*
	P-value	*0.191*	*0.254*	*0.423*	*0.423*		*0.227*	*0.423*	*0.184*	

Significantly different (P < 0.05). Values represent the mean ± standard error of the mean (SEM, n = 6)

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4.3.2 Bruises

The levels of bruises in sweetpotato packaged and transported from Afram Plains to Agbogbloshie market in Accra (urban market) is shown in Table 14. For the year one, all the packaging containers resulted in major bruises of the roots contained in them with the exception of those placed in wooden crates. Also, it was only the sweetpotato storage roots contained in the 50 kg wooden crate that maintained the same percentage of none bruised at both aggregation site and urban market centre. No major bruises were found on packaged sweetpotato roots at aggregation site before transport. The polypropylene sack containing 50 kg of sweetpotato roots was 17% and 49% higher in major bruised than existing polypropylene and existing jute sacks respectively. Generally, the polypropylene sacks resulted in higher major bruises of sweetpotato roots after transport. Also, the 50 kg wooden crates presented significantly higher quantity ($p = 0.003$) of none-bruised sweetpotato storage roots to the urban market after transport than existing polypropylene sacks, jute sacks and 50 kg polypropylene (Table 14). The wooden crates with holding capacity of 50 kg of sweetpotato roots delivered about 24% none bruised roots to the urban market which was the same as recorded from the aggregation centre.

During the validation study (year 2), roots contained in different packaging containers were not significantly ($p > 0.05$) different between each other in terms of all categories of bruises considered. However, the paired sample t-test comparison of major, minor and none bruises showed significant ($p < 0.05$) difference regarding major and none bruises after transport from Afram Plains to

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Agbogbloshie market in Accra (Table 14). More than 80% of major bruises occurred in each packaging container after transport to Agbogbloshie market. There was no packaging container which was able to protect wholly the sweetpotato roots against bruises during packaging and transportation to the urban market. This result corresponds to the transport experiment conducted in the first year where all packaging containers delivered bruised roots to the urban market except those 50 kg of roots contained in the wooden crates.

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Table 14: Percent bruises before transport and after transport for Afram Plains (Adawso) – Agbogbloshie route

' of :s	**Year 1 (2015) Packaging containers**					**Year 2 (2016) packaging containers**			
	Existing Polypropylene sack	Existing Jute sack	50 kg-polypropylene sack	50 kg-wooden crate	P-value	Existing Polypropylene sack	Existing Jute sack	50 kg-polypropylene sack	P-value
M g. site	0	0	0	0		0	0	0	-
M t	39.70±8.43	31.18±8.43	46.38±8.43	0.00±8.43	*0.005*	82.80±2.68	84.84±2.68	85.08±2.68	*0.808*
P-	*0.002*	*0.032*	*0.009*	-		*0.000*	*0.000*	*0.000*	
M g. site	40.64±10.21	44.56±10.21	50.00±10.21	76.03±10.21	*0.121*	24.32±1.86	22.48±1.86	28.42±1.86	*0.122*
M t	60.30±10.21	68.8±10.21	53.60±10.21	76.00±10.21	*0.398*	17.20±2.68	15.16±2.68	14.92±2.68	*0.808*
P-	*0.336*	*0.282*	*0.848*	-		*0.118*	*0.080*	*0.348*	
N site	59.36±10.78	55.44±10.78	50.00±10.78	23.97±10.78	*0.121*	75.68±1.86	77.52±1.86	71.58±1.86	*0.122*
N	0.00±4.62	0.00±4.62	0.00± 4.62	23.97±4.62	*0.003*	0.00	0.00	0.00	-
P-	*0.006*	*0.006*	*0.002*	-		*0.000*	*0.000*	*0.000*	

Significantly different (P < 0.05). Values represent the mean ± standard error of the mean (SEM, n = 6)

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With reference to Table 15, all categories of bruises (major, minor and none) assessed at aggregation site and destination site did not show any significant differences ($p > 0.05$) for the Bawku to Bittou transport. This means that no statistical difference was found between packaging containers used for packaging and transportation of sweetpotato to Bittou market from Bawku.

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Table 15: Percent bruises before transport and after transport for Bawku - Bittou route

	y of es	Year 1 (2015) Packaging containers					Year 2 (2016) packaging containers			
		Existing Polypropylene sack	Existing Jute sack	50 kg-polypropylene sack	50 kg-wooden crate	P-value	Existing Polypropylene sack	Existing Jute sack	50 kg-polypropylene sack	P-value
Tricycle (motorking)	M g. Site	1.73±0.59	2.07±0.59	2.81±0.59	2.17±0.59	*0.808*	0	0	0	-
	M t	1.83±0.59	2.15±0.59	2.18±0.59	2.77±0.59	*0.539*	0	0	0	-
	P	*0.423*	*0.423*	-	-		-	-	-	
	M g. Site	8.37±2.13	8.28±2.13	7.15±2.13	6.01±2.13	*0.697*	16.01±0.91	13.69±0.91	4.84±0.91	*0*
	M t	8.37±2.13	8.43±2.13	7.53±2.13	5.63±2.13	*0.514*	11.26±0.49	11.71±0.22	5.07±0.35	*0.205*
	P	-	*0.423*	*0.211*	-		*0.432*	*0.423*	*0.231*	
	N Site	89.90±2.65	89.65±2.65	90.66±2.65	91.81±2.65	*0.841*	95.16±0.91	86.31±0.91	83.99±0.91	*0*
	N	89.80±2.65	89.42±2.65	90.29±2.65	91.59±2.65	*0.833*	94.98±0.86	86.27±0.86	88.53±0.86	*0.192*
	P	*0.423*	*0.423*	*0.211*	-		*0.432*	*0.423*	*0.231*	
Donkey Cart	M g. Site	2.52±0.59	2.84±0.59	2.89±0.59	3.32±0.59	*0.892*	0	0	0	-
	M t	2.52±0.59	2.84±0.59	2.89±0.59	3.32±0.59	*0.892*	0	0	0	-
	P	*0.842*	*0.382*	*0.241*	*0.192*		-	-	-	
	M g. Site	10.38±2.13	10.82±2.13	9.35±2.13	8.89±2.13	*0.947*	10.10±1.54	10.37±1.54	10.16±1.54	*0.992*
	M t	10.38±2.13	10.82±2.13	9.35±2.13	8.89±2.13	*0.947*	10.26±1.48	10.44±1.48	10.79±1.48	*0.967*
	P	*0.536*	*0.743*	*0.252*	*0.281*		*0.184*	*0.218*	*0.423*	
	N Site	87.10±2.65	86.34±2.65	87.76±2.65	87.78±2.65	*0.987*	89.90±1.54	89.63±1.54	89.84±1.54	*0.992*
	None_mkt	87.10±2.65	86.34±2.65	87.76±2.65	87.78±2.65	*0.987*	89.21±1.52	89.56±1.52	89.21±1.52	*0.976*
	P-value	*0.076*	*0.216*	*0.607*	*0.586*		*0.423*	*0.195*	*0.423*	

Significantly different (P < 0.05). Values represent the mean ± standard error of the mean (SEM, n = 6)

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4.3.3 Cuts

The levels of cuts in sweetpotato roots packaged in the different packaging containers and transported from Afram Plains to Accra are presented in Table 16. No significant differences (P > 0.05) in major and minor occurred in cuts as a result of transport during the experiment for Afram plains–Accra route.

Table 16: Percent cuts before transport and after transport for Afram Plains (Adawso) – Agbogbloshie route (2015).

