Proceedings of the 13th ISTRC Symposium, 2007
pp. 672 - 681

Participatory evaluation and improvement of cassava and sweetpotato processing machines for the Eastern zone of Tanzania

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Abstract. Cassava and sweetpotatoes are important crops for improving livelihood of Tanzanians but have not been fully exploited, partly due to limited use of appropriate technologies to produce value added products. Most of the common cassava processing machines available in the market, but not popular in Tanzania, were chippers and graters of the International Institute of Tropical Agriculture (IITA) design. Popularization of such machines in Tanzania requires thorough participatory testing with stakeholders. Testing of the manual chipper and engine-powered grater in Muheza and Kibaha districts for peeled cassava resulted in unsatisfactory results. These were throughput of 11-18 kg/h and 270 kg/h for the manual chipper and the engine-powered grater, respectively. Despite the low throughput they were very difficult to operate. The engine-powered chipper resulted in throughput of 752 kg/h but lack of safety belt cover discredited it. Improvement on these machines mainly included use of pillow block bearings and increased stability for the manual chippers, provision of safety belt cover for the engine-powered chipper, and change of feed hopper design for the engine-powered chipper and grater. The exit chute design for the engine-powered grater was also modified. The modified machines were ergonomically satisfactory and their throughput increased by more than 100% with high acceptance levels. These machines are capable of processing cassava and sweetpotatoes into various value added products. From the capital cost point of view farmers can easily acquire manual chippers. Engine-powered machines are relatively expensive and can be acquired by a group of farmers or a single entrepreneur.

Introduction

Cassava (*Manihot esculenta*) and sweetpotato (*Ipomoea batatas*) roots are very important for the livelihood of Tanzanians. Cassava is more productive per unit of land and labour than even the high yielding cereals (Moran, 1976) and the highest producer of carbohydrate of all cereals and tubers (Vries, 1978). It is also increasingly becoming important in the fresh, boiled, roasted and fried forms (Ndunguru *et al.*, 1994; Nweke, 1994). The remarkable importance of sweetpotato tubers is the easiness to convert its carbohydrate into starch at the household enterprise level (Marter and Timmins, 1992) and suitability for consumption during hard labour due to its high sugar content. With the roots/tubers being the main edible part, these crops are highly perishable once harvested. Cassava deteriorates 2-3 days after harvesting mainly because the roots are reproductively inactive (Emekoma, 1994), hence the rapid setting in of physiological changes and subsequent 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.

Sweetpotato deteriorates at relatively lower rate with shelf life of almost 4 weeks (Anon, 1991). Sometimes, farmers use delayed harvesting tactics, with cassava being able to survive up to 2 years (Moran, 1976) and harvest the crops when required but this form of storage leads to poor quality and unnecessary holding of land. As the conventional storage methods are not feasible for these crops, the practical is processing into value added products. This enhances rural income generation (Wheatley *et al*., 1996) and food security since simple and low cost technologies can be used. Introducing cassava processing in areas where the crop was only consumed in the fresh forms was successful in Latin America (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 cassava 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, sweet cassava varieties are grated for making local dishes using a rasped metal sheet (Silayo *et al*., 2001). These methods are very rudimentary, leading to low appeal, short shelf lives, and in isolated areas high cyanogenic residues among others (Msabaha and Rweyangira, 1990). Improved and appropriate processing and packaging techniques will eliminate these problems (Nweke *et al*., 1998).

Improved processing requires use of tools and techniques that are reliable, efficient, labour 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. An approach to involve farmers right from the field trials 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 slicers. A manually operated slicing machine (Figure 1) of the IITA design equipped with a two-blade 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 (Figure 2) locally with provision for fixing on four light wooden stands. This would allow personnel to work while standing and quick manoeuvre. For each of the machine, chipping disc for interchangeability of slicing and chipping activities was also manufactured. The manufacturing work was done in collaboration

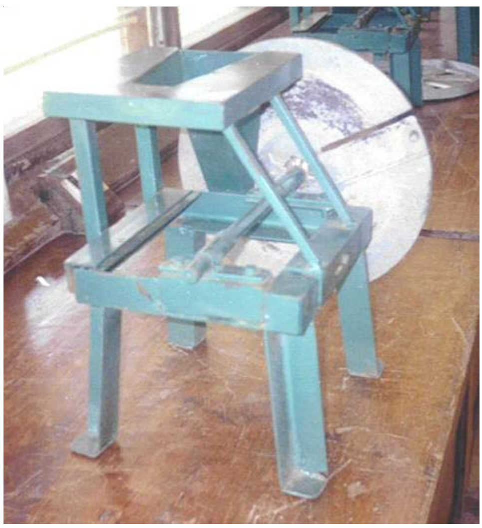

Figure 1: Manually operated slicing machine.

