Research Article

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Packaging containers for long-distance transport of sweetpotato [*Ipomoea batatas* (L) Lam] storage roots in Ghana

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Abstract: Two proposed containers (50 kg-polypropylene sack and 50 kg-wooden crate) were compared with existing packaging containers (100 kg-polypropylene and jute sacks) to transport sweetpotato storage roots from major aggregation sites to distant urban market centers. The extent of breaks, bruises and the impacts, incurred by storage roots packaged in the different containers, were assessed. Additionally, at the urban market centers, the visual quality of the transported storage roots was evaluated by both aggregators and consumers. The benefit cost ratio (BCR) for each of packaging options was calculated to ascertain their profitability for sweetpotato roots transportation. The existing polypropylene/jute sacks resulted in significant major breakages in both years ($p = 0.028, 0.016$) after transportation for the Afram Plains-Accra route in truck. The donkey-driven carts or tricycles used for the Bawku-Bitou route did not show any significant ($p > 0.05$) influence on the storage roots contained in the existing polypropylene/jute sacks. The average impact recorded at both loading and offloading sites was significantly different (13.4 - 19.3 g vs. 0 - 30.0 g; $p = 0.045$) for all the containers. The proposed 50 kg-wooden-crate had a significantly superior (mean rank of 127; $p < 0.0001$) visual quality compared with the other packages. All the packaging options showed profitability, because they had a BCR > 1.40, except for the 50 kg-wooden-crate. The 50 kg-polypropylene container delivered better quality roots to urban market centers than the existing packaging containers, and was more profitable than the 50 kg-wooden crates. The 50 kg-polypropylene container is recommended for the transport of sweetpotato storage roots in Ghana.

Keywords: Aggregators, Impact, Root quality, Sweetpotato, Transport, Urban market

1 Introduction

Sweetpotato (*Ipomoea batatas* L. Lam) is a hardy crop, relatively easy to cultivate, giving good yield on marginal soils, and is thus considered to be a food security crop in Sub-Saharan Africa (Agbemafle et al. 2014; van Oirschot et al. 2003). Although it is a food security crop, poor postharvest handling undermines its market value. Postharvest losses of food crops in Ghana are estimated to be 30%, annually (Nyanteng et al. 2003). Transportation plays a critical role in the value chain of fresh agro-produce such as sweetpotato, and farmers and aggregators incur huge losses due to transport.

Postharvest losses occur at harvest, handling, transportation, storage and processing (Affognon et al. 2014). In sweetpotato, losses resulting from poor postharvest handling on-farm, and transportation were reported to be 20 and 86%, respectively (Tomlins et al. 2000). While losses appear to be inevitable during postharvest handling, considerable care must be taken to minimize them to ensure greater utilization of food crops (Atanda et al. 2011).

Packaging of sweetpotato storage roots should be aimed at delivering the highest quality product to the consumer. Significant losses due to mechanical damage of sweetpotato roots have been attributed to haphazard packaging and the size of packaging containers used (Ray and Ravi 2005). For optimum utilization of sweetpotato storage roots, as well as any other fresh agro-produce, there should be effective

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methods for minimising losses associated with packaging and transport (Atanda et al. 2011).

Sweetpotato storage roots are highly susceptible to mechanical damage once they are harvested or when not harvested on time (Owori and Agona 2003: 103-111). 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 bruises, also known as skinning damage occurs, the underlying cells of a skinned area desiccate and die (Legendre, 2015). Desiccated and depressed areas may become unappealing to consumers thereby reducing the market value of the product.

It is a concern that the current existing packaging options in Ghana are reported to contain storages of about 160 kg (Peters 2013). 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: 717-737). 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: 1-260) also emphasized the significant role packaging plays in reducing losses in Africa. However, there is a dearth of information in Ghana regarding the effect of packaging containers on the quality of sweetpotato delivered at the urban market centers. During loading and off-loading of sweetpotato storage roots, sacks are often carelessly dropped resulting in high impact which causes breakages (Tomlins et al. 2000). This can result in the loss of more than half of the storage roots before they reach the consumers (Chakraborty et al. 2017). Furthermore, transport alone resulted in about 9% loss due to breaks and about 52% in skinning injuries (Tomlins et al. 2000).

