PARTICIPATORY EVALUATION AND IMPROVEMENT OF CASSAVA PROCESSING MACHINES FOR THE EASTERN ZONE OF TANZANIA

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Cassava processing machines previously introduced in Tanzania were chippers and graters of the International Institute of Tropical Agriculture (IITA) design. Popularization of such machines in Tanzania required thorough participatory testing with stakeholders. When tested with farmers in Muheza and Kibaha districts average throughputs were 11-18 kg/h, 752 kg/h and 270 kg/h for the manual chipper, engine-powered chipper and the engine-powered grater, respectively. Despite their low throughputs the manual chipper and the grater were very difficult to operate, and therefore demanded improvement. Improvement on these machines included modifications on the design for increased throughput, ease of operation and safety. The improved machines were ergonomically satisfactory and the throughput for the manual chippers and the engine-powered grater increased by more than 100% with high acceptance levels. The improved machines need popularization in order to stimulate formation of Small and Micro-Enterprises that will produce cassava value added products for commercialization.

Keywords: *Cassava, chippers, graters, participatory testing.*

INTRODUCTION

Cassava (*Manihot esculenta)* is a very important crop for the livelihood of Tanzanians. The crop is more productive per unit of land and labor than even the high yielding cereals (Moran, 1976) and the highest producer of carbohydrate of all cereals and tubers (Vries, 1978). Cassava roots are highly perishable once harvested, deteriorating 2-3 days after harvesting mainly because the roots are reproductively inactive (Emekoma, 1994), hence the rapid setting of physiological changes and subsequently rot and decay (Booth, 1976; FAO, 1986). Losses of up to 50% in monetary value have been reported (Ndunguru *et al.*, 1999). Inefficient harvesting and post-harvest handling (Boccas, 1987) can contribute to more quantitative losses. Sometimes, farmers do use delayed harvesting tactics, with cassava being able to survive up to 2 years (Moran, 1976) and harvest the crop when required but this form of storage leads to poor quality and unnecessary holding of land. As the conventional storage methods are not being feasible for this crop, the practical intervention that has also been practiced traditionally is processing into value added products with increased shelf life. In a study conducted in Latin America introducing cassava processing in areas where the crop was only consumed in the fresh forms was successful (Best *et al.*, 1991; Henry, 1992).

In Tanzania, traditional processing of cassava entails fermentation processes employed for the bitter varieties and non-fermentation processes employed for the sweet varieties to obtain dry products for flour production. In these methods peeling, size reduction through multiple slicing by hand held knife, and sun drying are involved. In addition to processing into flour, grating of sweet cassava varieties for making local dishes though at very low scales, using a rasped metal sheet has been practiced in Muheza (Silayo *et al.*, 2001a). These methods are very rudimentary, leading to low appeal, short shelf lives, and in isolated areas high cyanogenic residues among others (Msabaha and Rwenyagira, 1990). Improved and appropriate processing and packaging techniques will eliminate these problems (Nweke *et al.*, 1998). Areas requiring attention include peeling and size reduction. With the peeling technology still being worked out for further improvement (Emekoma, 1994) work on slicing/chipping equipment is relatively advanced.

Improved processing requires use of tools and techniques that are reliable, efficient, labor saving, safe, simple, and cost effective. The manual vertical reciprocating slicing machine developed at Sokoine University of Agriculture (Silayo *et al.*, 1999) was hard to operate and inefficient, requiring a lot of improvement. The noble way has been to adapt cassava chipping/slicing and grating machines of the International Institute of Tropical Agriculture (IITA) design, previously not known in Tanzania. Noting that in developing countries agricultural mechanization has led to a lot of development and research programs with contrasting results (Lassaux and Garin, 1994), an approach to involve farmers right from the first field trial of these machines was used. The main objective of this study was therefore to establish suitability of some IITA chipping and grating machines for adaptability in Tanzania based on farmers own perceptions and evaluations.