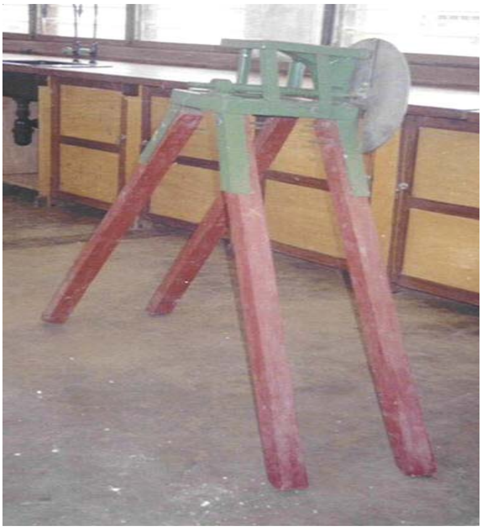

Figure 2: Manually operated slicing machine with wooden legs.

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° and the second one at about 60° 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 centre to the periphery. Disc support stiffeners separated clusters where the disc was firmly bolted.

Engine powered chipper (Figure 3). This was also acquired from Uganda and featured a feed hopper that was wide (45 cm x 30 cm) and slightly inclined (8°) to the horizontal, a chipping disc mounted on the frame with pillow block bearings, a system of pulleys, a driving belt, and a 5 HP petrol engine (Briggs and Stratton type). 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 centres was about 50 cm.

Engine powered grater (Figure 4). This was also of the IITA design manufactured in collaboration with Reliable Motor works in Dar es Salaam. The main features were a two-side concave hopper with 30 cm x 30 cm feed opening, a horizontally mounted rasped drum

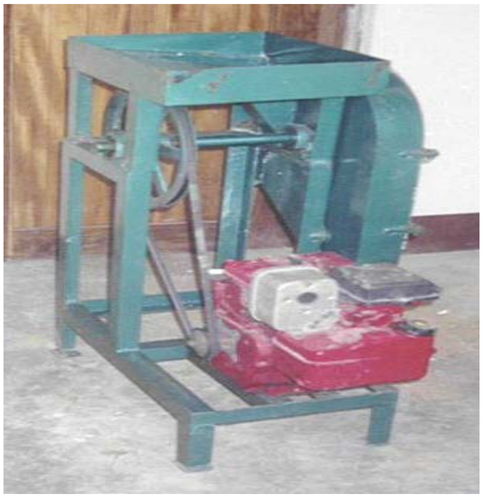

Figure 3: Engine powered chipper.

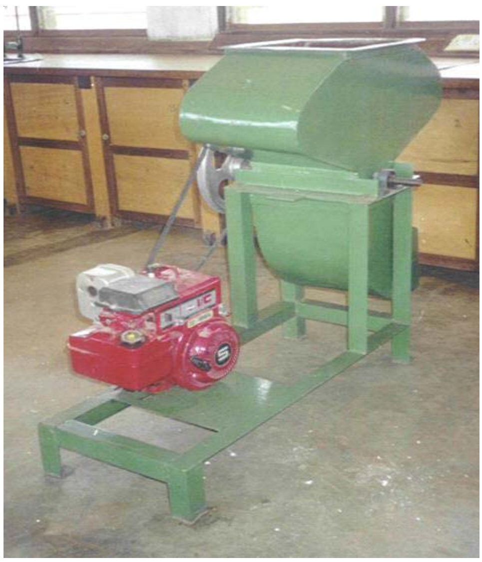

Figure 4: Engine powered grater.

at about 30 cm from the opening with the gripping surface 3 cm below the drum top surface, an exit chute oriented about 30o 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 (Figure 5) used for small-scale grating (Silayo *et al*., 2001). The drum length and diameter were about 29 cm and 18 cm, respectively. Power transmission ratio was 1 to 4 and distance between pulley centres was about 60 cm. The gap between the drum and the gripping surface was about 4 mm.

