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Postharvest handling, transport and quality of sweet potato in Tanzania

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SUMMARY
Commercial consignments of sacks of sweet potato, *Ipomoea batatas* (L) Lam, cvs. Polista and SPN/0, were surveyed, over two seasons, from harvest to markets at Mwanza and Dar es Salaam in Tanzania. The handling and transport system resulted in up to 20% and 86% of roots with severe breaks and skinning injury respectively. Reductions in market value were up to 13%. Impact loggers located at the centre of sacks indicated that the most severe impacts (greater than 20 **g**) occurred during unloading and loading from road vehicles and ships. However, skinning injury and broken roots were correlated with a large number of minor impacts (2 **g** or lower). Cultivar or season did not generally affect the responses. The use of cardboard boxes filled with fewer roots instead of overfilled polypropylene sacks and adoption of improved management procedures in the handling and transport are recommended.

Sweet potato (*Ipomoea batatas* (L) Lam) is a traditional crop for subsistence farmers in Tanzania, but is now increasingly being marketed. Production is centred in the Lake Zone, Southern Highlands and Western Zone. The marketing system, however, is poorly developed with significant loss in quality (Ndunguru *et al.,* 1998; Thomson *et al.,* 1997). For instance, roots attract a significant discount (10 to 30%) when shrivelled, cut or broken.

Monitoring the damage during handling is key to understanding the causes of the losses and developing the means of overcoming them. Objective methods for monitoring the handling of fruits and vegetables are available. Various electronic devices, "instrumented or electronic spheres" (Morrow and Ruscitti, 1990; Orr *et al.,* 1994; Thomson and Lopresti, 1996; Baheri and Baerdemaeker, 1997), "electronic tubers" (Peters and Leppack, 1991; Leppack, 1996), "pressure balls" (Herold *et al.,* 1996) and "artificial fruits and vegetables" (Anderson, 1990), have been used for investigating the mechanized handling of Irish potato (*Solanum tuberosum*).

Fresh sweet potatoes are transported in polypropylene sacks in Tanzania. In contrast, for export, partitioned fibreboard cartons filled with between 13.6 and 18.2 kg roots are recommended (Medlicott, 1990). Little is known about the handling, transport and quality of sweet potatoes in East Africa. The purpose of this study was to identify the critical stages in the handling and transport that reduce returns for sweet potato growers. In this study, commercial consignments of sweet potato sacks, cvs. Polista and SPN/0, were surveyed, over two seasons, from harvest to markets at Mwanza and Dar es Salaam in Tanzania.

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MATERIALS AND METHODS

Quality assessment

Sweet potato roots of cvs. Polista and SPN/0 were purchased from commercial farmers in the Lake Zone and from near Morogoro, respectively. Quality was assessed at harvest and at stages in the transport chain using the methods of Ndunguru *et al.* (1998). From each sack or freshly harvested roots, forty roots were selected at random and assessed for shrivelling and skinning

FIG. 1
Scoring system for broken roots.

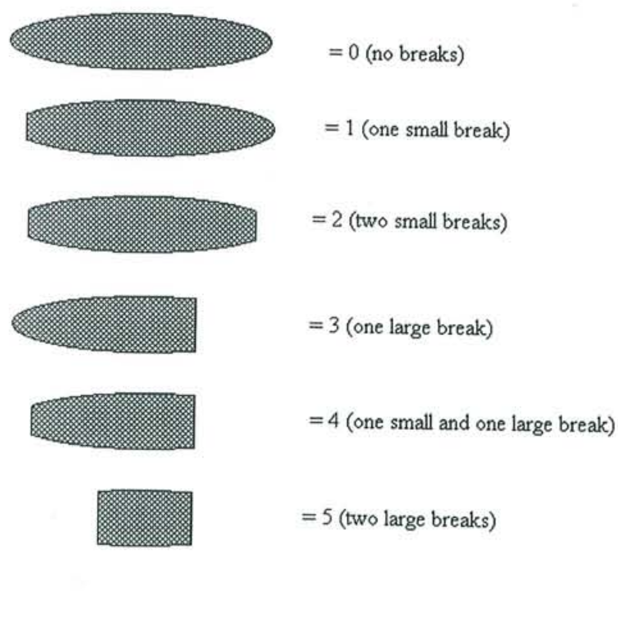


TABLE I

Root damage (total score and per cent roots with severe injury) for sweet potatoe (cv. Polista) when handled and transported during the low and main seasons in the Lake Zone