In this study, the extent of breaks and bruises and the impact incurred by storage roots packaged in the different containers were assessed. Additionally, at the urban market centers, the visual quality of the transported storage roots was evaluated by both aggregators and consumers. The benefit cost ratio (BCR) for each of packaging options was calculated to ascertain their profitability for sweetpotato storage roots transportation.

2 Materials and methods

2.1 Packaging and Transport

After reconnaissance survey, two proposed packaging containers: 50 kg-polypropylene sacks with dimensions; 54 x 90 cm (Plate 1a) and 50 kg-wooden crate of internal dimensions 0.5 m x 0.5 m x 0.5 m (Plate 1b) for storage roots transportation were compared with existing polypropylene packaging containers and jute-sacks with dimensions 100 x 70 cm (Plates 2a-b), reported to be filled to 160 kg with sweetpotato storage roots (Peters 2013). The two major production regions were the Eastern Region (Afram Plains) and Upper East Region (Bawku) (Ministry of Food and Agriculture/Statistics Research and Information Directorate 2012).

Plate 1a: Proposed 50 kg polypropylene sack with dimension: 54 x 90 cm

Plate 1b: Proposed 50 kg wooden crate Internal dimension: 0.5 m x 0.5 m x 0.5 m

2a: Existing 130 kg-polypropylene sack
Dimension: 113 x 65 cm

2b: Existing 130 kg-jute sack
Dimension: 100 x 70 cm

Plate 2a-b: Existing packaging containers used in the transport of sweetpotato storage roots in Ghana

Storage roots were packaged and transported to Agbogbloshie market in Accra from Afram Plains, and to Bitou market, an aggregation site in neighbouring Burkina Faso. In two consecutive years (2015 and 2016) the proposed packaging containers: 50 kg-polypropylene sacks 50 kg-wooden crate as well as existing options (polypropylene and jute sack reported to be filled to 160 kg) were used to transport storage roots in trucks over a distance of 143 km from Afram Plains to Agbogbloshie market. For the Bawku to Bitou route, either tricycle (locally called, *Motor King*) or by donkey cart, over a distance of 30 km, was used (Plate 1 and 2). The study was carried out under ambient conditions and as practised by aggregators. In 2016, the 50 kg- wooden crate was not included in the study as a packaging option.

2.2 Quality evaluation of packaging containers for sweetpotato storage roots

Sweetpotato storage roots were purchased from farmers and were individually assessed for bruises and breaks (Fig 1 and 2) based on the severity of damage as major, minor and none (Tomlins et al. 2000), before packaging in different containers at aggregation centers. For the existing packaging containers, the aggregators packaged the storage roots as they usually do. However, in the case of the proposed packages, storage roots were carefully arranged, making sure bigger storage roots were placed first, followed by smaller ones. The storage roots in each package option were then re-assessed, per root, based on the same scale, when arriving at the urban market. The severity rating scale for breaks was from 0 to 2. Zero indicates no symptom of breakage; 1, minor breakage (breakages of ≤ 10% of entire root length on one or both ends); and 2, major breakage (breakages > 10% of the entire length of the roots). Similarly, for bruises, 0 implies no symptom of bruises; 1, minor bruises (superficial bruises that do not cover up to 50% of the entire root area); and 2, major bruises (superficial bruises that cover more than 50% of the entire root area). Data were recorded by counting the number of roots for each severity rating class.

An impact logger (PTR30 TuberLog®) with minimum detection limit of 10 g was positioned at the center of all storage roots in each package options (Plate 5). Loggers were also placed closer to the top, in the existing polypropylene and jute sacks, due to their larger sizes, to monitor the impact on packages during loading and offloading.