Modification of chipping and grating machines

Chippers. Modifications to the equipment above (Figures 2, 3 and 4) were made based on recommendations from the participating farmers, extension agents, researchers, and local equipment manufacturers after testing the equipment. Following this, several modifications were made and participatory testing exercises 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 (Figures 6 and 7) for the manual chippers and fixing of the wooden stands in a trapezoidal mode for the manual chipper on wooden stands (Figure 7).

A more improved version of chipper called pedestal-type chipper was also manufactured (Figure 8). This took the same features of the

Figure 5: The traditional cassava-rasping sheet.

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 95 cm. Another modification was a re-design of the engine-powered chipper to make it dual purpose so that it could be operated with a 3.5-5.5 HP engine or without

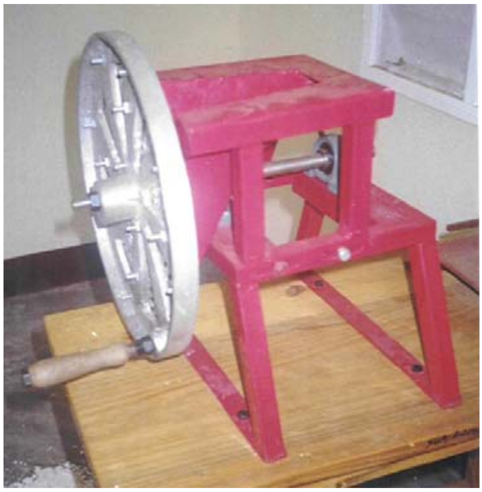

Figure 6: Table mounted manual chipper with pillow block bearings.

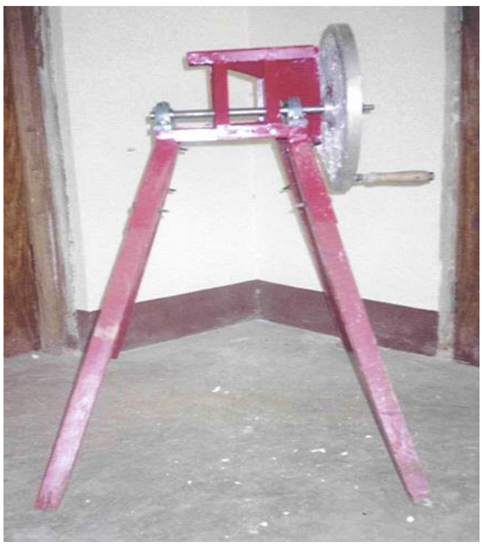

Figure 7: Wooden legged manual chipper with pillow block bearings.

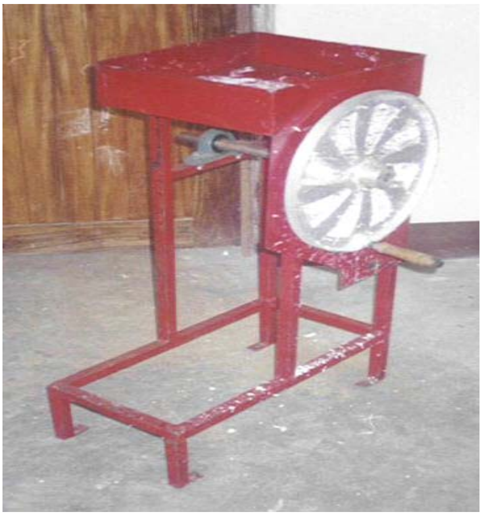

Figure 8: Pedestal-type chipper.

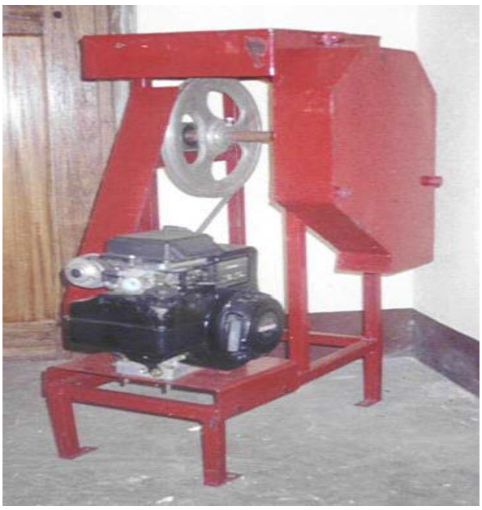

Figure 9: Engine-powered pedestal-type chipper.

the need to imitate the pedestal-type chipper and provision of belt safety cover (Figure 9).