Severity of Cuts	**Packaging containers**			
	Existing polypropylene sack	Existing Jute sack	50 kg-polypropylene sack	50 kg-wooden crate
Major_agg. Site	10.83±1.68	11.31±1.68	5.77±1.68	4.48±1.68
Major_mkt	10.83±1.68	11.31±1.68	5.77±1.68	4.48±1.68
P-value	*0.500*	*0.500*	*0.500*	*0.500*
Minor_agg. Site	8.79±2.15	11.23±2.15	8.38±2.15	10.64±2.15
Minor_mkt	8.79±2.15	11.23±2.5	8.38±2.15	10.64±2.15
P-value	*0.500*	*0.500*	*0.500*	*0.500*
None_agg. Site	80.4±2.98	77.5±2.98	85.9±2.98	84.9±2.98
None_mkt	80.4±2.98	77.5±2.98	85.9±2.98	84.9±2.98
P-value	*0.500*	*0.500*	*0.500*	*0.500*

Significantly different (P < 0.05). Values represent the mean ± standard error of the mean (SEM, n = 6)

Table 17 also presents data on the level of cuts in sweetpotato roots packaged in different containers and transported from Bawku to Bittou market. The t-test comparison showed no significant differences (P > 0.05) in major and minor cuts as a result of transport during the experiment for the Bawku-Bittou route. Cuts did not occur in transit when roots were packaged in either of the packaging containers used.

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Table 17: Percent cuts before transport and after transport for Bawku – Bittou route (2015).

	Severity of Cuts	Packaging containers			
		Existing polypropylene sack	Existing Jute sack	50 kg-polypropylene sack	50 kg-wooden crate
Tricycle (motorking)	**Major_agg. Site**	6.44±2.12	13.81±2.12	8.77±2.12	10.96±2.12
	Major_mkt	6.44±2.12	13.81±2.12	8.77±2.12	10.96±2.12
	P-value	0.500	0.500	0.500	0.500
	Minor_agg. Site	16.45±3.09	8.69±3.09	10.91±3.09	5.02±3.09
	Minor_mkt	16.45±3.09	8.69±3.09	10.91±3.09	5.02±3.09
	P-value	0.500	0.500	0.500	0.500
	None_agg. site	77.11±3.85	77.50±3.85	80.33±3.85	84.02±3.85
	None_mkt	77.11±3.85	77.50±3.85	80.33±3.85	84.02±3.85
	P-value	0.500	0.500	0.500	0.500
Donkey Cart	**Major_agg. Site**	4.44±2.12	10.56±2.12	8.40± 2.12	9.08± 2.12
	Major_mkt	4.44±2.12	10.56±2.12	8.40±2.12	9.08±2.12
	P-value	0.500	0.500	0.500	0.500
	Minor_agg. Site	9.13±3.09	13.67±3.09	9.23±3.09	7.74±3.09
	Minor_mkt	9.13±3.09	13.67±3.09	9.23±3.09	7.74±3.09
	P-value	0.500	0.500	0.500	0.500
	None_agg. site	86.43±3.85	75.77±3.85	82.37±3.85	83.14±3.85
	None_mkt	86.43±3.85	75.77±3.85	82.37±3.85	83.14±3.85
	P-value	0.500	0.500	0.500	0.500

Significantly different ($P < 0.05$). Values represent the mean ± standard error of the mean (SEM, $n = 6$)

4.3.4 Effect of packaging container on the impact the storage root incurred

The average impacts incurred by sweetpotato roots contained in the different containersduring loading and offloading for Afram Plains to Agbogbloshie market in Accra are presented in Figure 12. All packaging containers recorded impacts

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higher that 10 g, the minimum threshold, for the Afram plains to Agbogbloshie transport route. The impacts recorded were a quarter lower, in wooden crate and 50 kg polypropylene sack compared with those in the larger sacks (existing polypropylene and existing Jute sacks). In general, the storage roots contained in the 50 kg-packaging containers were 65% lower in impact than the existing packages.

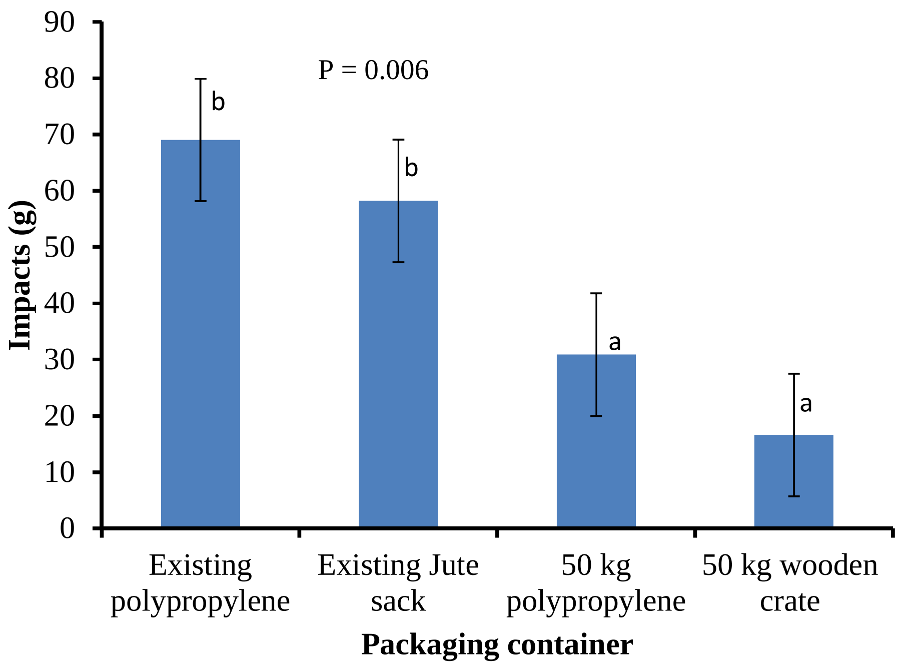

Figure 12: Impacts (g) on roots for each packaging container for the Afram plains (Adawso) - Accra transport

Bar represent the mean and error bars are standard error of the mean. Bars with different letters were significantly different (p < 0.05)

For the Bawku-Bittou route no significant differences (p = 0.48) among packages for impact were found during loading and offloading as shown in Figure 13. The

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impacts recorded were between 13 – 17 g for the polypropylene sacks and jute sack (Figure 13). However, the storage roots contained in the wooden crate did not record impacts because such impacts were too minimal (<10 g).

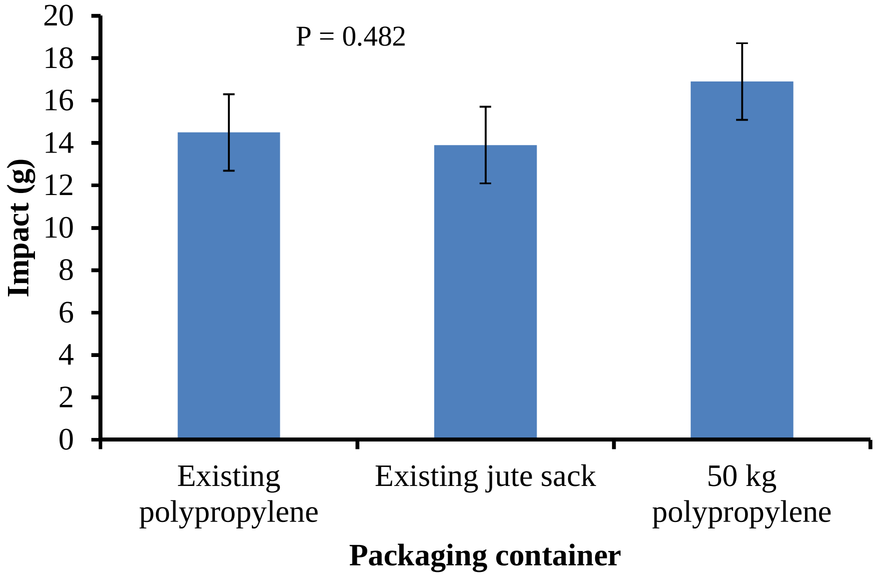

Figure 13: Impacts (g) on roots for each packaging container for the Bawku-Bittou transport.