2.3 Visual acceptance of roots after transport

Visual ranking, based on appearance of 10 kg of randomly selected storage roots transported in the different containers, was carried out at the market center in Agbogbloshie using a scale of 10% (least accepted) to 100% (most accepted) at the market center. These

Figure 1: Sweetpotato bruises severity rating scale from 0 to 2: 0= no symptom of bruises; 1= minor bruises (superficial bruises that does not cover up to 50% of the entire root area); 2= major bruises (superficial bruises that cover more than 50% of the entire root area)

Figure 2: Sweetpotato breakage severity rating scale from 0 to 2: 0= no symptom of breakage; 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)

assessments were done independently by consumers (*n = 48*) and aggregators (*n = 24*). However, for the Bawku-Bitou trade center, visual acceptance could not be done due to the nature of the market. It is an early morning (6:30-9:00 am) market where roots are sold and taken to another market, Pouytenga, in Burkina Faso for sale.

2.4 Economic evaluation

The net profit and benefit cost ratio (BCR) calculation for each packaging container were done. The cost of container, transport, and storage as well as loading and offloading charges were taken. Additionally, market tolls, number of times a package can be re-used for packaging and the value of roots at the aggregation site and market center data were considered. Net profit was obtained as the difference between total cost (TC) and total revenue (TR) (Müller and Padberg 2003). The BCR was also obtained by dividing TR by TC as reported elsewhere by Müller and Padberg (2003), a BCR equal to 1 indicates breakeven; >1, profitability; and <1, implies loss.

2.5 Statistical analysis

Data were analysed using Minitab v16.2™ (Minitab Inc., State College, PA, USA). Univariate analysis of variance (One-Way ANOVA) was done for the quality parameters (breaks, bruises). Paired sample t - test analysis was also carried out to compare quality parameters (breaks and bruises) between the aggregation center 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.

Ethical approval: The conducted research is not related to either human or animal use.

3 Results and discussion

3.1 Effect of packaging containers on root quality

The severity of breaks in sweetpotato storage roots, packaged and transported from Afram Plains to Agbogbloshie market in Accra (urban market), is shown in Table 1. Among the packaging containers evaluated, only existing polypropylene and jute sack resulted in a significant increase in breaks from aggregation point to market in both years. The roots contained in the existing packaging containers showed significant increase of about 158% in major (p = 0.028), and 61% in minor (p = 0.016) breaks between aggregation site and urban market for the first year of experimentation. In the second year, the 50 kg polypropylene package also resulted in a significant increase 85% (< 0.001) in major breaks after transport.

Table 1: Percent broken roots at aggregation site before transport from Afram Plains to the urban market in Accra

	Year 1 (2015)					Year 2 (2016)				
	Packaging containers					Packaging containers				
Severity of breaks	Existing Poly	Existing Jute	50 kg-poly	50 kg-wooden	P-value	Existing Poly	Existing Jute	50 kg-poly	50 kg-wooden	P-value
Major_agg. 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*
Major_mkt	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-value	*0.028*	*0.081*	*0.209*	-		*0.001*	*0.025*	*0.001*		
Minor_agg. 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*
Minor_mkt	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-value	*0.016*	*0.042*	*0.572*	-		*0.034*	*0.072*	*0.511*		
None_agg. 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*
None_mkt	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-value	*0.011*	*0.069*	*0.292*	-		*0.006*	*0.005*	*0.057*		

Values (Means ± SEM, *n* = 6); 0= no symptom of breakage; 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); *Packaging container not used

The existing jute sack showed significant increase of 43% in minor breaks (p = 0.042). None-broken storage roots at the urban market were reduced by 10% each by both existing polypropylene and jute sack in the first year of experimentation. Also, both existing polypropylene and jute sacks in the second year of experimentation resulted in significant reduction of 11% (p = 0.006) and 8% (p = 0.005) respectively for none-broken storage roots at the urban market.