MATERIALS AND METHODS

Acquisition and Description

Manual Slicing Machine

A manually operated slicing machine (Fig. 1) of the IITA design equipped with a two-blades slicing disc was obtained from Uganda. This was made to be fixed on a table but due to seemingly added costs of fixing it permanently on a table and thereby rendering it immovable, a decision was made to manufacture a similar one (Fig. 2) locally with provision for fixing on four light wooden stands. This would allow personnel to work while standing and quick maneuver. For each of the machine, chipping disc for interchangeability of slicing and chipping activities was also manufactured. The manufacturing work was done in collaboration with Reliable Motor Works workshop in Dar es Salaam. The main functioning features of the manual chippers/slicers were the frame, the chipping/slicing disc, and a small feed hopper with a feed chute that progressively increases from 4 to 10 cm and two-stage feeding angles, the first one at about 30^o and the second one at about 60^o from the horizontal plane to the chipping/slicing disc. The chipping/slicing disc was mounted vertically with disc shaft running through sleeve bearings. The chipping disc featured eight symmetrical clusters of 5 mm diameter holes, each cluster bearing 14 holes in double rows running in convex mode from the center to the periphery. Disc support stiffeners separated clusters where the disc was firmly bolted.

Engine Powered Chipper

This was also acquired from Uganda and featured a feed hopper that was wide (45 cm x 30 cm) and slightly inclined (8^o) to the horizontal, a chipping disc mounted on the frame with pillow block bearings, a system of pulleys, a driving belt, and a 5.5 HP petrol engine (Fig. 3). Configuration of the chipping disc was the same as for manual chipper described above. Power transmission ratio was 1 to 4, and distance between pulley centers was about 50 cm.

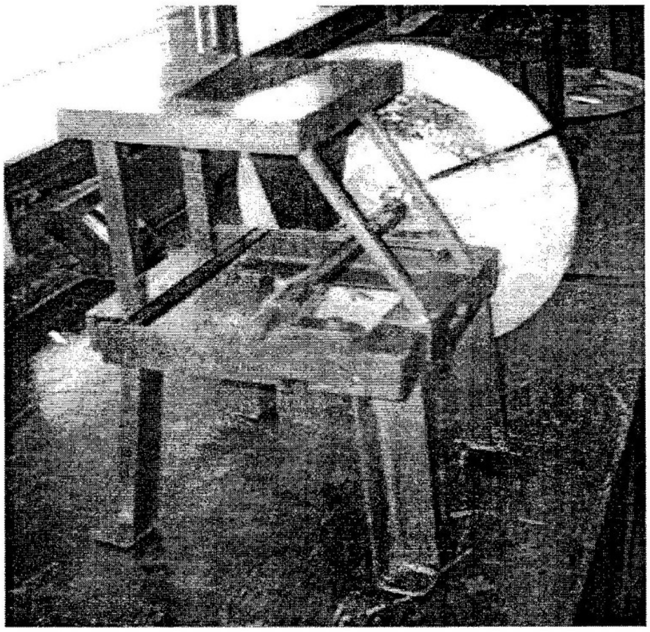

Figure. 1: Hand operated slicing machine

Engine Powered Grater

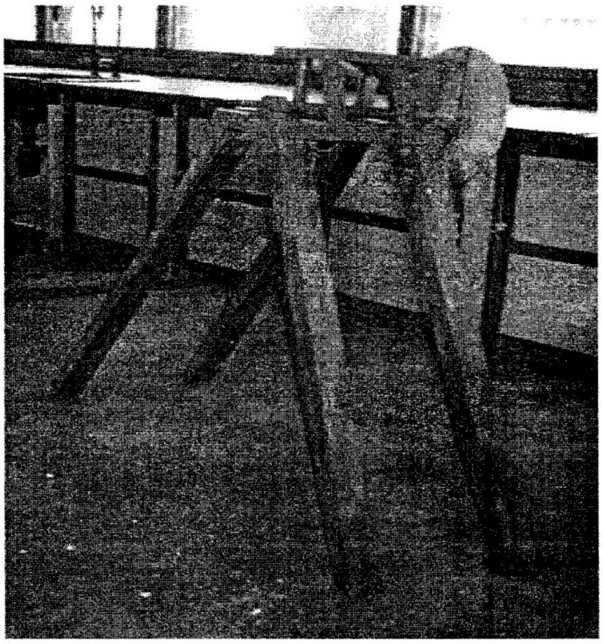

Figure. 2:. Hand operated slicing machine fixed on wooden stands

This was also of the IITA design manufactured in collaboration with Reliable Motor works in Dar es Salaam (Fig. 4). The main features were a two-side concave hopper with 30 cm x 30 cm feed opening, a horizontally mounted rasped drum at about 30 cm from the opening with the gripping surface 3 cm below the drum top surface, an exit chute oriented about 30^{o} from the horizontal, a system of pulleys, and a driving belt for transferring power from a 5.5 HP petrol engine. The rasped surface resembled that of the traditional cassava-rasping sheet (Fig. 5) used for small-scale grating (Silayo *et al.*, 2001a). The drum length and diameter were about 29 cm and 18 cm, respectively. Power transmission ratio was 1 to 4 and distance between pulley centers was about 60 cm. The gap between the drum and the gripping surface was about 4 mm.