Bar represent the mean and error bars are standard error of the mean. Bars with different letters were significantly different (p < 0.05)

4.3.4.1 Effect of packaging container on impacts at loading and off-loading

Figure 14 presents data on the interaction between package and the site (loading and off-loading). A significant effect (p = 0.045) was found when impact at loading was compared with impact at offloading. Generally, impacts received by sweetpotato roots in existing polypropylene were higher during off-loading relative to loading. At Afram plains to Accra route, the on-loading and offloading impact difference was about 22 g. During loading, polypropylene and jute sacks

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are thrown from heads of loaders onto trucks. Similarly, in offloading, sacks are dropped from the heads of off-loaders. These existing packages were very heavy (130 kg) and were uneasy to load and off-load.

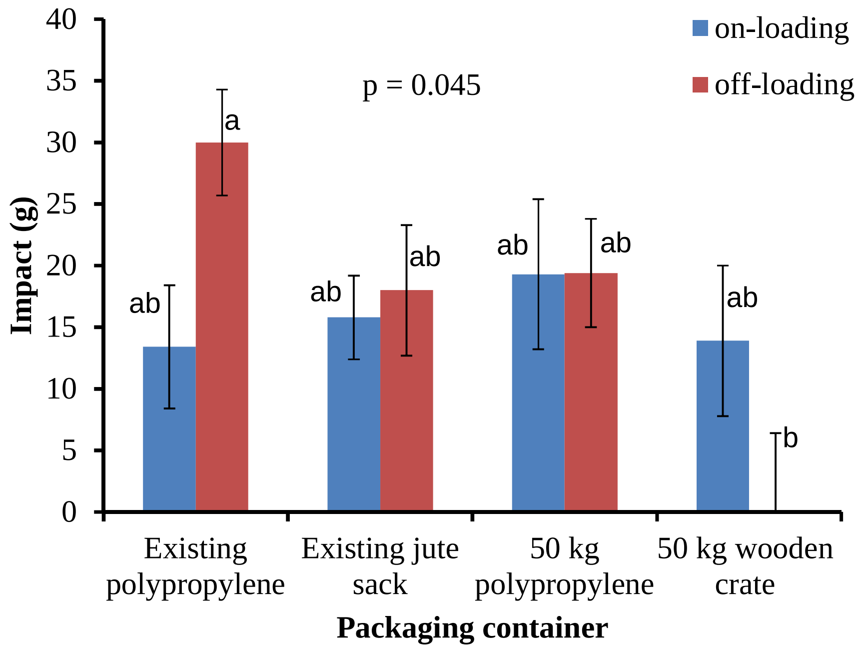

Figure 14: Impacts received by the different packaging containers during on-loading and off-loading for Afram Plains (Adawso) - Accra trade

Bar represent the mean and error bars are standard error of the mean. Bars with different letters were significantly different ($p < 0.05$)

The impacts received by roots in the different package containers during loading and off-loading was found not to be significantly ($p = 0.384$) different (Figure 15). However, the 50 kg polypropylene sack received relatively greater impacts, about 1.4 times more, during off-loading relative to loading.

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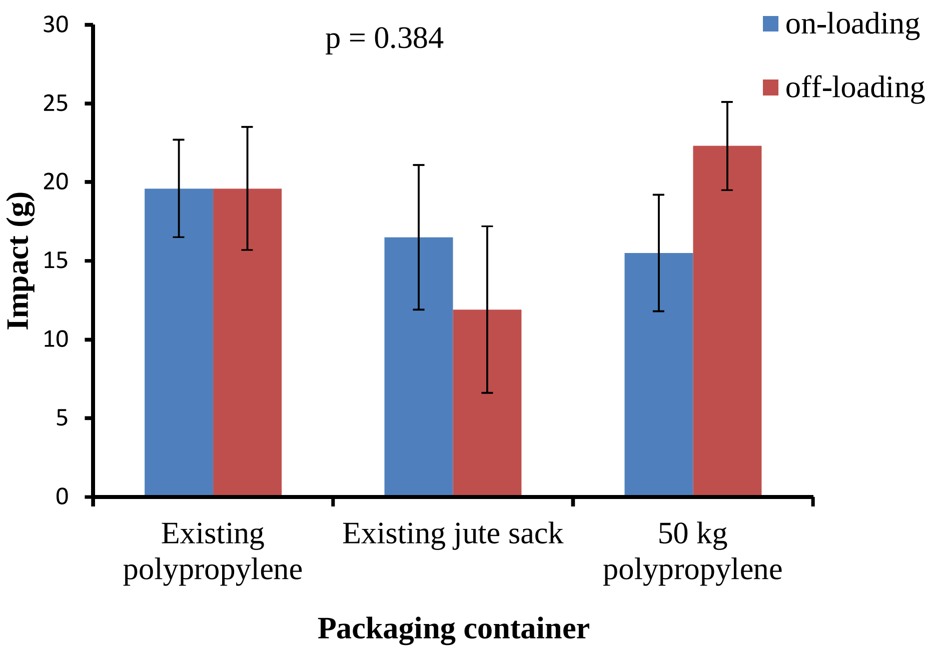

Figure 15: Impacts received by the different packaging containers during on-loading and off-loading for Bawku-Bittou trade

Bar represent the mean and error bars are standard error of the mean. Bars with different letters were significantly different (p < 0.05)

The mode of transport used for the Bawku-Bittou trade had no significant (p = 0.612) effect on the impact the roots in the various packaging containers received (Figure 16).

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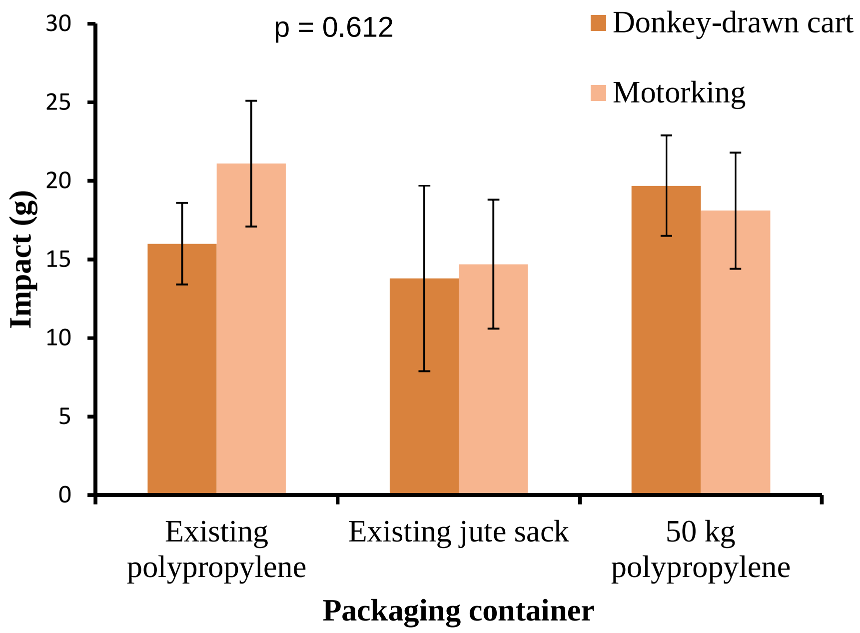

Figure 16: Impact received by roots packaged and transported using different modes of transport for the Bawku-Bittou route.