The current finding lends support to Tomlins et al. (2000) who reported a general decline in sweetpotato storage root quality with transportation. The level of breakages observed was between 20-55% due to transportation of sweetpotato roots to urban markets (Mtunda et al. 2001). Thompson et al. (1997) also reported 20% of sweetpotato storage roots with severe breaks translating into an average of 9% loss in market value due to transportation. The occurrence of significant breaks in existing polypropylene and jute may be due to their sizes and weight. Although Peters (2013) reported the weights of the existing packages was 160 kg, in this study the weight was 130 kg ± 2.61; $n = 3$. Heavy weights (> 100 kg) of polypropylene sacks have been identified with poor root quality and accounted for almost 13% losses in market value (Tomlins et al. 2000) and could potentially compromise their shelf life (Ndunguru et al. 2000). The loading onto vehicles and offloading of the heavier sweetpotato packages (about 130 kg) resulted in significant breaks.

No significant (p > 0.05) differences occurred in breaks between the packaging containers and mode of transport (donkey carts *vs*. tricycles) for the Bawku (Upper East region of Ghana) to Bitou (Burkina Faso) (Table 2). The modes of transport could be the factor for the insignificant breaks observed as both donkey carts and tricycle used for the Bawku to Bitou transport are lower from the ground making loading and off-loading much easier for the "loaders".

In general, the 50 kg-packaging containers were 65% lower in impact than the existing packages (Fig. 3). Similar findings were made by Tomlins et al. (2000). The higher impacts which occurred in the existing polypropylene and jute sacks may be the major factor responsible for the breaks of sweetpotato roots. The smaller packages; 50 kg-polypropylene and wooden crate were not carelessly handled during loading and offloading because they weight could be easily handled. The results corroborate those of Tomlins et al. (2010: 271 - 293), who found that higher weights (> 100 kg) of packages resulted in the delivery of poor quality roots at the market. Irrigation farmers in Zimbabwe preferred 50 kg sacks to 90 kg sacks because of the difficulty in loading the 90 kg sacks (Mukunyadzi 2009). Thus the 50 kg sacks for packaging could be recommended to Ghanaian farmers. Higher impacts (20 g) leading to breakages were recorded for higher heights (≥ 0.5 m) from the ground during loading and off-loading (Tomlins et al. 2000). Additionally, both donkey carts and tricycle travel at a lower speed leading to lesser shock on roots as a result of bad roads compared with the speed by the truck carting roots from Afram Plains to Accra.

All the packaging containers resulted in significantly (p = 0.005) higher major bruises of the roots contained within them except for the storage roots held in the 50