	Stage in marketing chain			
Root damage	Farm	Lakeshore	Port	Market
Broken roots	6.9 ± 2.2 (1)	11.5 ± 8.9 (4)	39.4 ± 10.9 (18)	41.1 ± 14.9 (18)
Skinning injury	21.7 ± 9.7 (1)	43.6 ± 21.6 (7)	96.0 ± 19.5 (43)	103.8 ± 26.5 (53)
Cuts	6.8 ± 1.9 (2)	8.7 ± 6.3 (2)	16.1 ± 5.8 (5)	14.1 ± 5.4 (4)
Shrivelling	0 (0)	0 (0)	1 (0)	0 (0)

Values represent the mean ± SE. Value in brackets is the percent of roots with severe damage (a score of three or greater).

injury using a 0 to 5 scale (0 = none; 5 = severe); the maximum possible score being 200. Cuts were scored as 0 = none, 1 = minor and 2 = major; the maximum possible score being 80. Details of the scoring system for broken roots are given in Figure 1. The total score for each type of damage was the sum of the individual scores for each of the 40 roots evaluated.

Surveys of sweet potatoes transported from the farm to markets

Farmers packed 100 kg of sweet potatoes into polypropylene sacks. A total of six consignments, varying between two and 12 sacks, of either Polista or SPN/0 were followed from the farm to the market. If the sacks were unloaded during transport, the quality of roots was assessed.

Dataloggers (RS Components, UK) were used to monitor: impact (Tinytag; acceleration of 0 to 50 g +/− 10%); temperature (Tinytalk II; +/− 0.2°C); and humidity (Tinytalk II; +/− 4%). They were fitted inside a plastic pipe (16 cm long and 6.5 cm diameter) approximately the same size as a sweet potato root and were positioned at the centre of sacks. The pipe prevented unrepresentative movement of the datalogger when inside a sack. The impact dataloggers were set to record the maximum acceleration (g) at either 30 or 60 s intervals and the temperature and humidity dataloggers recorded data at 10 min intervals.

The relationship between height of drop (m) and impact (g) recorded by the impact sensors was determined by dropping sacks, weighing 120 kg from heights of 0.25, 0.50, 0.75 and 1.00 m. Each sack contained duplicate sensors and the drops were replicated three times.

Control sacks, which remained on the farm, were also monitored when sufficient roots were harvested. Otherwise, 20 kg of roots were carefully wrapped in newspaper and transported in the cab of the vehicle.

Statistical methods

Regression analysis was carried out using SPSS (version 8.0) statistical software.

RESULTS AND DISCUSSION

Sweet potatoes from the Lake Zone and Dar es Salaam are traditionally transported in woven polypropylene sacks weighing between 100 and 200 kg. Farmers pack as many roots into a sack as possible because they are sold by volume. Traders or wholesalers will demand a discount if they do not do this. The sacks are usually not large enough to accept the required volume of roots and hence a "head of roots" is built to the sack by wrapping roots in sweet potato vines and string. In the Lake Zone, skinning damage is acceptable to consumers, but broken, cut or shrivelled roots reduce the market value by up to 30% (Thomson *et al.*, 1997; Ndunguru *et al.*, 1998).

Studies in the Lake Zone

Polista roots, to be sold at markets in Mwanza, were transported from the farm to the shores of Lake Victoria by handcart or bicycle. At the lakeshore, the sacks were loaded onto a ship and transported for 9–12 h to Mwanza. The roots were then transported by light commercial vehicle to markets in the town for sale. The total journey varied between 16 and 30 h (mean of 24 h).