Bar represent the mean and error bars are standard error of the mean. Bars with different letters were significantly different (p < 0.05)

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4.3.5 Visual acceptance

Visual root quality of sweetpotato roots packaged in the different packaging containers is shown in Table 18 for both aggregators and consumers. Consumers ranking showed significant difference in both year one ($p < 0.0001$) and year two ($p = 0.003$). The data for year one indicate that 50 kg-wooden crates resulted in the highest visual acceptance ranking for consumers. The consumers average acceptability rank for wooden crate was 47% higher than the sack-packaging containers. However, consumers and aggregators similarly ranked the roots which were packaged and transported in the three sack packaging containers.

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Assessment of the sack-packaging containers in the second year (as the wooden crate was not included) of experimentation revealed 50 kg-polypropylene as highly accepted by consumers than the existing polypropylene sacks. In accordance with the data for year two, 50 kg-polypropylene was highly accepted by consumers, about 34% higher than both existing polypropylene and jute sacks. Further assessment of the sack packaging containers revealed the average consumer acceptability rank for the 50 kg-polypropylene to be 55% and 18% higher than the existing polypropylene and jute packaging containers respectively.

Although aggregators visual acceptance of roots by packages followed almost the same trend as consumers, there were no significant difference for both year one (p = 0.053) and year two (p = 0.177) between the different packaging options as ranked by the aggregators. Wooden crates were ranked higher for the first year and the 50 kg polypropylene for the second year by consumers.

Table 18: Mean ranks for visual acceptance scoring on sweetpotato roots packaged and transported in different packaging containers.

Packaging container	Year 1 (2015)		Year 2 (2016)	
	Consumers (*n* = 48)	Aggregators (*n*=24)	Consumers (*n* =36)	Aggregators (*n*=14)
Existing polypropylene	69.20^{a}	37.90^{a}	37.79^{a}	58.37^{a}
Existing jute sack	96.30^{a}	48.90^{a}	49.71^{ab}	68.56^{a}
50 kg-polypropylene	93.50^{a}	47.10^{a}	58.68^{b}	71.56^{a}
50 kg-wooden crate	127.00^{b}	60.10^{a}	*	*
p-value	<0.0001	0.053	0.003	0.177

Values (rank mean). Values with different letters for each packaging container were significantly different (P<0.05).

**Packaging container not used for the Year 2*

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4.3.6 Internal necrosis

Sweetpotato roots which were transversely cut did not develop any internal necrosis after transport. Likewise, those roots that were stored under market conditions did not show any spots of internal necrosis. Internal necrosis did not occur as a result of transport or over a short time (7 days) of storage under market conditions.

4.3.7 Root diameter

There was no significant ($p > 0.05$) change in root diameter in any of the packaging containers compared from production centre, urban market and after one week of storage at the urban market (Figure 17).

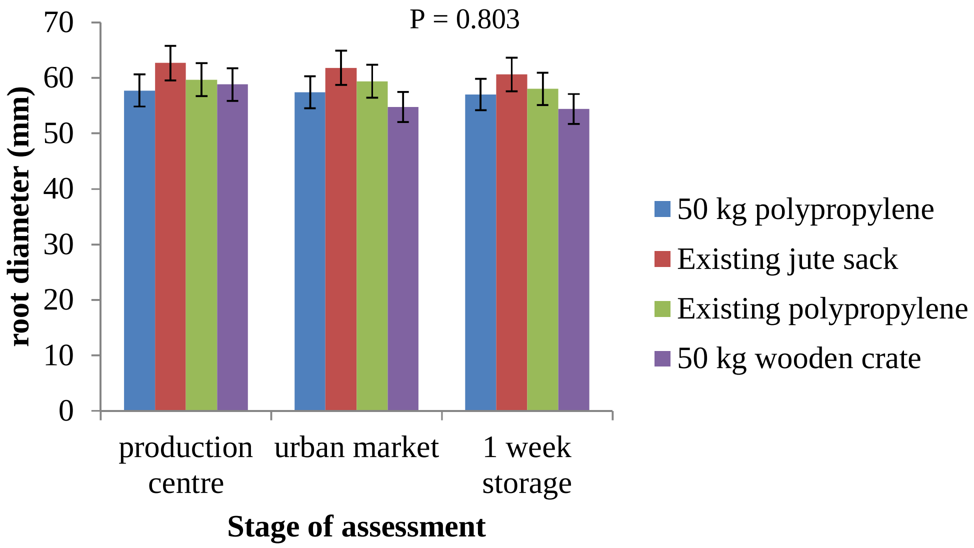

Figure 17: Diameter of roots measured from the production centre to storage at urban market

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4.3.8 Economic evaluation of packaging containers

It was observed from the sale of roots by aggregators at the urban market that no monetary value is added to roots which have less bruises. Table 19 presents data on BCR Analysis of the packaging containers used for the Afram Plains-Accra and Bawku-Bittou routes for the two years. The data indicates that all packaging containers had a BCR of 1 or above for the Afram Plains trade in both years. Aggregators using these different packaging containers for the Afram Plains-Accra trade are likely to make profits since their estimated BCR is above the break-even point (BCR = 1). Also, the different packaging containers evaluated for the Bawku to Bittou route showed that all the packaging containers had a BCR < 1. This means that traders using any of the packaging containers are likely not to make profits.

Table 19: BCR for different packaging containers with respect to transport routes for two years

Packaging container	BCR Year 1 (2015)		BCR Year 2 (2016)	
	Afram Plains-Accra	Bawku-Bittou	Afram Plains-Accra	Bawku-Bittou
Existing polypropylene	1.43	0.75	1.22	0.91
Existing jute sack	1.43	0.74	1.21	0.90
50 kg-polypropylene	1.44	0.71	1.28	0.89
50 kg-wooden crate	1.05	0.19	*	*

BCR =1 indicates breakeven; >1, profitability; and <1, implies loss.
**Packaging container not used*

However, it was observed that some farmers in the Bawku area use their own motorkings and donkey carts and so cost of transport is not really felt directly. In

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view of this observation for the Bawku-Bittou route, the BCR's were re-computed without considering transportation cost of each of the packaging containers (Table 20). The re-computed BCR's for the first year of experimentation were less than 1 indicating non-profitability of all the packaging containers for the Bawku-Bittou transport route. However, packaging containers except 50 kg polypropylene had a BCR of 1 indicating a break-even for the second year of evaluation of the packaging containers.

Table 20: BCR for different packaging containers excluding transport cost per bag for Bawku-Bittou route

Packaging container	BCR Year 1 (2015)	BCR Year 2 (2016)
Existing polypropylene	0.91	1.01
Existing jute sack	0.90	1.00
50 kg-polypropylene	0.85	0.98
50 kg-wooden crate	0.20	*

BCR =1 indicates breakeven; >1, profitability; and <1, implies loss.
**Packaging container not used*
¥*BCR values are for both motorking and donkey-drawn car*

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CHAPTER FIVE

5.0 DISCUSSION

5.1 Introduction

Discussion of the results was done by considering the following: sweetpotato packaging and transport, Assessment of packaging containers with regards to mechanical injuries, impact levels, visual acceptance of roots and reduction in root diameter and economic evaluation of packaging containers.

5.2 Survey on sweetpotato packaging and transport

The study showed that sweetpotato roots are obtained directly from farmers by the aggregators in the various production centres where the research survey was conducted. At harvest, farmers heaped sweetpotato roots on the field and covered them with the leaves and vines [personal communication]. These roots are packaged by the aggregators on the farm where the roots were cultivated.