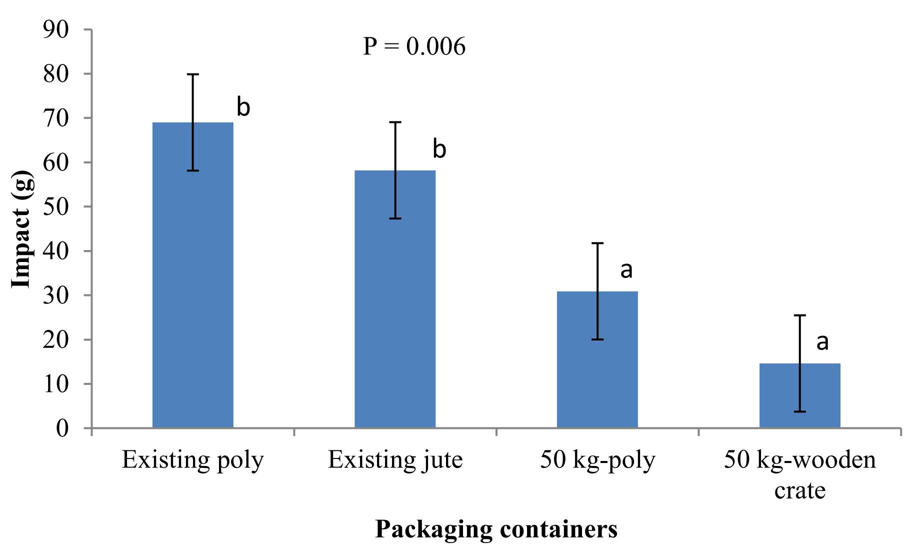

Figure 3: Average impacts (g) on roots for each packaging container for the Afram Plains - Accra transport. Bar values (Means + SEM; $n = 3$). Bars with the same letters are not significantly different (p > 0.05)

Table 2: Percent broken roots at Aggregation site before transport at Bawku and after transport to urban market in Bitou

	Severity of breaks	Year 1 (2015) Packaging containers Existing Poly	Existing Jute	50 kg-poly	50 kg- wooden	P-value	Year 2 (2016) Packaging containers Existing Poly	Existing Jute	50 kg-poly	50 kg-wooden	P-value
Tricycle (motorking)	**Major_agg. 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*
	Major_mkt	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-value	*0.423*	*0.583*	*0.244*	*0.208*		*0.067*	*0.184*	*0.423*		
	Minor_agg. 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*
	Minor_mkt	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-value	*0.189*	*0.275*	*0.186*	*0.114*		*0.742*	*0.218*	*0.423*		
	None_agg. 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*
	None_mkt	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-value	*0.209*	*0.423*	*0.186*	*0.138*		*0.238*	*0.195*	*0.423*		
Donkey Cart	**Major_agg. 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*
	Major_mkt	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-value	*0.189*	*0.284*	*0.423*	*0.193*		*0.394*	*0.26*	*0.186*		
	Minor_agg. 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*
	Minor_mkt	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-value	*0.224*	*0.434*	*0.423*	*0.423*		*0.417*	*0.656*	*0.184*		
	None_agg. 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*
	None_mkt	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*		

Values (Means ± SEM, $n = 3$); 0= no symptom of breakage; 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); *Packaging container not used

Table 3: Percent bruises at aggregation site before transport at Afram Plains and after transport to urban market in Accra.

Severity of bruises	Year 1 (2015) Packaging containers Existing Poly	Existing Jute	50 kg-poly	50 kg- wooden	P-value	Year 2 (2016) Packaging containers Existing Poly	Existing Jute	50 kg-poly	50 kg-wooden	P-value
Major_agg. site	0	0	0	0		0	0	0	*	-
Major_mkt	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-value	*0.002*	*0.032*	*0.009*	-		*0*	*0*	*0*		
Minor_agg. 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*
Minor_mkt	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-value	*0.336*	*0.282*	*0.848*	-		*0.118*	*0.080*	*0.348*		
None_agg. 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*
None_mkt	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-value	*0.006*	*0.006*	*0.002*	-		*0.000*	*0.000*	*0.000*		

Values (Means ± SEM, $n = 6$); 0= no symptom of bruises; 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); *Packaging container not used kg-wooden crate for the Afram Plains Accra route (Table 3). In the first year, the 50 kg-polypropylene was 17% and 49% higher in major bruised than the existing polypropylene and jute sack respectively. The finding corroborates with Tomlins et al. (2000) who reported higher bruising in roots transported in sacks due to mal-handling by "loaders" and "off-loaders". During transportation, crates are preferred to sacks, 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 packages. Unlike the sacks "loaders" and "off-loaders" did not have the freedom to throw them onto truck or drop them from trucks.

For the Bawku to Bitou route, all packaging containers showed no significant ($p > 0.05$) variation with regards to all levels of bruises (Table 4). The modes of transport could be a factor for the insignificant bruises observed as both donkey carts and tricycle used for the Bawku to Bitou transport were lower to the ground. Hence, 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. Bruises resulting from vibration during transport have been reported elsewhere (Jones et al. 1991; Singh and Singh 1992).