Modification of Chippers and Grater

Chippers

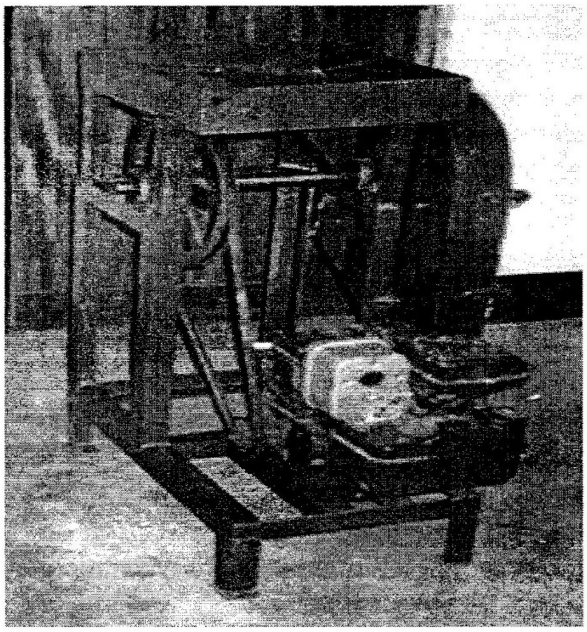

Figure. 3:.: Unmodified engine-powered grater

Modifications to the equipment above (Figs. 1, 2 and 3) were made based on recommendations from the participating farmers, extension agents, researchers, and local equipment manufacturers after testing the equipment for cassava in the field. Following this, several modifications were made and participatory testing exercises

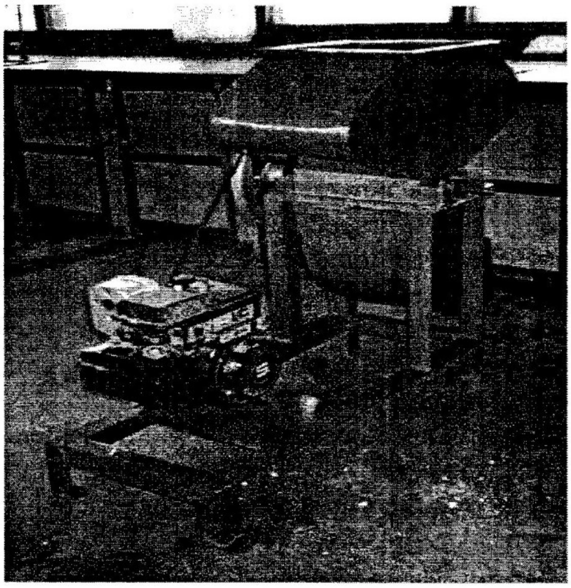

Figure. 4: Unmodified engine-powered grater

conducted in order to improve performance and acceptability. Made in collaboration with Intermech Engineering Co. Ltd of Morogoro, the concluded modifications were use of pillow block bearings (Figs. 6 and 7) for the manual chippers and fixing of the wooden stands in a trapezoidal mode for the manual chipper on wooden stands (Fig. 7).

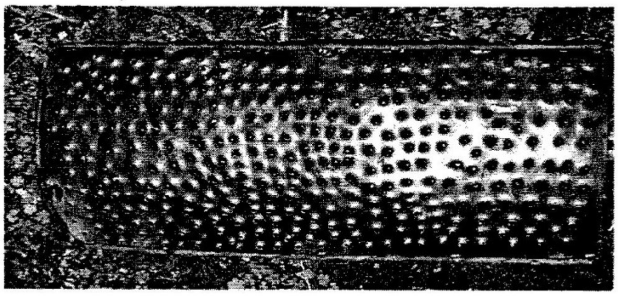

Figure. 5: The traditional cassava rasping/grating sheet

A more improved version of chipper called pedestal-type chipper was also manufactured (Fig.8). This took the same features of the modified manual chippers but with increased hopper size (39 cm x 35 cm) and a welded metal stand, making the overall height of the machine to be 95 cm. Another modification was re-design of the engine-powered chipper to make it dual purpose in the sense that it could be operated with a 3.5-5.5 HP engine or without to imitate the pedestal-type chipper and provision of belt safety cover (Fig. 9). Power transmission ratio and distance between pulley centers remained the same