The low usage of jute sacks as a packaging container could be due to its difficulty in handling when soaked during rainfall. Rainfalls do occur during the transportation of the storage roots; thus the propylene sack is commonly used. This result corresponds with the observation made in an earlier study (Rees *et al*., 2003b) where polypropylene sacks were commonly used.

The process of packing of roots in sacks is done irrespective of root size / shape. Improper stacking of sweetpotato storage roots and inappropriate packaging material has been suggested by Kitinoja and Kader (2002) to intensify postharvest losses of sweetpotato storage roots in developing countries.

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Furthermore, it has been earlier reported that sweetpotato storage roots packaged for the Ghanaian market weighed about 160 kg (Peters, 2013). During this survey, the samples of sweetpotato bags which were weighed at the urban markets revealed an average weight of about 130 kg per bag of packaged roots transported to urban market. This finding brings more evidence to the fact that a weight of packaged sweetpotato roots in Ghana is higher than the recommended weight of 100 kg. The current average far exceeds the recommended weight of a package for delivery of quality storage roots to the urban market. Tomlins *et al.* (2010) recommended that the weight of a bag should not exceed 100 kg in order to get quality sweetpotato roots transported to the urban market. The current Ghanaian sweetpotato packaging practice could be one of the major reasons responsible for the postharvest losses of the crop. Sacks are either thrown into vehicles during on-loading or dropped during off-loading. It is quite important to reduce size of packages in order to ensure a more careful handling of packaged roots.

The sweetpotato roots just like any other crop go through a chain of deliveries before it finally reaches the consumer. The marketing chain of sweetpotato storage roots begins from the local farmer through the local collector / aggregators who transport the roots to the urban market for sale out to retailers before the produce finally gets to the consumers. It was observed that the quality of storage roots is always affected at each stage of the marketing chain as a result of the improper handling. It has been earlier reported through a study that between 41 and 93% of roots arriving at urban market are damaged which may correspond to a loss in economic value of 11 to 36% (Rees *et al.*, 2001b). These damages caused

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to sweetpotato roots during the marketing chain may lead to reduced shelf life as earlier reported (Rees et al., 2001b). It may be important to consider the reduction in weights and possibly change of packages in order to deliver roots in good condition to the final consumer. This will ensure maximum utilization of the roots because it will store for a relatively longer period when not damaged.

In the Eastern region, roots were transported by wholesalers (aggregators) from the major production centres (Afram Plains and Begoro) to Agbogbloshie market in Accra where there was a hub for the retail of the crop. Roots from this area were usually transported using market trucks. The supplies from these areas to the Accra markets occur at different times of the year (January to December). However, there are variations in quantity of supplies from these production sites to the urban market (Agbogbloshie). On the other hand, sweetpotato roots are transported from the major production centre (Bawku) to Bittou, an aggregation center in neighboring country Burkina Faso (FAO, 2005; Peters, 2013). There is a potential of the sweetpotato root as an export crop for the people of Bawku and surrounding villages because of the demand at the Bittou market in Burkina Faso. For this reason, many of the aggregators from Bawku transport their sweetpotato storage roots to the Bittou market for sale. They travel a distance of about 30 km from the production area with tricycles (motorking) and donkey carts to the Bittou market on every third day during the peak harvest season of sweetpotato.

Though all seven cultivars of the Sweetpotato grown are transported to urban markets from Bawku, "Obaari" (white-fleshed) was the most preferred for transport. Its preference for transport is due to the fact that "Obaari" taste

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"sweeter" and more purchased by consumers. Its preference could also be the fact that it has a high dry matter content. It has been reported elsewhere by Tomlins *et al.* (2004) that most consumers in Africa prefer high dry matter sweetpotato cultivars. Among all the local cultivars reported by aggregators, "Kufour" is the only Orange Fleshed Sweetpotato (OFSP) transported from production centre (Bawku) to urban market (Bittou).

Cultivation of roots from the Northern part of Ghana starts in May and ends in October. During this period crops are intensively cultivated throughout northern Ghana. Harvesting of swetpotato storage roots mostly begin September and ends in December. However, some farmers store their sweetpotato roots till January before sale in order to attract higher prices. The peak of the season when most roots are harvested by farmers in Bawku is November.

Due to the two seasons (minor and major) for the southern part of Ghana, the period of availability of roots is longer. At Afram Plains aggregators start transportation of sweetpotato roots to urban markets in the month of July. The transportation of the produce continuous till November when aggregators do not get roots adequate commercially for transport from the Afram plains area. The peak of the business season for aggregators transporting sweatpotato storage roots from Afram Plains to Accra is July to October. During this period the supply to the urban market centre is much higher. This leads to roots dumped at the market centre for 3-4 weeks before sale leading to rotting. However, these aggregators are anxious to get alternative ways of processing the roots and an opportunity to export roots to neighboring countries just as it is done in the Upper East region in order to prevent the spoilage during peak seasons.

5.3 Assessments of packaging containers with regards to root quality factors

5.3.1 Breaks

Mechanical damage is the most important harvest factor, much of which is sustained during harvest itself, transport and marketing (Ray *et al*., 2010). However, the necessity of keeping these damages at the possible lowest level cannot be over-emphasied.

The occurrence of significant breaks in existing polypropylene and jute may be due to their sizes and weight (130 kg). The current finding lends support to Tomlins *et al*. (2000) who reported a general decline in sweetpotato storage root quality with transportation. Thompson *et al.* (1997) also reported 20% of sweetpotato storage roots with severe breaks translating into an average of 9% loss in market value. Heavy weights (> 100 kg) of polypropylene sacks have been fingered and accounted for almost 13% losses in market value (Tomlins *et al.*, 2000) and can potentially compromise their shelf life (Ndunguru *et al.*, 2000).

The on-loading onto vehicles and offloading of the heavier sweetpotato packages resulted in significant breaks. Similar findings were made by Tomlins *et al.* (2000). The higher impacts which occurred in the existing polypropylene and jute sacks due to higher weight may be the major factor responsible for the breaks of sweetpotato roots. However, the other smaller weight of 50 kg packages

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(polypropylene sacks and wooden crate) were not significantly affected on breakage of roots. This finding was as a result of the smaller weight packages being handled with much ease during on-loading and off-loading. The results corroborate those of Tomlins *et al*. (2010), who found that higher weights (>100 kg) of packages resulted in the delivery of poor quality roots at the market. The findings of Mukunyadzi (2009) also support reduced packaged weights of sweetpotato storage roots for transport to urban markets. Irrigation farmers in Zimbabwe preferred 50 kg sacks to 90 kg sacks because of the difficulty in loading the 90 kg sacks (Mukunyadzi, 2009). The reduced weights could directly increase the quality of sweetpotato storage roots delivered at the urban market. Breaks and other damage factors in sweetpotato roots enhances water loss and deterioration (Rees *et al*., 2003b) through higher respiration, softening of texture (Ray *et al*., 2010), accelerated metabolic activities and high ethylene production (Buescher *et al*., 1975). These could be significantly reduced with the use of the lesser weight packages.

Conversely, the transport of roots for the Bawku – Bittou route where donkey carts and tricycles (motorking) were used had no significant effect on breakage of sweetpotato roots. The insignificant breaks for the Bawku-Bittou transport route were largely due to the modes of transport used. Donkey carts and motorkings move with lower speed compared with trucks. Additionally, the distance covered by donkey carts and motorkings are much shorter (about 30 km). They are also much easier to on-load and offload without throwing-in and dropping-down of packages. Therefore, higher impacts are not caused on packaging containers. It

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was observed that the loading and off-loading impact of the storage roots in all the containers for Bawku to Bittou were less severe compared with Afram Plains to Accra, that is 15 g for Bawku - Bittou route as against 42 g for Afram Plains (Adawso) - Accra route. This observation was possible because the donkey carts and tricycles (motorkings) are closer to the ground. They are not so high to compel "on-loading boys" to throw the storage roots on the vehicles or to drop them during offloading.