All packaging containers recorded impacts higher than 10 g for the Afram Plains to Agbogbloshie transport route for loading and offloading (Figure 3). The impacts recorded were significantly lower (14.6 g; $p < 0.006$) in 50 kg-wooden crate almost 2, 4 and 4.7 times lower than 50 kg-polypropylene, existing jute sack and polypropylene respectively. The higher impacts that occurred in the existing polypropylene may be the major factor responsible for the breakages and bruises in transport (Tomlins et al. 2000). On the Afram Plains to Agbogbloshie route, an average impact for all packaging containers was 1.8 times higher at off-loading than at loading (Figure 4). The combined effect of package and site showed significant ($p = 0.045$) differences as shown in Figure 4. During loading sack containers are thrown onto trucks at height of about 2-3 m high. Similarly, at off-loading sacks are dropped from the heads of off-loading boys. Higher impacts (20 g) leading to breakages were recorded for higher heights (≥ 0.5 m) during loading an off-loading (Tomlins et al. 2000). Packages with reduced size and weight (50 kg polypropylene and 50 kg wooden crates) were easily handled. Hence, lower impacts and fewer breaks were observed for the smaller weights.

The Bawku-Bitou route showed no significant ($p = 0.48$) differences among packages for impact during loading and off-loading as shown in Figure 5. The polypropylene and jute sacks recorded impacts between 13-17 g (Figure 4). However, the roots contained in the wooden crate did not record impacts because impacts were too minimal, lower than the minimum detection limit (< 10 g) of Tuberlogs such that they could not be recorded. The lower impacts received at loading and off-loading could account for the insignificant occurrences in breaks and bruises for the Bawku-Bitou route.

3.2 Visual acceptance

The effect of transportation of sweetpotato roots packaged in the different containers on visual root quality is shown in Table 5 for aggregators and consumers. Consumers' ranking showed significant differences for both year one ($p < 0.0001$) and year two ($p = 0.003$). The data for year one

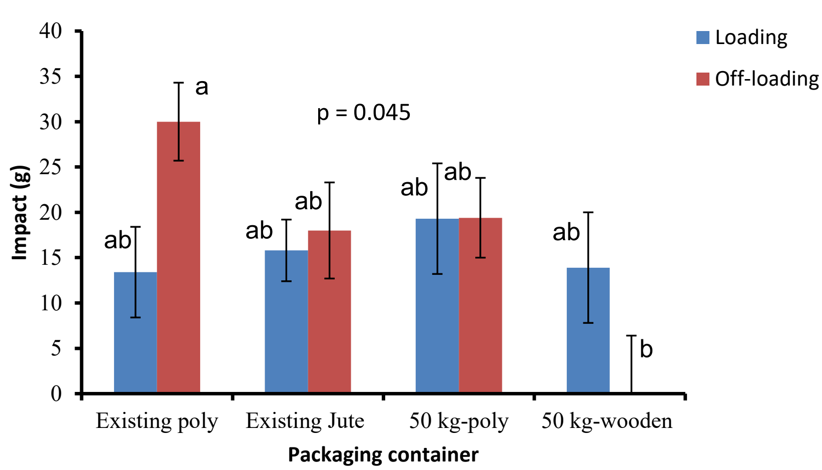

Figure 4: Impacts received by the different packaging containers during loading and off-loading for Afram Plains Accra trade. Bar values (Means + SEM; *n* = 3). Bars with the same letters are not significantly different ($p > 0.05$)

Table 4: Percent bruises at aggregation site before transport at Bawku and after transport to urban market in Bitou.