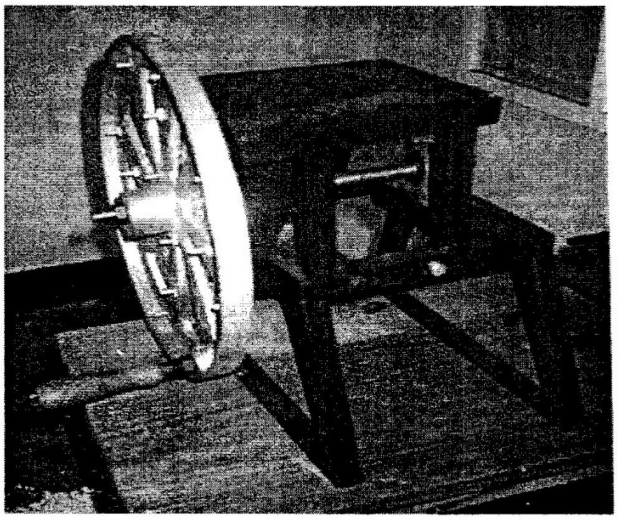

Figure. 6:. Modified table-mounted hand operated chipper

The Grater

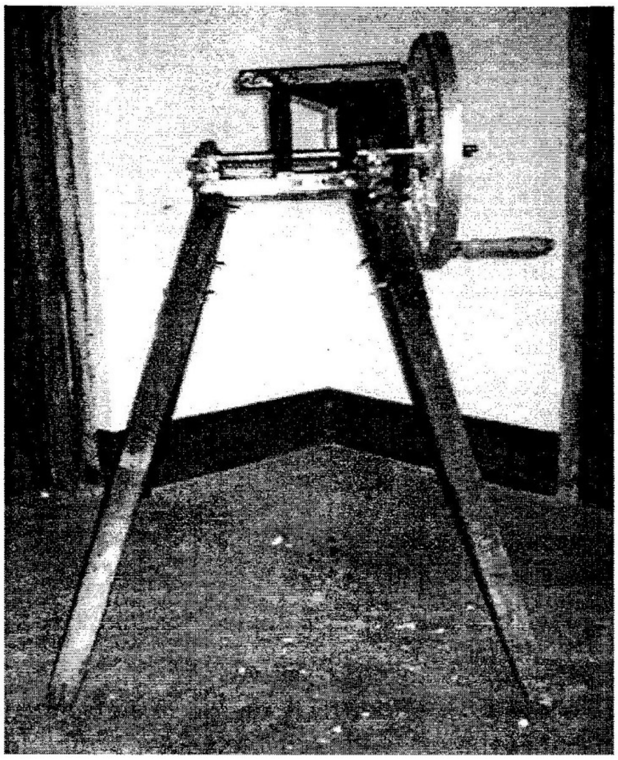

Figure 7: Modified hand operated chipper fixed on wooden stands

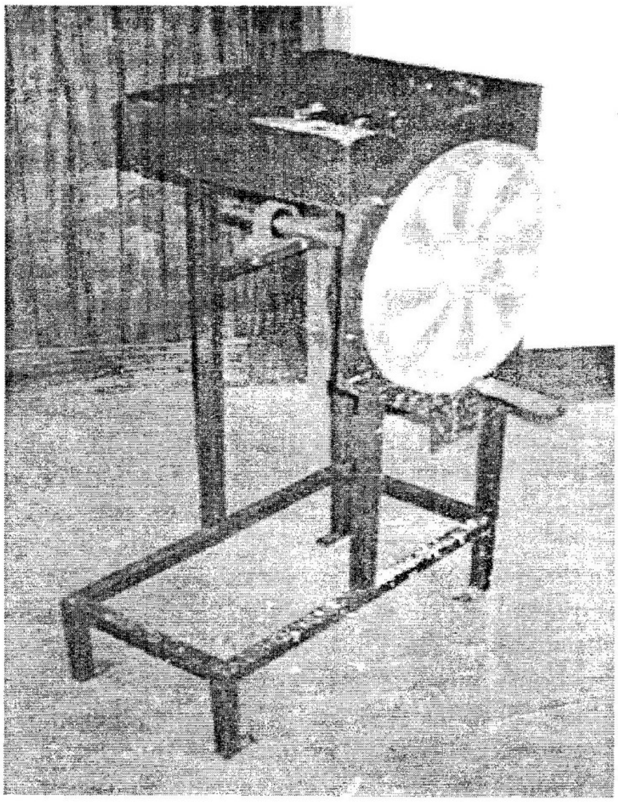

Figure. 8:. Pedestal-type chipper

Modifications to the grater mainly included provision of a hopper box (42 cm x 40 cm) with a base inclined at about 35° extended close to the top surface of the rotating drum in order to improve gripping to the working surface and minimize splattering, and a vertical straight rectangular (40 cm x 22 cm) exit chute (Fig. 10). The drum was made of hard wood, with length and diameter of 39 cm and 15 cm, respectively. The drum was fixed with stainless steel pins instead of rasped aluminium or galvanized sheet. The pins were fitted in about 12 rows along the length of the drum at intervals of about 2 mm from pin to pin and protruding 2 mm above the drum surface. The drum was run by a 5.5 HP engine, with power transmission ratio of 1 to 2 and 30 cm distance between the transmission pulleys.

Equipment Testing

Due to the high cost of making a working table for fixing cassava slicing/chipping machine, the manual chipper/slicer that was meant to be operated while fixed on a table was operated while held firmly on the ground (Fig. 1), parallel with the same design fitted on wooden legs (Fig. 2). At both the inception and the modification stages chipping and grating machines were tested by 40 participating farmers of the age ranging between 19 and 60 years, about half of them women, in collaboration with extension agents in Kibaha and Muheza districts and researchers at Sokoine University of Agriculture. The experiments were done on local cassava varieties and prior to chipping and grating the roots were peeled and washed to avoid introducing soil particles that could damage the moving parts of the machines. The parameters evaluated were weight processed using a weighing machine and processing time using a stopwatch, which were converted to throughput (kg/h). Other parameters included percent losses measured as the amount that passed the machine without being processed, acceptability, and physical attributes of the machines during processing. The mean throughputs and losses were compared using analysis of variance and separated using