5.3.2 Bruises

The findings of this study corroborate Tomlins *et al.* (2000) who reported higher bruises of roots packaged in sacks due to mishandling by "on-loaders" and "off-loaders". During transportation crates are preferred to sack because sacks result in rubbing of the surface skin (Mukunyadzi, 2009). This probably explains why bruises in the 50 kg-wooden crate were lower than the sack-package containers. Unlike the sacks, "on-loaders" and "off-loaders" did not have the freedom to throw them onto truck or drop them from trucks. Although bruises resulting from mechanical damage influence the shelf life of roots (Rees *et al.*, 2001), aggregators do not consider roots with bruises (skinning injury) to be unacceptable, a phenomenon that has earlier been reported by Ndunguru *et al.* (1998) and Ndunguru *et al.* (2000). Wooden crates were handled more carefully because they could not be thrown in vehicles during on-loading or dropped during off-loading. The inability of "on-loaders" to mishandle the wooden crates resulted in the insignificant occurrence of mechanical damages (breaks and bruises) in

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them. Hence the use of 50 kg wooden crates in the first year of this study resulted in the delivery of higher quality roots to the Agbogbloshie market.

The modes of transport could be the factor for the insignificant bruises observed as both donkey carts and tricycles used for the Bawku to Bittou transport have load platforms closer to the ground. Hence, on-loading and off-loading is much easier resulting in minimal impacts (< 20 g) on storage roots. The findings lend support to Tomlins *et al.* (2000) who reported a direct linear relationship between mechanical damage of storage roots and impacts received.

5.3.3 Cuts

Cuts do occur during harvesting at the farm site. The roots are often cut by harvesting implements (Rees *et al.*, 2003b). This is largely due to inappropriate harvesting techniques and tools. It was clear that cuts do not occur in transport when roots were packaged in either of the packaging containers used. These cuts were only as a result of harvesting with sharp tools. None occurrence of cuts on sweetpotato roots on transit would have been as a result of the protection the different packages provided. The roots did not rob against the trucks on which it was carried. The packages held roots intact and safely from being pierced by any sharp parts of the trailers on which they were carried.

5.4 Impact levels of packaging containers

Impacts may be the major responsible factor causing the breakages and bruises of sweetpotato roots in transport (Tomlins *et al.*, 2000). The significant breaks and bruises of sweetpotato roots which occured in transit from aggregation sites to market centres may be due to higher impacts. This came about as a result of the improper packaging, improper loading and offloading of the existing packages (existing polypropylene and existing jute sacks). The loading and off-loading of sweetpotato storage roots packaged in sacks was as a result of the larger sizes and weights of packages. This manner of on-loading and off-loading, exerted more pressure on roots resulting in high impacts (Tomlins *et al*., 2000). However, the 50 kg-polypropylene sacks and 50 kg-wooden crates were easily and properly handled during on-loading and off-loading due to its lighter weights. Hence, lesser impacts and fewer breakages were observed in them.

It is as well obvious that the lesser impact (13-17 g) on roots for the Bawku to Bittou route is the major reason for the insignificant mechanical damages. However, the roots contained in the wooden crate had no record of impacts because the impact loggers used could only record impact above 10 g. This observation was as a result of the fact that the 50 kg wooden crate could not be mishandled compared with the roots contained in the sack packaging containers.

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The lower impacts received at on-loading and off-loading could account for the insignificant occurrences in breaks and bruises for the Bawku-Bittou route. The speeds of both the tricycles (motorkings) and the donkey carts were also much lower and impacts were also insignificant during transit. This result confirms the hypothesis that higher impacts on sweetpotato roots is mainly responsible for the breaks and bruises which may occur during transportation.

5.5 Visual acceptance of roots

Appearance might be a factor rightly considered by consumers before purchasing a product. Earlier review of Tomlins *et al.* (2007) indicated that consumer

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preference has an important role to play in sweetpotato marketing. From the results, wooden crates recorded the highest visual acceptance ranking for consumers in the year one of experimentation. However, the aggregators similarly ranked all packaging containers for visual appearance for the two years.

The general acceptability ranking by consumers and aggregators corresponded with the quality (breaks and bruises) results found. Wooden crates were ranked higher because it delivered higher percentage of none bruised and none broken roots to the urban market. Hence, samples of roots drawn from the wooden crates appeared more visually attractive than all other samples from the other packaging containers. On the other hand, existing polypropylene sack was also ranked lower because it delivered more broken and highly bruised roots to the urban market. More breaks and bruised roots in displayed samples were mainly the factors responsible for the ranking of roots transported in the packaging containers.

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Though sweetpotato roots in different containers were significantly ranked by consumers, no monetary value was added to roots which had less bruises. This could be linked to the fact that a reduction in skinning injury may not result in an increase in market value of sweetpotato (Ndunguru *et al*., 1998; Ndunguru *et al*., 2000). Again, the observations in the urban markets is much related to the conclusion made by Ndunguru *et al*. (2000) that skinning injury is not a price influencing factor though it has the potential of enhancing the shelf life of the sweetpotato root.

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5.6 Root diameter

Root diameter is one of the most important factors to consider in the determination of shrinkage in sweetpotato roots. Considering the difference in diameter of roots from the production centre, at the urban market and after one week (7 days) of storage under market conditions, an insignificant result was found. The insignificant reduction in root diameter could be as a result of the shorter period of storage. Reduction in root diameter could have been very significant if the storage under market conditions continued for about two to three weeks (Amoah *et al*., 2011). A corresponding observation was made by Amoah *et al*. (2011) who observed a sigmoid pattern of shrinkage in sweetpotato roots from the second week of storage. Amoah *et al*. (2011) found that the percentage rate of shrinkage rose from the second to fourth week, declined from the fourth to fifth week and afterwards showed an indefinite rise towards senescence.

5.7 Economic evaluation of packaging containers

The profitability of the different types of the packaging containers was computed from the difference between total costs incurred from the aggregation point through to the urban market and the total revenue accrued from the sale of a bag of sweetpotato. This means that an aggregators profit may be affected as a result of the type of packaging material used. While transportation cost is incurred for transporting an empty wooden crate to the aggregation centre, the sacks (existing jute, polypropylene and 50 kg polypropylene) do not incur any major transport cost to the aggregation centre. The low Benefit Cost Ratio (BCR) for the 50 kg-wooden crate packaging option, although delivered the best quality roots, is due to

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the cost of the container and the difficulty in moving it from one farm to another as a means of gathering storage roots for transport. Interestingly, the transportation of sweetpotato storage roots from Bawku to Bittou does not appear to be economically beneficial as the BCR for the packaging containers were <1. Similar observations have been made by Mukunyadzi (2009) that sweetpotato farmers in Zimbabwe had reduced gross margins due to high cost of production, transport and marketing. Previous reports have shown sweetpotato production is a profitable venture among farmers in Bawku (FAO, 2005). The low BCR for the Bawku to Bittou route could be due to the fact that many of the farmers own the tricycles (motorking) and donkey cart which are mostly not costed during transportation. However, the price of roots at the Bittou market largely depends on the quantity of supply to the market. Earlier studies have noted that the perishability and seasonality of sweetpotato in Sub-Saharan Africa results in variation in quantity and quality of roots in the market (Low *et al.*, 2009), with associated price swings (Anyaegbunam *et al.*, 2015; Low *et al.*, 2009). Therefore, the price of storage roots at the Bittou market depends on the supply and the time of the year. Based on the computed BCRs, it is not cost effective to package and transport sweetpotato roots in the 50 kg polypropylene sacks to Bittou market from Bawku. However, aggregators will neither lose nor gain when the existing polypropylene and existing jute sacks are used.