Table I shows the mean quality of the sweet potato roots at each stage in the transport chain. The means were generally similar for the two seasons, and so have been pooled. Quality generally declined with transportation with losses in quality occurring between the lakeshore and the port at Mwanza when sacks were loaded and unloaded from the ship. This is therefore a critical point in the transport system. Twenty percent of roots had severe breaks equating to a loss of between 3% and 13% (mean 9%) in market value (Thomson *et al.*, 1997). Root with skinning injury followed by a similar pattern to breaks with most damage occurring at the port. The proportion of roots with severe skinning

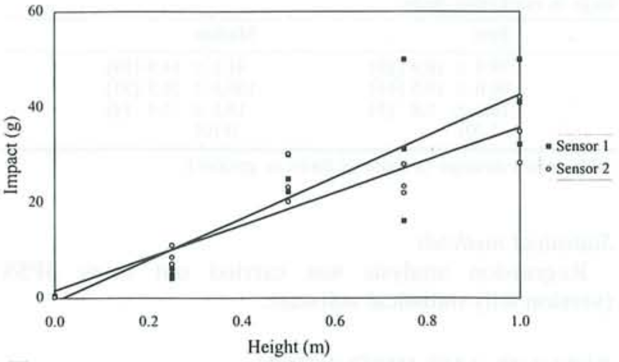
TABLE II

Root damage (total score and per cent roots with severe injury) for sweet potatoes (cv. SPN/0) when handled and transported to markets in Dar es Salaam

	Location in transport system		
	Farm	Market	
Type of injury		Control wrapped in newspaper (20 kg)	Sack (100 kg)
Broken roots	16 ± 1.8 (2)	15 ± 1.5 (1)	42 ± 2.9 (15)
Skinning injury	8 ± 1.6 (0)	6 ± 1.4 (0)	75 ± 9.7 (34)
Cuts	4 ± 1.1 (3)	5 ± 0.5 (2)	6 ± 0.9 (3)
Shrivelling	0 ± 0.0 (0)	0 ± 0.0 (0)	0 ± 0.0 (0)

Values represent the mean ± SE. Value in brackets is the percent of roots with severe damage (a score of three or greater).

FIG. 2
Correlation between impact (g) and height (m) from which a polypropylene sack filled with 120 kg sweet potatoes was dropped.



Where

Sensor 1 – R^2 adjusted = 0.792, a = −0.761, b = 43.413, $P = 0.000$

Sensor 2 – R^2 adjusted = 0.875, a = 1.547, b = 34.187, $P = 0.000$

injury increased from 1% at the farm to 53% at the market. Skinning injury, however, has no effect on price in Tanzania (Thomson *et al.*, 1997).

Thomson *et al.* (1997) noted a seasonal influence on the occurrence of shrivelling where the incidence was greatest during the low harvest season and least during the main harvest season. In this study, however, shrivelling was rare, regardless of the season. Shrivelling was probably not attributed to transport and handling, but occurs if roots remain at the farm for too long before transport. Delays may occur when the yields are low and farmers wait until sufficient roots have been harvested to fill a sack.

Since the sweet potatoes were stuffed tightly into the sacks, it was hypothesized that the internal pressures might contribute to the loss in quality; however, roots that were not transported suffered no loss in quality.

Studies during transport to Dar es Salaam

SPN/0 roots, to be sold at the Tandale market in Dar es Salaam, were transported from Morogoro for a distance of about 300 km. The journey took between 21 and 31 h (mean 25.5 h). Table II shows the losses in quality that occurred during the journey. Broken roots and skinning injury were greater after handling and transportation. The reduction in quality as equivalent to a loss of between 6 and 13% in market value. The incidence of cuts did not change. Control samples, wrapped in newspaper, showed no increase in broken roots, cuts or skinning injury after transport.

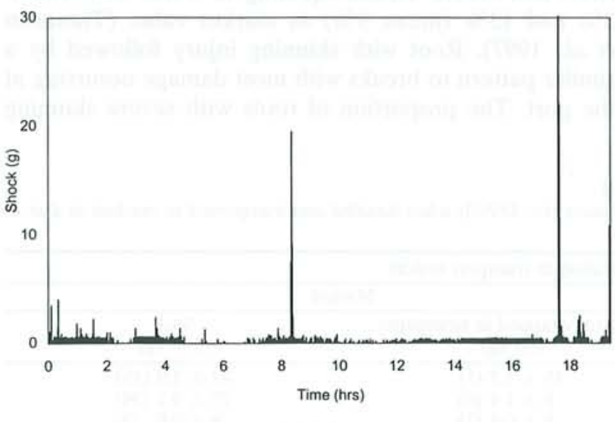


FIG. 3
Example impact history chart for a sack transported by cart and boat to Mwanza market.