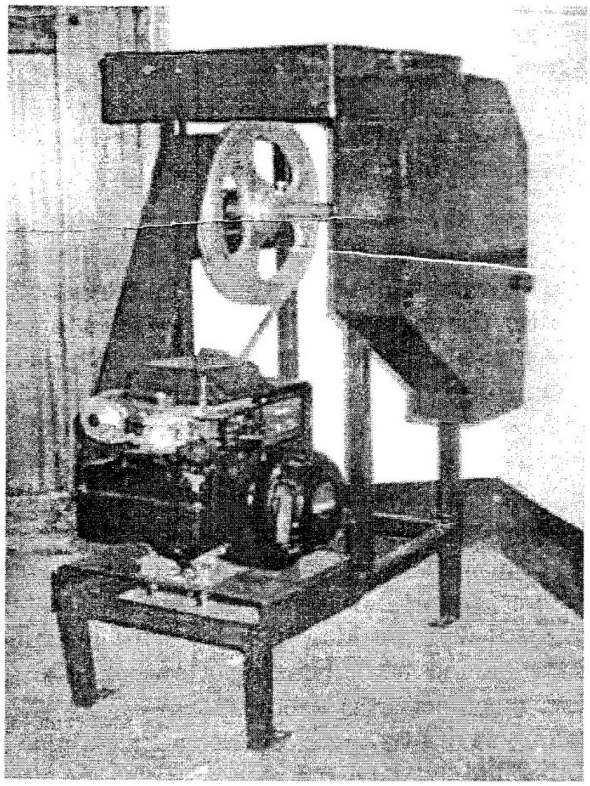

Figure. 9:. Modified engine-powered chipper

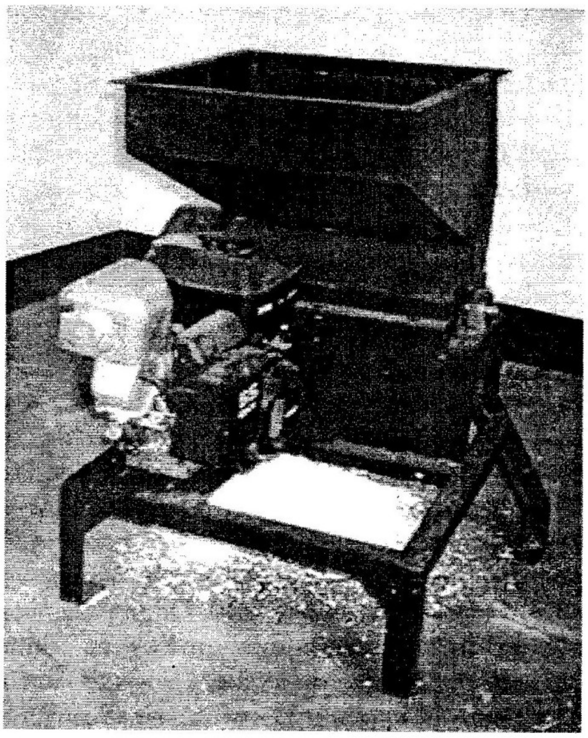

Figure. 10:. Modified engine-powered chipper

Duncan's Multiple Range Test (P=0.05) (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

Performance of the Newly Introduced Machines: Chippers/ Slicing Machines

Operating the manual slicer/chipper with the two-blade slicing disc was very difficult, and some farmers, especially women failed to crank the disc continuously. This led to rejection of these machines when fitted with the two-blade slicing disc by almost all farmers who participated in the testing. With the slicing disc replaced with the chipping disc the machines (chippers) performed slightly better but the throughput values were still very low (Table 1). Working with the manual chipper fitted with wooden stands resulted in higher output compared with working with the same machine on the ground while bending. However, use of these machines was labor intensive, as they require use of two operators, one for feeding and another for cranking the chipping disc. Manual chipping resulted in high losses (19-20%) of the roots. These were the portions that were just broken and some passing without being processed. This was caused by high concentration of fibers at the end of the roots, which ended in the last bits of cassava not being processed as observed by 23% of respondents, suggesting the removal of the end portions before chipping. The thin roots also ended up being broken or pass without being processed. In addition, manual chippers were still difficult to operate as observed by 50% and 29 % of the respondents for the chipper operated while on the ground and that fitted with wooden stands, respectively. This was mainly due to the use of sleeve bearings on the disc shaft. The former was more difficult to operate because one had to bend while operating it, making it more ergonomically unfit. The engine-powered chipper had the highest score, including throughput, which was more than thirty times the manual chippers. Nevertheless, this machine showed some drawbacks, including passing of unprocessed chunks as observed by 60% of the respondents. This was due to the same reasons as for the manual chippers. Another drawback was exposure of the driving belt, which was a safety hazard. Acceptability (27%) of the manual chippers was low, calling for a need for improvement while that of the engine-powered one (58.4%) was relatively high. The results show an increase of acceptability with increasing throughput and decreasing losses (Table 1), implying that these factors influence adoption rates. Some respondents (25%), however, suggested the need to experience working with all the types of chipping machines, with an implication that the observed performance could improve.

The Engine-Powered Grater

In comparison with the local rasping sheet that can produce about 4 kg/h of grates (Silayo *et al.*, 2001b) the performance shown by the engine-powered grater (270 kg/h) was relatively high (Table 1). However, the machine faced almost absolute rejection by farmers, advocating improvement. This was due to a number of problems including choking of the exit chute due to low angle of exit, low gripping by the drum due to poor hopper design, and splattering of cassava chunks due to poor hopper design and high speed of the drum, which were caused by design and manufacturing errors. To assist gripping, one had to press cassava against the drum using a wooden paddle fixed on a long stick, which was cumbersome.