The grater. Modifications to the grater mainly included provision of a hopper box (42 cm x 40 cm) with a base inclined at about 35^{o} 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 (Figure 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 (Briggs and Straton type), 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 (Figure 1), parallel with the same design that was improvised with wooden legs (Figure 2). At both the inception and the modification stages chipping and grating machines were tested by 40 participating farmers about half of them women, in collaboration with researchers and 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

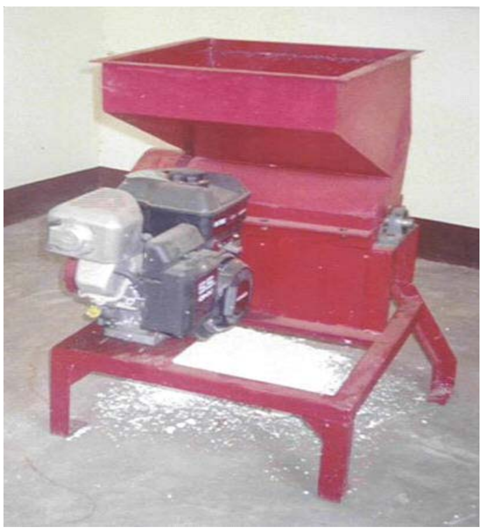

Figure 10: Engine powered grater.

and washed to avoid introducing soil particles that could damage the moving parts of the machines. The parameters evaluated were weight processed and processing time. These were converted to throughput (kg/h). Other parameters included percent losses measured as the amount that passed through 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 Duncan's Multiple Range Test (P=0.05) (Steel and Torrie, 1980).

Results and Discussion

Performance of the newly introduced machines

Chippers/slicers. 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 legs resulted in higher output compared with working with the same machine on the ground while bending. However, use of these machines was labour intensive, as they require two operators, one for feeding and another for cranking the chipping disc. Manual chipping resulted in high losses (l9-20%). 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 resulted in the last bits of

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	-	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

Values bearing different superscripts in a column are significantly different (P<0.05).

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±0.14[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

Values bearing different superscripts in a column are significantly different (P<0.05).

cassava not being processed, suggesting the removal of the end portions before chipping. The thin roots also ended up being broken or passed 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 fixed on 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 allowing passage of unprocessed chunks. 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 of the manual chippers was low, (27%) while that of the engine-powered one was relatively high (58.4%). 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 have been higher.

The engine-powered grater. In comparison with the local rasping sheet that can only produce about 4 kg/h of grates (Silayo *et al*., 2001) 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.

Performance after modifications

Chippers/slicers. Mean throughput of the improved manual chippers (Table 2) increased by more than five times 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 pillow-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 on wooden stands demonstrated higher performance (99.3 kg/h) than when operated on the ground (81.6 kg/h). The pedestal-type chipper (Figure 8) resulted in throughput that was 16% higher and losses that were 13% lower than for the modified manual chipper on wooden stands. This was mainly due to the use of pillow-block bearing and 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 on wooden stands could be improved further if the hopper size was increased. Use of the engine-powered chipper resulted in about eight times and six times as much throughput compared with the modified manual chipper 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 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. Preliminary testing of chipping machines with sweetpotatoes also produced good chips. These chips could be used for frying or drying where there is need.

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 large 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. Intensive work on use of these machines for diversifying use of sweetpotatoes is also required. 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 and sweetpotato farming in Tanzania.

Acknowledgements

The authors wish to acknowledge contribution by FOODNET for supplying the initial prototypes of the IITA manual chipper and the engine-powered chipper. Greatly acknowledged is TARPII-SUA project funded by the Royal Government of Norway and the United Republic of Tanzania for supporting the research work that enabled involvement of researchers, farmers, extension agents, and equipment manufacturers, particularly the Reliable Motor Works of Dar es Salaam and Intermech Engineering of Morogoro. The later is highly commended for successful modification of these machines for adoption in Tanzania.

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