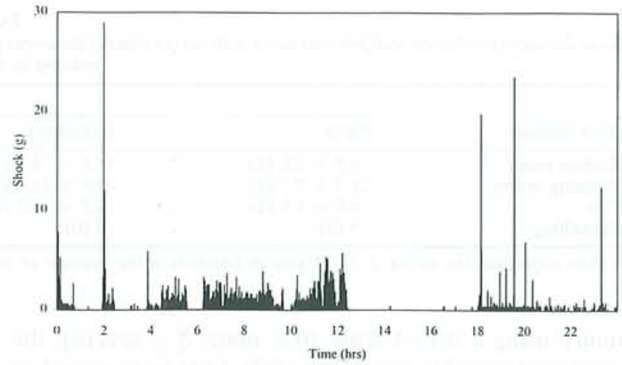


FIG. 4
Example impact history chart for a sack transported by truck to Tandale market, Dar es Salaam.

Relationship between acceleration (g) recorded by impact dataloggers and the height that a sack was dropped

The relationship between the height that a sack was dropped and impact (**g**) recorded by duplicate dataloggers is illustrated in Figure 2. The curves indicate that the impact increased with the height of the drop ($R^2 = 0.875$ and 0.792 for dataloggers a and b respectively) and that the dataloggers gave similar results. The scatter in the data is thought to be because of the movement of sweet potatoes within the sack.

Use of the impact dataloggers

The loggers provided a low-cost method for measuring the handling of sacks during transport. Impact histories for roots transported to Mwanza in the Lake Zone and to Dar es Salaam were different (Figures 3 and 4). In the Lake Zone, where boats are used, the sacks were transported by hand-cart to the Lake Shore, then loaded on the boat 8.5 h later, unloaded at the port in Mwanza (after 17.5 h) and handled at the market (after 19 h). For the sack transported by road to Dar es Salaam, the impacts during the first 12 h are thought to occur when the truck was moving with possible stops after 3, 6 and 10 h. The vehicle stopped between 12 and 18 h. Subsequent impacts were associated with unloading at the market.

For both methods of transport, the largest impacts were recorded at times of loading and unloading.

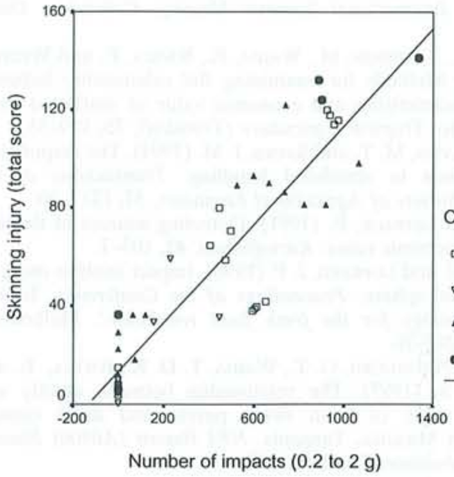
The occurrence of impacts by category (0.2 to 2 **g**, 2 to 5 **g**, 5 to 10 **g**, 10 to 20 **g**, 20 to 30 **g** and greater than 30 **g**)

TABLE III
Mean occurrence of impacts (by category) for sacks of sweet potato transported to Dar es Salaam or Mwanza

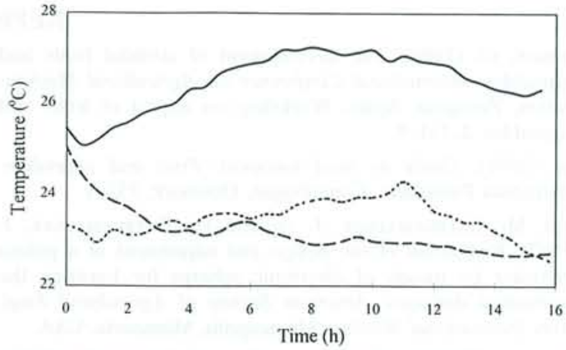
Impact category (g)	No. of impacts	Occurrence (%)
0.2 to 2	1163 ± 116.0	97.5
2 to 5	21 ± 4.0	1.7
5 to 10	6 ± 0.6	0.5
10 to 20	2 ± 0.4	0.2
20 to 30	1 ± 0.2	0.1
30+	1 ± 0.1	0.0

Values represent the mean ± SE of 21 sacks.