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CHAPTER SIX

6.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

6.1 Summary

The packaging and transport of sweetpotato roots from aggregation sites to urban markets pose a threat to sweetpotato quality indices thus resulting in great losses. The objective of the study was to ensure the delivery of quality roots to the urban market through the assessment of the current packaging containers used to transport sweetpotato to urban market centres in Ghana. In response to the objective, a survey was conducted in the major sweetpotato production regions in Ghana; Upper East and Eastern regions using a structured questionnaire. Soon after the reconnaissance survey, experiments were modeled and conducted to assess the current and potential packages for the transport of sweetpotatoes in Ghana.

From the survey, it was found that sweetpotato is an important root crop that is produced and transported to urban markets by aggregators and sold to retailers and consumers. It is mostly packaged in polypropylene sacks (130 kg) and jute sacks (130 kg) sacks and transported in market trucks, tricycles and donkey carts. Tricycles (Motorking) and donkey carts are mostly used in the Upper East region of Ghana for transport of sweetpotato, while from the Eastern region market trucks (Kia trucks) are used.

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Most aggregators (81%) in Bawku transport their sweetpotato roots from Bawku to Bittuo market in neighboring Burkina Faso while a handful of the aggregators (19%) transport their roots from Bawku to Bolgatanga.

At Afram plains in the Eastern region, harvested sweetpotato roots are mainly transported by aggregators to the National capital, Accra. Aggregators mainly obtain sweetpotato roots from the local farmers at production centres and then transport the roots to the urban market where they are sold to retailers who in tend sells to the final consumers.

The packaging material and the mode of transport affect the quality of roots delivered at the urban markets leading to heavy losses. The results of the experiments indicated that the existing packages used affect the quality of the sweetpotato roots during packaging and transport. The existing polypropylene and the jute sacks were higher in percentage broken roots, impacts and lower in visual acceptance compared with the wooden crates and polypropylene sacks with the holding capacity of 50 kg of sweetpotato roots. These proposed packages (50 kg wooden crate and 50 kg polypropylene sack) generally delivered fairly wholesome sweetpotato roots to the urban market. Also, the 50 kg polypropylene sacks were found to be more profitable than the other packaging containers evaluated.

Therefore the findings of this research are much useful in transforming the sweetpotato marketability in Ghana. It is well known that the mechanical damages (breaks, cuts, bruises) reduce the storability and shelf-life of sweetpotato both at

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the urban market and the home. In view of such a challenge, this study presents the solution through packaging and transport in polypropylene sacks of holding capacity of 50 kg sweetpotato roots for delivery of quality roots and for higher profits.

6.2 Conclusions

Sweetpotato aggregators in Ghana mostly package sweetpotato roots in woven polypropylene sacks of about 130 kg. These stacking of larger quantities of sweetpotato in polypropylene and jute sacks for transport negatively affected sweetpotato root quality thus reducing its shelf life as well as its attractive value at the urban market centres. Among the packaging containers evaluated the 50 kg-packages (polypropylene sack and wooden crate) delivered quality (reduced breaks and bruises) sweetpotato storage roots to the urban market from the production centres for the Afram Plains-Agbogbloshie trade compared with the other packaging containers. Although the 50 kg-wooden crate delivered more wholesome roots over long distances, transportation to aggregation centres and handling was a problem for aggregators and “loading-boys”. It also was less profitable using wooden crates. However, packaging containers showed no marked differences in the quality of roots delivered at the urban market for the Bawku-Bittou trade. Therefore, current packages are worth maintaining for the Bawku to Bittou transportation route. Impacts received were lower in the 50 kg packaing containers compared to the 130 kg polypropylene and jute sacks for Afram-Plains-Agbogbloshie trade. The sack-packaging containers irrespective of size recorded BCR > 1, an indication of profitability for the Afram Plains-

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Agbogboloshie route. Therefore, transporting sweetpotato storage roots in 50 kg-sized sacks may lead to higher profit for aggregators and delivery of more wholesome roots at the urban market.

6.3 Recommendations

- Regardless of the limitations of the study, the 50 kg polypropylene sack is comfortably recommended as a replacement for the existing polypropylene (130 kg) and Jute sacks (130 kg) for the packaging and transport of sweetpotato roots from production site market centres to urban market centres for the Afram Plains-Accra sweetpotato transport route.
- Also, existing packages (130 kg polypropylene and Jute sacks) are worth maintaining for the Bawku-Bittou sweetpotato transport route.
- Sweetpotato roots were freshly harvested and packaged for the transport experiment. Instead of the fresh packaging, it might be better as a quality control measure to first of all cure freshly harvested roots for about a week before packaging and transport to urban market centres.
- Wooden crates have the potential to maintain quality of sweetpotato roots to the market than the other containers evaluated. However, its cost was higher resulting in no profits. Therefore, it might also be possible to conduct a follow-up study on the use of cardboard boxes at more lesser weights as a replacement for wooden crates for the packaging and transport of sweetpotato roots to urban market centres in Ghana.

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PLATES

Plate 14: A typical sweetpotato market in Bawku

Plate 15: Loading of market truck with sweetpotato

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Plate 16: Tricycles (Motorking) loaded with sweetpotato from Bawku

Plate 17: Donkey carts loaded with sweetpotato

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APPENDICES

Appendix 1: Survey questionnaire

Thank you for your precious time that you will spend in answering this questionnaire. My name is Sampson Alhassan, a student of the University for Development studies offering MPhil Horticulture. This survey questionnaire is to gather relevant information on major sweetpotato production areas in Ghana. Furthermore, the information you will provide and the results of this survey will form the grounds for more research to improve the transportation system of sweetpotato from aggregation points to urban markets. You are therefore assured of the confidentiality of your relevant information.

Questionnaire Code: …………………   Date: dd……..mm……yr……….

REGION: ……………………...   DISTRICT:……………………… TOWN:……………………

GENERAL INFORMATION

1. Name ofsweetpotato roots dealer (in bulk):………………………………..

2. Sex: (a) Male   (b) Female

3. Marital status: (a) Married, (b) Divorced/Separated, (c) Single/Engaged, (d) Widow

4. Age (years): (a) Under 20, (b) 20- 25, (c) 26-30, (d) 31-35, (e) 36-40, (f) 41-45, (g) 46-50,(h) 51-55, (i) over 55 years

5. How many people live in your household? [] people

6. Contact details: ………………………………………………………….

7. GPS coordinates from point of aggregation [   ] and at central market [ ]

TRANSPORTATION OF SWEETPOTATO ROOTS

8. Where is your source of roots? (a) Own farm (b) relatives(c) from farmers (d) retailers/buyers

9. If from farmers/retailers, how many do you deal with? [   ]

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10. How long have you been in the sweetpotato business as an aggregator/buyer?
(a) < 1(b) 1 - 2 (c) 3 – 4 years (d) 5 years (e) >5 years

11. Proprietorship: (a) This is my business (and my family's), (b) Working for my dad/relative, (c) Working on commission, (d) Other (specify)______

12. Do you package the roots before transport? (a) Yes (b) No

If yes continue from question 13, but if no jump to question 14

13. What packaging material do you package the roots in before transport to market centre?
(a) Polypropylene sack (b) Jute sack (c) Wooden boxes (d) Others (specify) ……………………

14. Do you rent storage facility for your sweetpotato? (a) Yes, (b) No
15. If No, do you own storage? (a) Yes, (b) No
16. If you rent storage, how much do you pay? []GHS per week/month (specify)
17. What is the size of the packaging container/sack used?
(a) 25kg (b) 50kg (c) 100kg (d) 150kg

18. How many bags do you normally transport in a single trip? (a) Less than 10, (b) 10 – 20, (c) 21 – 40 (d) 41 – 60 (e) 61 – 100 (f) 101– 150 (g) 151 – 200 (h) >200
19.What is the cost of transportation per bag from aggregation point to the urbanmarket centre per trip? (a) Less than GHS 3 (b) GHS 4 (c) GHS 5 (d) GHS 6 (e) GHS 7 (f) >GHS 8

20. List the urban market centres you transport the roots to 1...................... 2................. 3...........

21. What mode of transportation do you use to transport sweetpotato to the urban market? (a) Donkey cart (b) Motor king (c) Trucks (d) Others (specify) ………………………..