Table 1:. Performance and acceptability of chipping and grating machines before modifications

Type of machine	Factory price T shs	Mean throughput (kg/h)	Losses (%)	Acceptability (%)
Manual chipper operated on the ground	40,000	11.4±1.3[d]	20±2.01[b]	26.9
Manual chipper fixed on wooden stands	45,000	18±1.9[c]	19±1.80[b]	26.7
Engine-powered chipper	Donated (value not known)	752±2.0[a]	7±1.20[c]	58.4
Engine-powered grater	790,000	270±6.32[b]	29±2.49[a]	2.5

Performance After Modifications

Chippers/ Slicers

Mean throughput of the improved manual chippers (Table 2) increased by five times more while that of the improved engine-powered grater increased by about two times compared with the unimproved ones (Table 1). The increase in throughput corresponded to decrease in losses and increased acceptability despite the relatively higher purchasing cost. Improved throughput was due to provision of pilow-block bearings on the disc shaft of the manual chippers that resulted in smooth rotation compared with use of sleeves before modification. Same as before modifications the manual chipper fixed on wooden stands demonstrated higher performance (99.3 kg/h) than when operated on the ground (81.6 kg/h). The pedestal-type chipper (Fig. 8) resulted in throughput that was 16% higher and losses that were 13% lower than for the modified manual chipper fixed on wooden stands. This was mainly due to increased feed hopper size, although stability due to increased weight by the supporting metallic structure could also have contributed. This suggests that throughput from the manual chipper fixed on wooden stands could be improved further through increasing the hopper size. Use of the engine-powered chipper resulted in about eight times and six times as much throughput compared with the modified manual chipper fixed on wooden stands and the pedestal-type chipper, respectively. The respective losses were lower by about 67% and 62%, showing superior performance of the engine-powered chipper. The results (Table 2)

Table 2:. Performance and acceptability of chipping and grating machines after modification

Type of machine	Factory price T shs	Mean throughput (kg/h)	Losses (%)	Acceptability (%)
Manual chipper operated on the ground	60,000	81.6±0.19[e]	18.03±1.11[c]	49
Manual chipper fixed on wooden stands	70,000	99.3±0.30[d]	17.2±0.93[c]	54
Pedestal type chipper	120,000	136±014[c]	14.8±1.30[a]	93
Engine-powered chipper	780,000 (5.5 HP engine)	768±1.78[a]	5.68±0.51[b]	89
Engine-powered grater	780,000 (5.5 HP engine)	507.7±2.52[b]	Nil	74

also indicate a positive correlation between increase in acceptability with increasing throughput and decreasing losses, making the pedestal-type chipper the best preferred amongst the manual chippers, irrespective of the relatively high cost. At the purchasing cost of about 780,000 Tanzanian shillings, the engine-powered chipper resulted in a very high throughput but its acceptability decreased slightly from that of the pedestal-type chipper. This was due to higher cost compared with pedestal-type chipper. This implies that acceptability of chipping machines is a compromise between performance and capital cost. Consequently, this requires careful consideration by technology developers, manufacturers, and extension agents for adoption and sustainability.

The Modified Engine-Powered Grater

Throughput of the modified grater (Table 2) was almost twice as much that of the unmodified one (Table 1) and no losses were experienced. Due to the absence of other versions of graters to compare with apart from the crude rasped sheet acceptability of the improved grater was high. The observed throughput would increase if operators experienced working with this machine for a longer time. The paste produced was generally fine except a few fibrous particles that could be removed manually before further use for products such as starch and *kibabu* (*kebab*) (Silayo *et al.*, 2003).

CONCLUSIONS

The participating stakeholders successfully tested the manual chipping machine and the engine-powered chipper received from Uganda. Performance of the manual chipper was unsatisfactory while that of the engine-powered chipper was satisfactory pending provision of safety belt cover. Performance of the IITA design of grater made in Tanzania was also unsatisfactory. Due to involvement of farmers in the testing successful modifications of these machines were achieved and performance improved. However, the manual chippers need to be made with enlarged feed hopper to increase throughput. Due to its superiority over other chippers, the pedestal-type chipper needs popularization for wider use to produce chips. The slicing disc for interchanging with the chipping disc need to be improved and the performance of the subsequent processes on chips and slices be evaluated and compared. Due to economic constraints it is recommended that the engine-powered machines (chipper and grater) be owned by farmers' groups or by a single entrepreneur for providing service to the community. Fuel consumption and energy expenditure on these machines under field conditions need to be evaluated. Innovations to produce improved manually operated graters for individual smallholder farmers seem inevitable. In order to attract more customers to acquire the proven modified machines a thorough cost-benefit analysis is required in all transects of societies involved in cassava farming in Tanzania.

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