FIG. 5
Effect of number of impacts between 0.2 and 2 **g** on skinning injury for sweet potatoes transported in 100 kg sacks.



Where; R^2 adjusted = 0.833, a = 13.367, b = 0.0998, P = 0.000



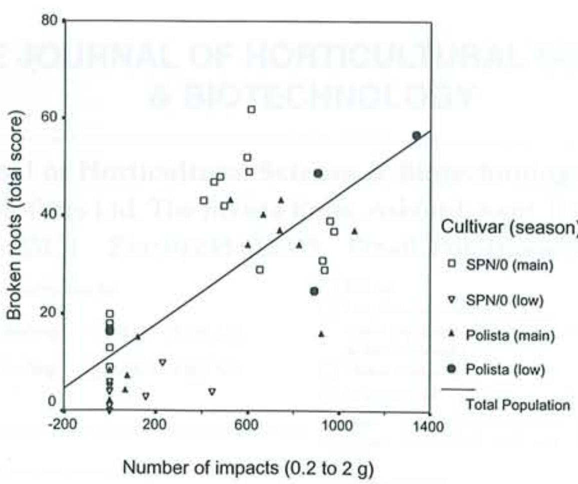
Where: temperatures for SPN/0 (main season) and Polista (main season) and Polista (low season) are means of 12, 4 and 3 sacks respectively

FIG. 7
Internal temperatures of sacks containing 100 kg sweet potatoes during transport in two regions of Tanzania.

was similar for sacks transported to Dar es Salaam and Mwanza and therefore the results were pooled (Table III). Most of the impacts (97.5%) were less than 2 **g**. The larger impacts (greater than 20 **g** and equivalent to a drop height of about 0.5 m or greater), generally occurred during loading and off-loading from the truck or from the ship and port.

Relationships between impact and injury to sweet potatoes

Skinning injury (Figure 5) and to a lesser degree broken roots (Figure 6), were related to the number of impacts from 0.2 to 2 **g**; cultivar or season did not significantly influence the responses. While the impact sensor could predict skinning injury, an instrument capable of measuring compression forces might be more suited to predicting broken roots.



Where; R^2 adjusted = 0.535, a = 11.177, b = 0.033, P = 0.000

FIG. 6
Effect of number of impacts between 0.2 and 2 **g** on broken roots for sweet potatoes transported in 100 kg sacks.

Temperature and humidity inside sacks during handling and transport

Sweet potato generates more heat from respiration than the Irish potato (150 W ton^{-1} and 50 W ton^{-1} at 20°C respectively; Anon., 1989). The mean temperature (Figure 7) was mostly influenced by the ambient temperature but was similar across cultivars. It was also lower in the main harvest season (23°C vs. 26°C). Relative humidity in the sacks was similar (90% or greater). These conditions did not appear to affect the quality.

CONCLUSIONS

The major causes of loss in quality of sweet potato during handling and transport have been identified. The handling was most severe during loading and unloading operations at the port where sacks were transported by boat or at the roadside when transported by road.

Dataloggers showed that the impact during the loading and unloading activities could exceed 20 **g** which was equivalent to dropping a sack from heights of 0.5 m or greater. Most of the loss in quality, however, appeared to be caused by the large number of minor impacts (less than 2 **g**) and was not affected by the cultivar or harvest season. A sensor that measures compression rather than acceleration, might be more suited to measuring broken roots. Overcoming problems associated with severe handling might require the use of alternative packaging materials, for example, cardboard boxes containing fewer roots instead of overfilled polypropylene sacks, the introduction of a curing stage, education of handlers and in some cases, redesigning the unloading areas. These are worthy of further investigation.

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