		Year 1 (2015)					Year 2 (2016)				
		Packaging containers					Packaging containers				
Severity of bruises		Existing Poly	Existing Jute	50 kg-poly	50 kg- wooden	P-value	Existing Poly	Existing Jute	50 kg-poly	50 kg-wooden	P-value
Tricycle (motorking)	Major_agg. site	1.73±0.59	2.07±0.59	2.81±0.59	2.17±0.59	*0.808*	0	0	0	*	-
	Major_mkt	1.83±0.59	2.15±0.59	2.18±0.59	2.77±0.59	*0.539*	0	0	0	*	-
	P-value	*0.423*	*0.423*	-	-		-	-	-		
	Minor_agg. 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*
	Minor_mkt	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-value	-	*0.423*	*0.211*	-		*0.432*	*0.423*	*0.231*		
	None_agg. 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*
	None_mkt	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-value	*0.423*	*0.423*	*0.211*	-		*0.432*	*0.423*	*0.231*		
Donkey Cart	Major_agg. site	2.52±0.59	2.84±0.59	2.89±0.59	3.32±0.59	*0.892*	0	0	0	*	-
	Major_mkt	2.52±0.59	2.84±0.59	2.89±0.59	3.32±0.59	*0.892*	0	0	0	*	-
	P-value	*0.842*	*0.382*	*0.241*	*0.192*		-	-	-		
	Minor_agg. 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*
	Minor_mkt	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-value	*0.536*	*0.743*	*0.252*	*0.281*		*0.184*	*0.218*	*0.423*		
	None_agg. 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*		

Values (Means ± SEM, n = 3); 0= no symptom of bruises; 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); *Packaging container not used

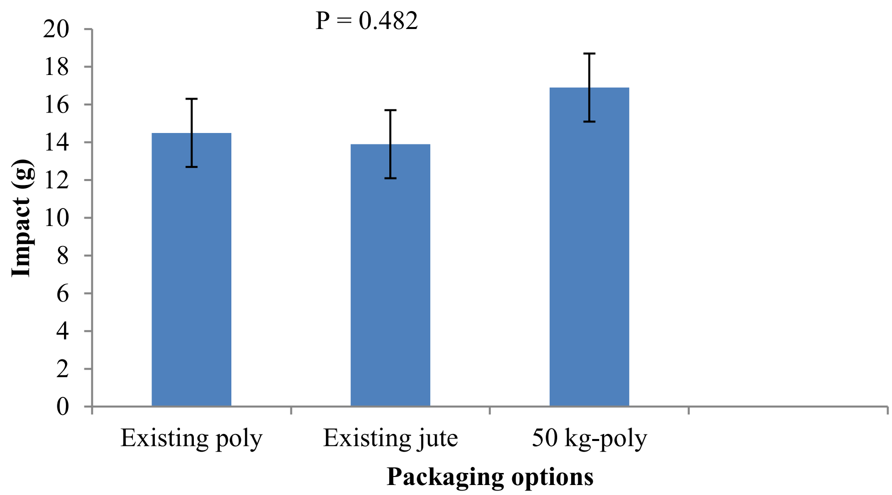

Figure 5: Average impacts (g) on roots for each packaging container for the Bawku-Bitou transport. Bar values (Means + SEM; *n* = 3).

Table 5: Mean ranks for visual acceptance scoringby both consumers and aggregators on roots transported in different packaging containers for two successive years

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 are mean ranks; mean ranks in the same column with different letters are significantly different (p <0.05)

Score; 10% (least accepted) to 100% (more accepted)

*Packaging container not used

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. Wooden crates were ranked higher because they delivered a higher percentage of none bruised and none broken roots to the urban market. Similarly, the 50 kg-polypropylene presented fairly wholesome roots to the urban market. Assessment of the sack packaging containers in the second year of experimentation revealed 50 kg-polypropylene as being more highly accepted by consumers than the existing polypropylene and jute sacks. In accordance with the data for year two, the average consumer acceptability rank for 50 kg polypropylene were 55% and 18% higher than the existing polypropylene and jute packaging containers, respectively.