22. Where do you get the transport medium that you use? (a) My own, (b) rented, (c) Shared rented transport, (d) Other (specify)...............

23. Do you transport the sweetpotato roots with other foodstuffs? (a) yes (b) no

24. If yes, list the other foodstuffs. 1.................. 2.................3...................4.....................

25. Do you load the vehicle together with other aggregators/buyers (a) Yes
(b) No

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26. If yes, how many buyers load one vehicle? (a) 2-3 (b) 4-5 (c) > 5

27. At what frequency (number of times) do you transport in a month at the peak of the business season? (a) Once (b) Twice (c) 3 times (d) 4 times (e) others (specify) ………………………

28. What months within the year do you get more sweetpotato roots for transport to the market?

Month	Please tick
January	
February	
March	
April	
May	
June	
July	
August	
September	
October	
November	
December	

29. Do you get enough quantity of sweetpotato as you need at the peak season? (a) Yes (b) No

30. If No, what is the reason? *Circle all that apply*(a) Not enough production, (b) Bad roads, (c) No space to store, (d) Other (specify)_______

PREFERED CULTIVARS

31. Name the cultivars of sweetpotato grown in the production centre where you buy?a)…………………………………..................
b)…………………………………….…….
(c)……………………………………………d)…………………………………
…………...

32. Complete the table below with your preference for the cultivars

Preferred Cultivar	Reason for preference

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MARKET PRICES OF SWEETPOTATO ROOTS

33. How many bags of sweetpotato roots do you retail per week at the urban centre?

(a) <5 (b) 5-10 (c) 11-15 (d) 16 -20 (e) 21 -25 (f)26-30 (g) > 30

34. What is the size of the bag used for sale to retailers at the urban centre?
a) 50 kg (b) 100 kg (c)150 kg (d) 200 kg

35. How much did you buy a bag of sweetpotato roots from the aggregation centre last year? (a) < GHS 25 (b) GHS 25 – 30 (c) GHS 31 - 35 (d) GHS 36 – 40 (e) > GHS 40

36. How much did you buy a bag of sweetpotato roots from the aggregation / collection centre this year? (a) < GHS 25 (b) GHS 25 – 30 (c) GHS 31 - 35 (d) GHS 36 – 40 (e) > GHS 40

37. How much was the same bag retailed in the urban market last year?
(a) < GHS 40 (b) GHS 41 - 50 (c) GHS 51- 60 (d) GHS 61 - 70 (e) GHS 71 - 80 (f) GHS 81- 90 (g) > GHS 91

38. How much is the same bag retailed in the urban market this year?
(a) < GHS 40 (b) GHS 41 - 50 (c) GHS 51- 60 (d) GHS 61 - 70 (e) GHS 71 - 80 (f) GHS 81- 90 (g) > GHS 91

Thank you

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Appendix 2: Cost and revenue for calculation of BCR at the Eastern region (2015)

	Cost of item with respect to packaging containers			
Cost item	**Existing poly (GH¢)**	**Existing Jute (GH¢)**	**50 kg poly (GH¢)**	**Wooden Crate (GH¢)**
Empty container	2.50	3.00	2.00	15.00
Transport to aggregation centre	-	-	-	6.00
Transportation to urban market	30.00	30.00	10.00	10.00
Storage at urban market	0.33/day	0.33/day	0.33/day	0.33/day
Loading and offloading	6.00	6.00	2.00	3.00
Commission paid	-	-	-	-
Market tolls	1.00	1.00	0.50	0.50
Cost of sweetpotato/bag	100.00	100.00	38.50	38.50
Total cost (TC)	**139.83**	**140.33**	53.33	**73.33**
Total revenue (TR)	**200.00**	**200.00**	**77.00**	**77.00**
Net profit (TR - TC)	**60.17**	**59.67**	**23.67**	**3.67**
Benefit cost ratio (TR/TC)	**1.43**	**1.43**	**1.44**	**1.05**

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Appendix 3: Cost and revenue for calculation of BCR at the Upper east region (2015)

	Cost of item with respect to packaging containers			
Cost item	**Existing poly (GH¢)**	**Existing Jute (GH¢)**	**50 kg poly (GH¢)**	**Wooden Crate (GH¢)**
Empty container	2.50	3.00	2.00	60.00
Transport to aggregation centre			-	-
Transportation to urban market	11.00	11.00	3.60	3.60
Storage at urban market	-	-	-	-
Loading and offloading	-	-	-	-
Commission paid	-	-	-	-
Market tolls	-	-	-	-
Cost of sweetpotato/bag	48.00	48	16.00	16.00
Total cost (TC)	**61.50**	**62.00**	**21.60**	**79.60**
Total revenue (TR)	**46.00**	**46.00**	**15.30**	**15.30**
Net profit (TR - TC)	**-15.5**	**-16.00**	**-6.30**	**-64.30**
Benefit cost ratio (TR/TC)	**0.75**	**0.74**	**0.71**	**0.19**

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Appendix 4: Cost and revenue for calculation of BCR at the Eastern region (2016)

	Cost of item with respect to packaging containers			
Cost item	**Existing poly (GH¢)**	**Existing Jute (GH¢)**	**50 kg poly (GH¢)**	**Wooden Crate (GH¢)**
Empty container	2.50	3.00	2.00	-
Transport to aggregation centre			-	-
Transportation to urban market	40.00	40.00	10.00	-
Storage at urban market	0.33	0.33	0.33	-
Loading and offloading	6.00	6.00	2.00	-
Commission paid	-	-	-	-
Market tolls	1.00	1.00	0.30	-
Cost of sweetpotato/bag	130.00	130.00	43.00	-
Total cost (TC)	**179.83**	**180.33**	**57.83**	**-**
Total revenue (TR)	**220.00**	**220.00**	**74.00**	**-**
Net profit (TR - TC)	**40.17**	**39.67**	**16.17**	**-**
Benefit cost ratio (TR/TC)	**1.22**	**1.21**	**1.28**	**-**

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Appendix 5: Cost and revenue for calculation of BCR at the Upper east region (2016)

	Cost of item with respect to packaging containers			
Cost item	**Existing poly (GH¢)**	**Existing Jute (GH¢)**	**50 kg poly (GH¢)**	**Wooden Crate (GH¢)**
Empty container	2.50	3.00	2.00	-
Transport to aggregation centre	-	-	-	-
Transportation to urban market	6.00	6.00	2.00	-
Storage at urban market	-	-	-	-
Loading and offloading	1.00	1.00	0.30	-
Commission paid	-	-	-	-
Market tolls	-	-	-	-
Cost of sweetpotato/bag	50.00	50.00	16.00	-
Total cost (TC)	**59.50**	**60.00**	**20.30**	**-**
Total revenue (TR)	**54.00**	**54.00**	**18.00**	**-**
Net profit (TR - TC)	**-5.5**	**-6.00**	**-2.30**	**-**
Benefit cost ratio (TR/TC)	**0.91**	**0.90**	**0.89**	**-**

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