Assessment of the sack packaging containers in the second year of experimentation revealed that roots contained in the 50 kg-polypropylene was highly accepted by consumers, about 34% higher than the existing polypropylene and jute sacks.

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 because they delivered a higher percentage of none bruised and none broken roots to the urban market. Similarly, the 50 kg-polypropylene presented fairly wholesome roots to the urban market. On the other hand, existing polypropylene was ranked lower because it delivered more broken and highly bruised roots to the urban market. More broken roots in displayed samples were mainly responsible for the lower ranking of roots transported in the existing polypropylene and Jute sack. Although, bruises resulting from mechanical damage compromise the shelf life of roots, aggregators and consumers alike did not consider roots with skinning

Table 6: Benefit Cost Ratio for different packaging containers with respect to transport routes

Packaging container	BCR Year 1 (2015)		BCR Year 2 (2016)	
	Afram Plains-Accra	Bawku-Bitou	Afram Plains-Accra	Bawku-Bitou
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

injury to be unacceptable, as it was observed from the sale of roots by aggregators at the urban market that no monetary value was added to roots with fewer bruises. This could be because a reduction in skinning injury may not directly result in an increase in market value of sweetpotato as reported by Ndunguru et al. (1998; 2000) though it has the potential of enhancing the shelf life of the sweetpotato storage root. Thus bruises in sweetpotato may not be an index for quality as in the case of other fruits and vegetables. However, van Zeebroeck et al. (2007) reported about 50% losses due to bruises in apple.

3.3 Benefit Cost Ratio evaluation of packaging containers

BCR of the different packaging containers evaluated for both the Afram Plains-Agbogbloshie route and Bawku-Bitou route for two successive years are represented in Table 6. The data indicate that all packaging containers had a BCR above 1 for the Afram Plains trade in both years. This implies that aggregators using these packaging containers for the Afram Plains-Accra trade are likely to make profits, except for the 50 kg-wooden crate as it has almost a break even BCR of 1.05. The low ratio for the 50 kg-wooden crate packaging option, although delivered the best quality roots, is due to 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 Bitou does not appear to be economically beneficial as the BCR's for the packaging containers were < 1 (Table 6). Similar observations have been made by Mukunyadzi (2009) who showed that sweetpotato farmers in Zimbabwe had reduced gross margins due to high cost of production, transport and marketing. Previous reports have shown that sweetpotato production is a profitable venture among farmers in Bawku (FAO 2005: http://www.fao.org/docrep/008/a0013e/a0013e00.htm). The low BCR for the Bawku to Bitou route could be partly because most farmers own either a Motor King or donkey cart for the transport of storage roots to the market. The cost of transportation is usually not costed, as in the case of this study. However, the price of roots at the Bitou 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: 359-390), with associated price swings (Anyaegbunam et al. 2015: 517-522; Low et al. 2009). Therefore, the price of storage roots at the Bitou market is not static, depending on the supply and the time of the year. This could explain the variation in the differences in profitability in the present study and the previous one (FAO 2005).

4 Conclusion

Among the packaging containers evaluated the 50 kg packages (polypropylene sack and wooden crate) delivered quality (reduced breaks and bruises) storage roots to the urban market from the production centers 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, the transportation of crates to aggregation centers and handling was a problem for aggregators and "loading-boys". It was also 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-Bitou trade. Therefore, current packages are worth maintaining for the Bawku to Bitou transportation route. Impacts were lower in the 50 kg packaging 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-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. This study was done with standard

Plate 3: Modes of transport for Bawku (Ghana) –Bitou (Burkina Faso) transport route

Plate 4: Mode of transport (Trucks) for Afram Plains (Ghana) – Accra (Ghana) route

Plate 5: Impact data loggers inserted in sweetpotato storage root packages for transport to urban market.

varieties in the sweetpotato trade. Efforts are underway to promote OFSP, which often is reported to be more prone to scuffing, and it would be worthwhile continuing this work with new varieties entering the sweetpotato trade.

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